Planning Assistance to States

Assabet River, Massachusetts
Sediment and Dam Removal Feasibility Study

DRAFT



September 2009

US Army Corps
of Engineers
New England District

ASSABET RIVER
SEDIMENT AND DAM REMOVAL FEASIBILITY STUDY

Planning Assistance to States Program

DRAFT

Department of the Army
New England District
U.S. Army Corps of Engineers
Concord, MA
September 2009

Executive Summary

The purpose of this study is to provide planning assistance to the Massachusetts Department of Environmental Protection (DEP). DEP in conjunction with EPA and watershed stakeholders are investigating and implementing measures to improve water quality and the aquatic ecosystem of the Assabet River in order to meet its Class B water quality standard ("fishable and swimmable"). The study's role in this effort is to provide scientific and engineering information that will inform the decision making process.

For most of its length, the Assabet River suffers from the effects of severe eutrophication due to nutrient loadings (particularly phosphorus) from wastewater treatment facilities (WWTFs), nonpoint sources, and sediments. Nuisance aquatic vegetation impairs designated uses including recreation, aesthetics, and fish and wildlife habitat. Due to excessive vegetation dissolved oxygen concentrations can vary a great deal over the course of a day particularly during the summer months, threatening the survival of fish and other aquatic organisms in the river. It is also aesthetically objectionable to many who live near the river and/or use the river for fishing and boating and other forms of recreation. Effects are most evident behind the numerous impoundments along the river where nutrients settle out.

The DEP in 2004 prepared a "Total Maximum Daily Load for Phosphorus" (TMDL) for the river to address the eutrophication problem. The TMDL required implementation of measures to decrease phosphorus loading to the river and adopted an adaptive management approach in accordance with EPA approved procedures. The TMDL for the river can be viewed at http://www.state.ma.us/dep/brp/wm/tmdls.htm.

Phase 1 of the TMDL required that the four aging WWTFs discharging to the Assabet River decrease the total phosphorus in their effluent to 0.1 mg/l (April to October) and 1.0 mg/l (November to March). The 0.1 mg/l requirement resulted in the need to add new phosphorus removal technology at the same time as doing significant facility upgrades. These upgrade are currently being implemented and paid for by the communities that own or use the WWTFs.

Phase 2 of the TMDL required additional projects be implemented to continue to decrease total phosphorus loading to the river. The phosphorus TMDL indicated that to achieve water quality standards a 90 percent reduction in sediment phosphorus flux was needed in addition to decreasing the WWTFs effluent to 0.1 mg/l. Measures suggested to achieve the 90 percent sediment phosphorus flux reduction included dam removal and dredging. If these measures were

determined to be inadequate in achieving the desired reduction in phosphorus loading to the river then further decreases in discharges of phosphorus from the WWTFs would be required.

Given the inherent difficulty in predicting the impact of sediment flux under the water quality conditions present at the time the TMDL was developed, it is reasonable from a scientific standpoint to monitor the effectiveness of the present wastewater treatment facility (WWTFs) upgrades before selecting the appropriate option(s) for making the necessary sediment flux reductions and verifying the model predictions. EPA and DEP have developed a detailed monitoring plan for the river to assess conditions following the implementation of phosphorus discharge reductions.

The Corps "Planning Assistance to States" study provides information on dam removal and dredging to decrease sediment phosphorus flux and improve the aquatic habitat of the river. The Corps contracted with CDM to perform river analysis and modeling for the dam removal and dredging assessments.

Dredging analysis results prepared by CDM showed dredging alone would at best achieve only short-term (~ two to four years) reductions in sediment-phosphorus release. This was because the continuing phosphorus discharge from the WWTFs and non-point sources replenish the phosphorus cycling from the sediment. Future monitoring of the effectiveness of the WWTFs upgrades and the rivers response to this decreased loading is needed to assess and verify modeling predictions. Based on the modeling done for this study dredging alone is not considered a viable control measure.

An additional finding of the CDM analysis was that phosphorus discharge in the winter is an important part of the annual phosphorus budget in the Assabet River. This finding appears to indicate that lower winter limits on WWTFs discharge of phosphorus may contribute significantly to reducing sediment phosphorus flux and might be another control measure for DEP and stakeholders to consider to control phosphorus loading to the river. This winter load was previously recognized by DEP in the TMDL and monitoring was required. MassDEP will continue to use an adaptive management approach to evaluate results as measures to decrease phosphorus loading to the river are implemented.

There are six dams on the river that were considered for removal and these are:

- Aluminum City Dam, Northborough
- Allen Street Dam, Northborough
- Hudson Dam, Hudson
- Gleasondale Dam, Stow

- Ben Smith Dam, Maynard.
- Powdermill Dam, Acton

Dam removal analysis showed that dam removal plus the Phase 1 WWTFs improvements would almost meet the 90 percent goal, achieving an estimated 80 percent reduction of sediment phosphorus load. Dam removal will have benefits in the form of improved water quality and restored aquatic ecosystem. Removal of Ben Smith Dam would have the most benefit because it is the longest impounded river reach.

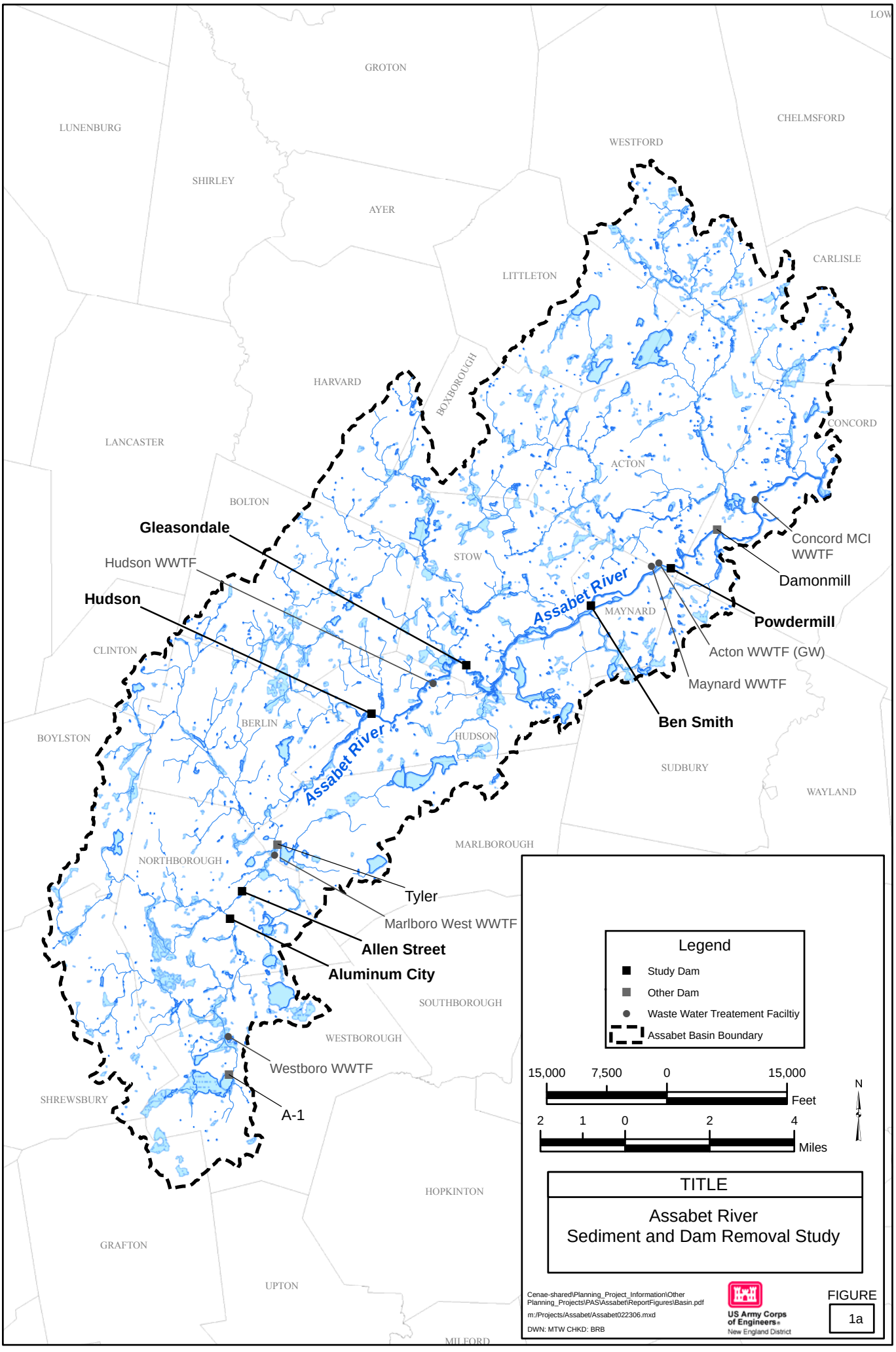
It was determined that dam removal project construction costs may range from $1 million (Aluminum City Dam) to about $13 million (Ben Smith Dam), with a significant portion of the dam removal cost associated with sediment management (dredging and disposal) to prevent excessive movement of sediment downstream.

Removing the dams will change the existing water levels in the river. Many of the wetlands along the Assabet River exist because of the water backed up by the dams. The largest changes in wetlands communities will occur for the Ben Smith, Gleasondale, and Hudson dam removal projects.

All of the dams have identified cultural resource value. Ben Smith, Gleasondale, Hudson, and Allen Street Dams are contributing elements to historic districts eligible for the National Register of Historic Places and removal would be an adverse impact and require further studies and documentation of the resources.

Dam removal is expected to benefit fluvial dependent and fluvial specialist target fish communities for the Assabet River. The U.S. Fish and Wildlife Service is working to restore the migratory corridor to the Sudbury, Assabet, and Concord Rivers to provide access for anadromous species such as alewife to historic breeding and nursery habitats. Dam removal on the Assabet would be consistent with these restoration plans.

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GROTON
LUNENBURG
SHIRLEY
AYER
WESTFORD
CHELMSFORD
CARLISLE
LITTLETON
HARVARD
BOXBOROUGH
CONCORD
LANCASTER
ACTON
BOLTON
STOW
MAYNARD
CLINTON
BERLIN
HUDSON
BOYLSTON
SUDBURY
WAYLAND
MARLBOROUGH
NORTHBOROUGH
SOUTHBOROUGH
WESTBOROUGH
SHREWSBURY
HOPKINTON
GRAFTON
UPTON
MILFORD
Assabet River
Assabet River
Gleasondale
Hudson WWTF
Hudson
Concord MCI WWTF
Damonmill
Powdermill
Acton WWTF (GW)
Maynard WWTF
Ben Smith
Tyler
Marlboro West WWTF
Allen Street
Aluminum City
Westboro WWTF
A-1
Legend
Study Dam
Other Dam
Waste Water Treatement Faciltiy
Assabet Basin Boundary
15,000 7,500 0 15,000
Feet
2 1 0 2 4
Miles
N
TITLE
Assabet River
Sediment and Dam Removal Study
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DWN: MTW CHKD: BRB
US Army Corps of Engineers
New England District
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CDM Reports

Assabet River Sediment Management Plan, December 2008

Assabet River Sediment and Dam Removal Study, Modeling Report, June 2008

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INTRODUCTION

Study Authority

This investigation was conducted by the New England District of the Corps of Engineers under the Corps Planning Assistance to States (PAS) Program as authorized in Public Law 93-251 and amended in subsequent legislation. The study was performed through a 50/50 cost sharing agreement with the Massachusetts Department of Environmental Protection (DEP). The DEP entered into a Memorandum of Understanding with the six Assabet River Consortium communities (Westborough, Shrewsbury, Northborough, Marlborough, Hudson, and Maynard) for the sediment and dam removal study. The MOU established a Study Coordination Team (SCT) made up of twelve members, six from the communities and six selected by DEP including the Organization for the Assabet River (OAR), to collaborate in the study effort.

Study Background

The Assabet River does not meet state requirements for water quality. Areas behind dams experience significant variations in dissolved oxygen and excessive growth of aquatic vegetation. Both factors result in degraded aquatic habitat. The primary issue is too much phosphorus input to the waterway. Phosphorus, a nutrient, when elevated above normal background levels causes excessive production of floating and rooted aquatic plants. This vegetation growth and decomposition negatively impacts water column dissolved oxygen levels. Adequate dissolved oxygen is required to support aquatic life. Phosphorus loadings originate from both point and non-point sources. Point sources include four publicly owned wastewater treatment facilities (WWTFs)[1], while non-point sources include internal recycling of phosphorus from sediments and stormwater runoff. The four facilities are the Westborough, Marlborough Westerly, Hudson, and Maynard WWTFs.

The U.S. Environmental Protection Agency (EPA) and DEP have developed a Total Maximum Daily Load (TMDL) that requires seasonal reductions of phosphorous loadings from the four WWTFs that discharge to the river to 0.1 mg/l April to October and 1.0 mg/l November to March.. In addition, the TMDL requires a 90 percent reduction in sediment phosphorus flux in order to achieve water quality compliance.

[1] There is a fifth small institutional wastewater treatment facility on the river at MCI Concord.

Restoration Goals and Objectives

Goals for the Assabet River are: 1) improved water quality to meet Massachusetts water quality standards; and 2) achievement of a sustainable and restored aquatic ecosystem.

Water quality objectives for the river are improved dissolved oxygen levels, acceptable levels of biomass production, and acceptable ambient phosphorus concentrations[2]. The primary focus of this study is the goal of 90 percent reduction of phosphorus release by the sediments as specified in the nutrient TMDL for improved water quality.

Aquatic ecosystem objectives include restoration of a riverine habitat to support fluvial dependent and fluvial specialist fish and improvements in the migratory corridor for species such as American eel and river herring.

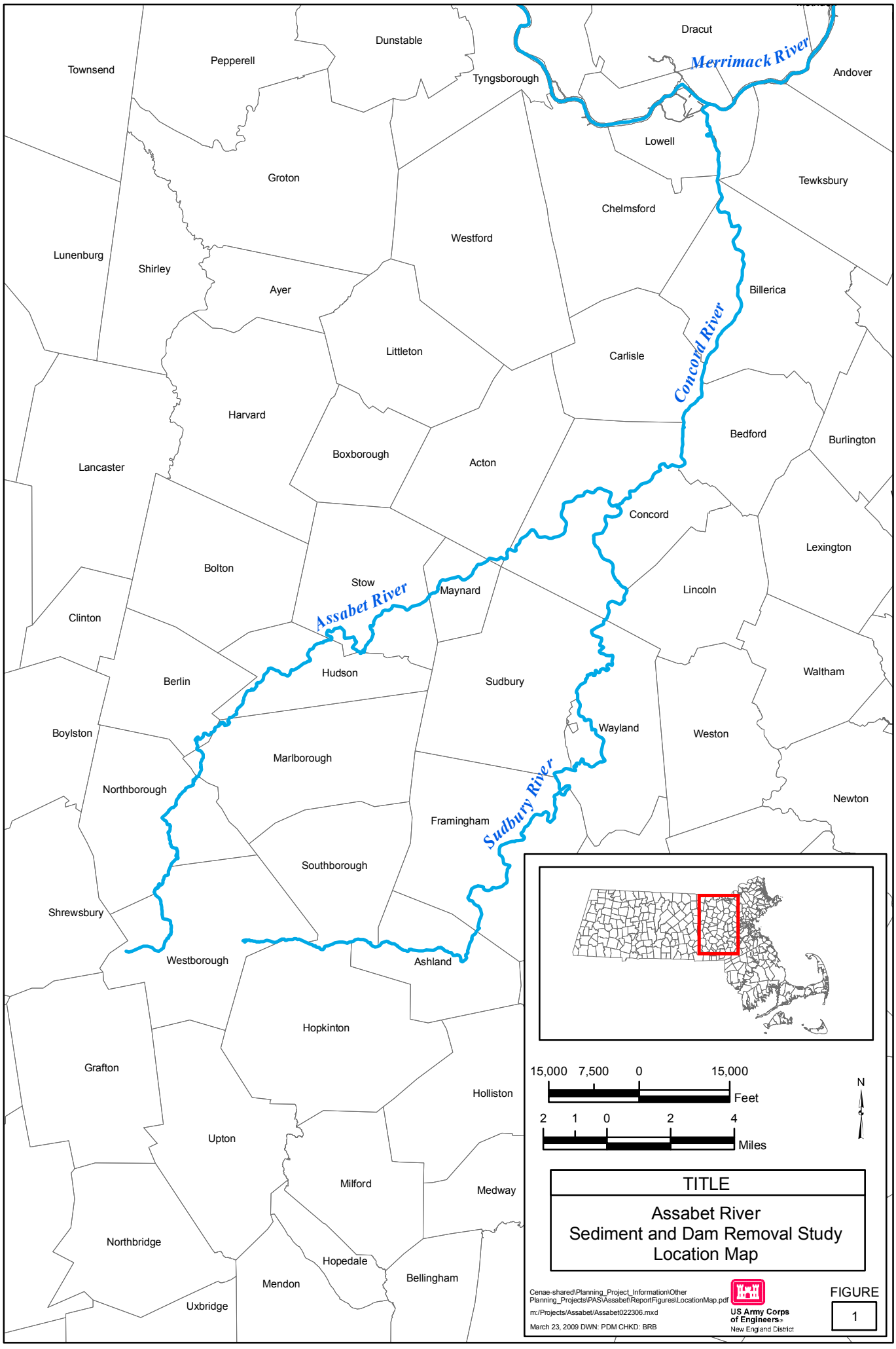
Study Area

The Assabet River is located in eastern Massachusetts, approximately 20 miles west of Boston. The Assabet River has a length of about 32 miles, and drains a watershed of approximately 177 square miles, flowing through the towns of Westborough, Northborough, Marlborough, Berlin, Hudson, Stow, Maynard, Acton, and Concord, Massachusetts. The Assabet River joins the Sudbury River in Concord to form the Concord River. (See Figure 1.) The Concord River flows about 16 miles northward to the city of Lowell, where it joins the Merrimack River. The Merrimack River continues about another 40 miles to the northeast where it discharges to the Atlantic Ocean at Newburyport, Massachusetts.

The Assabet River drops 177 feet over its 32-mile length for an average slope of 5.5 feet per mile (ENSR, 2001). Generally, the river's slope is relatively flat, approximately 2 feet per mile. Several steeper sections, with gradients as great as 25 feet per mile occur in the river, often immediately below dams. (See Figure 2.)

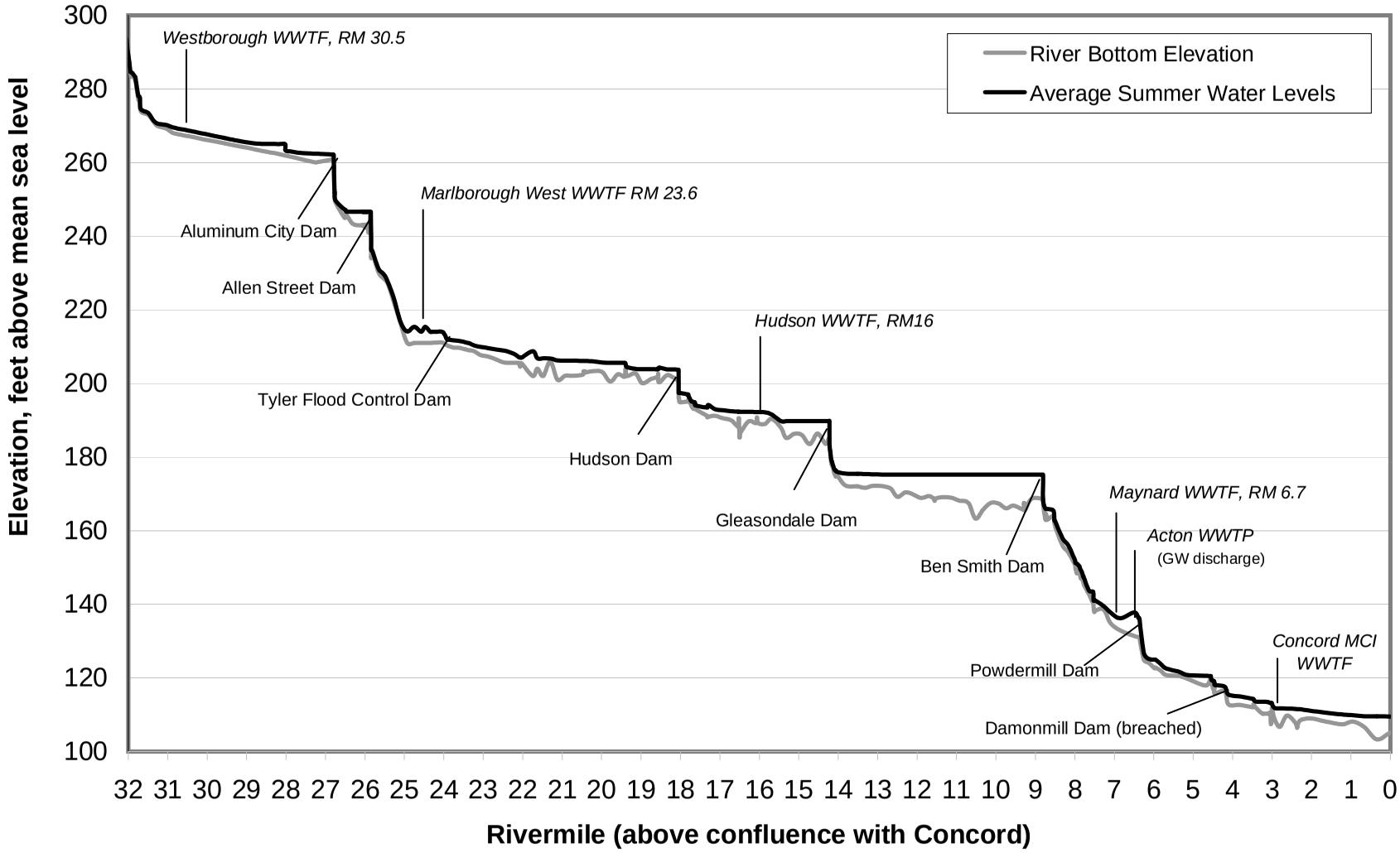
Precipitation averages 47 inches/year and average temperatures range from 25 degrees Fahrenheit in January to 71 degrees Fahrenheit in July (USGS, 2004).

[2] DEP's phosphorus TMDL did not establish a specific in-stream target concentration for total phosphorus instead a weight-of-evidence approach of all available information will be used to set site-specific permit limits.


Townsend
Pepperell
Dunstable
Tyngsborough
Dracut
Merrimack River
Andover
Lowell
Tewksbury
Groton
Chelmsford
Westford
Lunenburg
Shirley
Ayer
Billerica
Littleton
Carlisle
Concord River
Harvard
Bedford
Burlington
Lancaster
Boxborough
Acton
Concord
Lexington
Bolton
Stow
Maynard
Lincoln
Assabet River
Clinton
Berlin
Hudson
Sudbury
Waltham
Boylston
Wayland
Weston
Marlborough
Northborough
Framingham
Sudbury River
Newton
Southborough
Shrewsbury
Westborough
Ashland
Hopkinton
Grafton
Holliston
Upton
Milford
Medway
Northbridge
Hopedale
Bellingham
Mendon
Uxbridge
15,000 7,500 0 15,000
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Assabet River
Sediment and Dam Removal Study
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March 23, 2009 DWN: PDM CHKD: BRB
US Army Corps of Engineers
New England District
FIGURE
1

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Figure 2. Assabet River Elevation Profile



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Stream flow data for the Assabet River is available at a USGS stream gauge located in Maynard (river mile 7.4). Approximately 2/3 of the Assabet river watershed is upstream of the gauge. Average monthly flows at the Maynard gauge range from about 60 to 75 cubic feet per second (cfs) during low flow summer conditions to about 400 cfs during March and April (ENSR, 2001). Estimates of 7Q10 (seven day, ten year) low flow at the Maynard gauge is estimated to be 15.1 cfs. Under low flow conditions, wastewater treatment plant effluent flows can account for a substantial percentage of river flow[3].

There are nine dams on the river. The Assabet River begins in Westborough at the George H. Nichols Dam, also known as the A1 site. The Assabet Reservoir is created by this dam. The dam was constructed by the National Resource Conservation Service (NRCS) in 1968 for flood prevention and fish and wildlife habitat. Downstream from this are seven old mill dams and one additional flood control dam, the Tyler Dam. The Tyler Dam is a "dry bed" flood control facility that was constructed in 1965 by NRCS. The seven old mill dams on the river are:

- Aluminum City Dam, Northborough
- Allen Street Dam, Northborough
- Hudson Dam, Hudson
- Gleasondale Dam, Stow
- Ben Smith Dam, Maynard.
- Powdermill Dam, Acton
- Damonmill Dam, Concord

The locations of these dams are shown in Figure 1 and in Plates 1 to 6 included in Appendix A. The first six dams have year round impoundments above the dams. In addition, above Ben Smith Dam, part of the river is diverted through a canal to a series of mill head ponds at Clock Tower Place (the former American Woolen Mill). This mill pond at Clock Tower Place depends on flows diverted from above the dam to maintain the pond water levels. The last dam on the river, the Damondale Dam in Concord is breached and canoe and fish passage are not blocked by the remnants of the dam.

[3] The four WWTF discharge to the river above the USGS gage and comprise approximately 80% of the flow at the USGS gage in Maynard during low flow periods. The seven-day average low flow expected once every 10 years (7Q10) is 15.1 cubic feet per second. DEP 2004.

The impoundments associated with the old mill dams are generally long and narrow with depths ranging from 3 to 12 feet and widths of 100 to 300 feet. The "visual impoundments" at the dams range in length from about 0.1 to 2 miles with longer extents of influence. Most of the impoundments contain significant deposits of sediments that have built up over time. The free-flowing sections of the Assabet River are relatively narrow and shallow, typically 30 to 60 feet wide and 2 to 4 feet deep.

The Assabet River watershed is moderately to densely developed, with an average population density of approximately 1,000 people per square mile. Development along the impoundments varies. In urbanized areas the river channel is constrained by walls and other development, but outside of developed areas the Assabet often flows through broad riparian corridors that are buffered from development by floodplain wetlands.

There are two federally designated areas associated with the river. The Assabet River National Wildlife Refuge in Stow adjacent to the river and upstream of Ben Smith Dam and the National Park Service, National Wild and Scenic River designated river reach. This designated reach includes the a 4.4-mile segment of the Assabet River beginning 1,000 feet downstream from the Damon Mill Dam in the town of Concord, to its confluence with the Sudbury River at Egg Rock in Concord.

The Assabet River is recognized as one of the significant recreational and natural areas in Massachusetts. Restoration of the river has strong, longstanding public support. Advocacy groups supporting the restoration of the river include the Organization for the Assabet River, the Sudbury Valley Trustees, and the Sudbury Assabet Concord Watershed Community Council. These groups represent a wide range of constituency.

Prior Studies and Reports

Numerous studies have investigated the Assabet River. Studies conducted prior to 2000 were summarized by ENSR (2001). These include a variety of water quality studies, stream flow, flood boundary and flood management studies, wastewater discharge studies, and biological studies conducted during the 1960's through 1990's. Water quality and modeling studies were done by ENSR in 2001 and 2004 and a TMDL was completed by DEP in 2004. In addition, studies have been completed by USGS including the USGS Assabet River Sediment Studies (USGS 2005) and the USGS Ground Water Flow Study (DeSimone 2004).

Water Quality in the Assabet River

Classification. The Assabet River is designated as a Class B water under Massachusetts water quality standards [314 CMR 4.05(3)b]. Class B waters are designated as capable of providing and supporting habitat for fish and other aquatic wildlife, and for primary and secondary contact recreation. Criteria for such waters include that dissolved oxygen (DO) shall not less be less than 5.0 mg/l in warm-water fisheries; and that surface waters shall be free from pollutants in concentrations that form nuisances, produce objectionable odor, color, taste, or turbidity, or produce undesirable or nuisance species of aquatic life. The goal for the Assabet River is to achieve these water quality standards.

Existing Water Quality Conditions. From its source at the outlet of the Assabet River Reservoir to its confluence with the Concord River, the Massachusetts Department of Environmental Protection (DEP) rates the Assabet River as impaired due to nutrients, and organic enrichment leading to low DO, and also to large diurnal DO fluctuations including super-saturation. Nuisance aquatic vegetation including algal mats, floating macrophytes, rooted vegetation, and phytoplankton impair designated uses including recreation, aesthetics, and fish and wildlife habitat. While the entire river is considered impaired, the main problems occur in the impoundments where nutrient-rich sediments deposit and low velocities, shallow depths, and large surface areas open to sunlight allow floating macrophytes and algae to thrive and accumulate. Decay of these plants, especially duckweed, causes odors and violations of DO standards. DO levels below 5 mg/l are mainly recorded in the larger impoundments, but they have also been observed in the river above Aluminum City and below Powdermill Dams. Excessive floating macrophyte growth is not observed in the free-flowing reaches of the Assabet; while macrophytes do exist in the sunlit free-flowing reaches, they are generally rooted species adapted to the higher velocities and generally not excessive or a nuisance.

Biomass. Excessive biomass is considered a major impairment of designated uses in the Assabet River. Decay of dying duckweed causes odors and violations of dissolved oxygen standards. Excessive growths of both floating and rooted macrophytes in the impoundments are detrimental to primary and secondary contact recreation. It also causes extreme variations in DO leading to both super-saturation and violations of the minimum criteria. The Organization for the Assabet River (OAR) estimated biomass production in the four of the largest impoundments (Allen Street, Hudson, Gleasondale, and Ben Smith) in 1999, 2000, and 2005. They found that the annual variation in total biomass was very high, and that Hudson, Gleasondale, and Ben Smith impoundments produced the most biomass as measured by both total weight and weight per surface area.

Phosphorus Loading. The water quality problems noted above are directly related the phosphorus loading to the river that stimulates nuisance plant (biomass) growth in the impoundments. The most consistent sources of phosphorus loading to the Assabet River are the four WWTFs, which are in Westborough, Marlborough, Hudson, and Maynard. While non-point sources must be considered, the seasonality of the eutrophication problems, as manifested by nuisance aquatic plant growth, is most directly related to the high loadings of phosphorus from the WWTFs combined with limited inflow from groundwater during the natural growing season for aquatic vegetation. This combination is particularly important during periods of low flow and especially during the 7Q10. During the growing season, direct non-point source contributions of phosphorus, other than from sediment phosphorus flux, are generally minor compared to the consistent contribution from the WWTFs.

TMDL Findings. Evaluation of nutrient loadings during intensive field surveys found that WWTFs contributed 88 to 98 percent of biologically available phosphorus, and the majority of this loading was in the dissolved form that is directly available for uptake by plants. Dissolved phosphorus that was not taken up by plants was assumed to pass through the system and not accumulate; therefore, its removal from WWTF discharges was considered only necessary during the growing season, from 1 April through 31 October. Sediment-phosphorus flux was the principal non-point source during summertime low flow periods, but its contribution to overlying phosphorus concentrations was relatively minor compared to loads from the WWTFs.

However, phosphorus loadings from sediments become important when the WWTF loads are reduced. To achieve the goal of meeting state water quality standards, the study concluded that total phosphorus in WWTF discharges must be reduced to 0.1 mg/l during the growing season, and there must be a 90 percent reduction in phosphorus-sediment flux.

Year-round monitoring and reporting of effluent data for total and dissolved phosphorus was required due to concerns that particulate phosphorus might be settling in the impoundments during the non-growing season and becoming available for plant growth during the growing season. The WWTFs were required to optimize the removal of particulate phosphorus during the non-growing season by going to a 1 mg/l winter limit.

PLAN FORMULATION FOR WATER QUALITY IMPROVEMENTS

Modeling Studies

In order to develop plans to achieve the goal of 90 percent reduction in sediment P flux it was determined to develop computer simulations models of the river to provide information on the nature of the P-flux from the sediments. The modeling effort is summarized in the CDM report entitled "Assabet River Sediment and Sampling Study, Modeling Report", June 2008.

CDM Field Studies. In order to calibrate their computer models to properly predict the effects of different combinations of dredging and dam removal, CDM collected hydraulic, water quality and sediment data, and performed laboratory sediment-phosphorus flux measurements. Test water was collected only at Aluminum City – downstream of Westborough which was discharging ~ 2.8 mg/ L TP at the time. This collection effort was to fill in data gaps from the previous studies by ENSR.

CDM laboratory flux measurements indicated that high concentrations of dissolved phosphorus were not entirely passing through the system in the winter but were being absorbed in significant amounts to the sediments. This had three important implications; first, it meant that dredging would have only short-term benefits in reducing sediment-phosphorus release because most of the phosphorus being released was recently absorbed and not from historic deposits. Secondly, it meant that consideration should be given to reducing phosphorus levels in WWTF discharges during the non-growing season. A third conclusion was that sediment-phosphorus flux was too complex to allow the modeling to predict actual DO and biomass levels following specific combinations of dam removal, dredging, and reductions in phosphorus levels in WWTF discharges. Instead, the evaluation indicates which actions would contribute to achieving desired goals, and the qualitative level of benefits.

CDM Model Studies. ENSR developed an HSPF model to examine water quality in the Assabet River. CDM's study required refining this and supplemental models to answer questions about existing conditions and the effects of proposed dam/sediment removal and potential sediment movement with dam removal. CDM used a combination of models including HEC-RAS for river hydraulics, HEC-6 for sediment movement, and HSPF for water quality. They also used a spreadsheet model, developed based on equations from QUAL2K to estimate sediment-phosphorus flux for use in the HSPF model. For existing conditions, CDM's models generally matched ENSR's results well for water quality parameters; the main differences were due to changes in impoundment hydraulics due to updated bathymetry.

Modeling Scenarios. CDM modeled six scenarios: (1) existing conditions; (2) effects of planned WWTF phosphorus reductions alone; (3) removal of all 6 study dams; (4) dredging behind all 6 dams; (5) removal of Gleasondale, Hudson and Ben Smith dams; and (6) reduction in phosphorus levels in WWTF discharges during the non-growing season. Except for the modeling of existing-conditions and reductions in winter WWTF discharges, all scenarios assumed that WWTF discharges met planned reductions to 0.1 mg/l phosphorus during the growing season and 1 mg/l during the rest of the year.

Results. Modeling limitations due to the complexity of sediment-phosphorus flux behavior meant that quantitative predictions of DO and biomass levels could NOT be made, and the results of implementing different scenarios could only be qualitatively assessed. Therefore, it is recommended that additional field study be undertaken should different summer and/or winter effluent permit limits be considered for the WWTFs in the future.

Dredging alone achieved limited short-term benefits at best; sediment-phosphorus flux was estimated to be reduced for only about two years, and the increased hydraulic residence time in the impoundments would likely do more to stimulate biomass growth than the reduction in sediment phosphorus loading would inhibit it.

The other scenarios all contributed toward achieving water quality goals, with the more aggressive having the most effect. Expected improvements from dam removal and reductions in WWTF phosphorus levels include higher minimum DO levels, lower ranges of diurnal DO fluctuation, fewer and less severe occurrences of DO super-saturation, cooler water temperatures, and less nuisance aquatic vegetation.

Floating macrophytes and algal blooms will be particularly reduced. Aesthetics will improve due to reductions in algae and plants such as duckweed and due to reduced odors resulting from higher minimum DO levels and smaller amounts of biomass decay. Stream temperatures will be cooler due to reduced water surface areas to collect solar energy. Shading from trees and large bushes growing along stream banks will further reduce water temperatures.

Levels of nitrogen are not likely to change significantly, although the form of it may; as less biomass is generated and decays, more of the nitrogen will be in the form of nitrate and less of it as ammonia. Downstream loads of phosphorus and biomass to the Concord River will be reduced, but the degree of expected benefits is beyond the scope of this study. A summary of expected water quality benefits are displayed in the Table below taken from the CDM 2008 report. (CDM summarized expected water quality changes as either good, fair, or poor based on a the review of the HSPF model output, however as this model was not calibrated for the new hydraulic representation, only qualitative statement could be made.)

Table 1. Summary of Water Quality Findings, Various Alternatives (CDM, 2008)

Dam	Base Condition (2000)	Planned Improvements	Dredging	Dam Removal
Aluminum City	●	●	*	+
Allen Street	●	●	*	+
Hudson	●	●	*	++
Gleasondale	●	●	*	++
Ben Smith	●	●	*	+++
Powdermill	●	●	*	++
Downstream Load to Concord River	●	●	*	+

Legend Existing Conditions: ● = Good, ● = Fair, ● = Poor

Improvements: (*) = No improvement, (+) = some improvement,

(++) = good improvement, (+++) = significant improvement

Reductions in Phosphorus Flux

A second benefit from removing dams would be reduced sediment phosphorus flux from the reduced biomass growth. Less biomass growth would produce less algae to settle and less phosphorus cycling through the sediments. Also dam removal will result in a narrower river and thus less river bed will be exposed to water. The sediment phosphorus flux reduction is expected to be approximately 80 percent, near the TMDL target of 90 percent reduction. (See Table 2.) Given the inherent limitations and uncertainties of predictive modeling of a dynamic physical, chemical and biological system, establishing definitive percent reductions is not possible. The accuracy and effectiveness of target reductions can only be confirmed by subsequent monitoring. A third benefit from dam removal is increased reaeration in the shallower water depths. Increased reaeration will improve dissolved oxygen in the river.

A summary of the anticipated P-flux reductions for various alternatives is shown in Table 2. These findings are based on results from the HSPF and the P-flux model. The analysis indicated that the planned improvement will result in a 60 percent reduction in P-Load and the dam removals will provide another 20 percent reduction. The estimated 20 percent is a conservative estimate and the percent reduction from dam removal may be greater.

Table 2. Summary of Anticipated P-Flux Reduction, Various Alternatives

Scenario	**P-Flux (mg P/m2-day)**	**P Flux Change**	**Sediment P[3] Load (lbs/day)**
Base Condition	D/S[1]: 21.6 U/S[1]: 12.0	No Change	28.0 [4]
Planned Improvements (WWTP TP @ 0.1 mg/l summer 1.0 mg/l winter	D/S: 8.6 U/S: 4.8	60% reduction	11.2
Dam Removal – 6 dams[2]	D/S: 4.3 U/S: 2.4	80%	4.2
Dam Removal – 3 dams (Hudson, Gleasondale, Ben Smith) [2]	D/S: 4.3 U/S: 4.8	80% (Hudson and d/s) 60% (u/s – same as planned improvements)	6.7
Dam Removal – 1 dam[2] (Ben Smith only)	Ben Smith and d/s: 6.5 Gleasondale and u/s: 4.8	70% (Ben Smith and d/s only) Gleasondale and u/s same as planned improvements	8.4
Dredging – short term[2] (less than 2 years)	D/S: 4.3 U/S: 2.4	80%	5.6
Dredging – long term[2] (more than 2 years)	D/S: 8.6 U/S: 4.8	60% (planned improvements)	11.2

Notes:

1) U/S notates upstream of Gleasondale. D/S notates Gleasondale and downstream.
2) Includes Planned Improvements
3) Sediment P Load includes reduction in P flux and reduction in sediment bed area associated with dam removal.
4) From the Assabet River DEP TMDL Study, September 2004, page 42. The TMDL set a goal of 90% reduction from 28.0 lbs/day of Total P to a value of 2.8 lbs/day of Total P.

Conclusions. Planned reductions in phosphorus discharges from WWTFs and the goal of a 90 percent reduction in sediment-phosphorus release are not independent; the planned improvements at WWTFs are likely to collectively yield a significant reduction in sediment-phosphorus flux.

The removal of Ben Smith dam is a key component to achieving water quality goals through reductions in sediment-phosphorus flux, because the biomass growth and settling that ultimately drives the sediment flux would decrease. Removing Hudson and Gleasondale dams would contribute incrementally to these goals. Removal of the two most upstream dams in this study, Aluminum City and Allen Street, would result in water quality improvements in stream reaches affected by the existing impoundments, but would have minimal effects on downstream water quality.

Similarly, removal of Powdermill dam will have only localized benefits. Removing the immediately upstream Ben Smith dam is the most effective option for improving water quality in the Powdermill dam impoundment. Due to its large size and long residence time, the Ben Smith impoundment is a significant contributor of biomass growth that affects the Powdermill dam impoundment and further downstream river reaches.

Dredging of any or all of the impoundments is recommended only to control sediment movement following dam removal; it has no significant long term water quality benefits by itself.

Although consideration of lower WWTF winter P-discharge limits were not part of this study, the P-flux model based on limited laboratory data indicated that winter P-loading may have an effect on summer sediment flux rates. Additional reductions in phosphorus levels in WWTF discharges during the non-growing season may make a significant contribution to achieving water quality standards, especially if only limited dam removal is undertaken.

Actions to Improve Water Quality

In order to improve water quality it appears that a combination of reduction in loadings from point sources and dam removals will need to be considered.

- Implement WWTF Improvements as planned to decrease P discharge to 0.1mg/l during the growing season. Evaluate the potential of lower winter limits (non-growing season) to improve water quality.

- Consider removal of Ben Smith Dam to decrease sediment P-flux.

- Also consider removal of Gleasondale and Hudson Dams to decrease sediment P-flux.

- Remove sediment behind dams as part of dam removal projects to prevent sediment from moving downstream.

- Consider removal of Allen Street Dam and Aluminum City Dam for habitat and localized water quality benefits. Removal of these dams will not have a significant effect on overall river water quality.

- Removal of Powdermill Dam has water quality benefits similar to Gleasondale and Hudson. However, the current dam owner is planning to generate hydropower at the site.

The CDM Modeling study found that further reductions in summer phosphorus discharge requirements at the WWTFs below 0.1 mg/L without further analysis to determine appropriate winter limits would not contribute significantly to further reduction in phosphorus flux from the sediment.

DAM AND SEDIMENT REMOVAL ALTERNATIVES

Dam Removal

As described above and summarized below, modeling studies indicated that four dams whose removals would most benefit water quality in the Assabet River are Ben Smith, Gleasondale, Hudson, and Powdermill Dams with Ben Smith providing the most significant water quality benefit.

In addition, dam removal would restore the natural connectivity of the river system and provide for a more sustainable riverine ecosystem. In consideration of the second goal to restore the aquatic ecosystem and also provide localized water quality benefits removal of Aluminum City and Allen Street Dam are included. All six dams are retained for consideration for removal.

> Removing all 6 dams would have a very beneficial impact on water quality. Removing a dam would have multiple benefits in water quality. First, the residence time in each impoundment would be reduced which would reduce the biomass growth in the river. Removing the dams for the larger impoundments would have the largest benefits. Removing Ben Smith dam would have the largest benefit; Hudson, Gleasondale, and Powdermill dam removals would have the next best benefits, and Aluminum City and Allen Street would have the smallest benefits. A second benefit from removing dams would be reduced sediment phosphorus flux from the reduced biomass growth. Less biomass growth would produce less algae to settle and less phosphorus cycling through the sediments. The sediment phosphorus flux reduction is expected to be approximately 80 percent, near the TMDL target of 90 percent reduction, if three of the larger dams (Hudson, Gleasondale and Ben Smith) were removed. A third benefit from dam removal is increased reaeration in the shallower water depths. Increased reaeration will improve dissolved oxygen in the river.
>
> *Excerpt from Page 6-4 of the Assabet River Sediment and Dam Removal Modeling Report (CDM, June 2008)*

Sediment Removal

Sediment removal alone was also considered as an alternative in the modeling studies performed by CDM, however this alternative was determined to be of little value and in some cases may have negative impacts on water quality. Sediment removal alone without dam removal was dropped from further consideration as a long term solution.

> Sediment removal/dredging with the goal of reducing the phosphorus flux will not improve water quality in the river system. This alternative was simulated in the HSPF model which predicted a negative impact on water quality. Though the phosphorus sediment flux will be reduced, the benefit will only last a few years (estimated 2 to 5 years). The phosphorus sediment flux is "driven" by the biomass growth and instream phosphorus concentrations. Additionally, up to 3 feet of sediment will need to be dredged to effectively reduce the phosphorus sediment flux based on past sediment cores by USGS. This sediment dredging increases the impoundment volumes which has several negative impacts on water quality. With the sediment removal/dredging alternative, the residence time would be longer in each impoundment, which would allow additional biomass growth, which in turn will increase sediment phosphorus flux. Also, re-aeration (transfer of oxygen from the air to the water) would be reduced in each impoundment from the deeper impoundment depths.
>
> *Excerpt from Page 6-4 of the Assabet River Sediment and Dam Removal Modeling Report (CDM, June 2008)*

Sediment Deactivation

In some cases, sediment deactivation can be an effective approach for mitigating the impacts of phosphorus enriched sediment on a water body, particularly a lake or pond where anaerobic conditions at the sediment water interface can result in release of phosphorous to the water column creating a potential significant in-lake (internal) source of phosphorus. However, sediment deactivation in rivers is not a widely used approach. See the following analysis of sediment deactivation provided by CDM for the Assabet River. Sediment deactivation for the Assabet River was determined to be ineffective and dropped from further consideration as a long term solution. (However, this does not rule out the possibility that stakeholders may wish to pursue a pilot study with USGS to gather field data to determine short-term benefits.)

Sediment deactivation is generally only used when there is good control of watershed (external) sources of phosphorus and when the historic sediments contain a significant source of phosphorus to the overlying water column. The general approach is to apply a chemical (aluminum, iron and calcium salts have been used but alum is most frequently applied) uniformly across the lake so that the chemical both scavenges inorganic phosphorus in the water column and then seals the sediment to significantly hinder the recycling of sediment phosphorous into the water column. To achieve the correct dose of the chemical it is important to understand the lake's water chemistry, particularly pH and alkalinity as these determine the potential additional need to add a buffering agent. A modified weed harvester is most frequently used for alum application.

Due to the dynamic nature of the Assabet River system, and the fact that the sediments themselves are not the sources of P-flux, sediment de-activation is not considered to be a viable option for improving water quality or meeting overall objectives of the Assabet River Sediment and Dam Removal Study as a long term solution

As discussed in detail in the Assabet River Sediment and Dam Removal Modeling Report (CDM, 2008) the major factors affecting sediment P-flux in the river system are in-stream phosphorus concentrations, resulting from both wastewater treatment plant discharge, non-point sources in the Assabet River watershed, and the characteristics of the river system itself. If sediment de-activation was performed in the Assabet River, the phosphorus in the sediment would be fairly rapidly (2-5 years) replenished from the settling of biomass and in-stream phosphorus. The effects of in-stream phosphorus and associated settling into existing sediment in the Assabet River, are further compounded due to the presence of large impoundments (e.g. Hudson, Gleasondale, Ben Smith and Powdermill), which essentially allow more time for phosphorus from the water column to be incorporated into biomass to settle into existing sediment due to significant residence times in the impoundments.

Therefore, if sediment de-activation were considered as an alternative to control P-flux from sediments in the Assabet River, and if the in-stream phosphorus concentration were to remain as is (planned improvement conditions, as discussed in Assabet River Sediment and Removal Study Modeling Report (CDM, 2008)) the source of sediment phosphorus would not change significantly.
Information Source: CDM Memo dated July 29, 2008

DESCRIPTION OF DAMS CONSIDERED FOR REMOVAL

General Characteristics

The six Assabet River dams considered for removal were originally constructed either in the 1900s or pre-1900s. (See Table 3.) Although the river has been dammed for several centuries these dams did change what was once a free flowing river with ripples and pools, wetlands, and small waterfalls to an impounded river system. The dam's impoundment areas as reported in the USGS 2003 report page 40 vary from about 0.3 aces to 145.8 acres and in length from about 0.06 miles to 2.15 miles. The impoundment area in the USGS report is the area that an observer of the shoreline and open water areas would characterize as the impounded area however as the CDM modeling shows, the extent of influence of the dams on the water levels extends past the observed impoundment areas. (See Table 4.) The extent of influence of the dams on water levels were determined by reviewing the Tables in Appendix F of the CDM 2008 modeling report. Photographs of the dams and additional information on each dam are included in Appendix B.



Figure 3. View of Ben Smith Impoundment

Table 3. Dam Information, Year Built

Dam Name	Town	DAM ID	Year Built	Dam site dates from	General Condition
Aluminum City	Northborough	MA02843	1925	pre-1900	poor
Allen Street	Northborough	MA00995	1900	1720	poor
Hudson	Hudson	MA00447	Repaired 1987	1860	good
Gleasondale	Stow	MA00820	1924/1883	1750	poor
Ben Smith	Maynard	MA00752	1850	1850	good
Powdermill	Acton	MA00128	1924	pre-1835	Under re-construction

NOTES:
DAM ID - Massachusetts Conservation and Recreation, Dam Safety Bureau, DAM ID
GENERAL CONDITON- For planning purposes only, not engineering assessment

Table 4. General Dam and Impoundment Characteristics

Dam Name/Location	Estimated Impoundment Length (miles)	Impoundment Area from USGS Report (acres)	Impoundment Max. Water Depth, USGS report (ft.)	Estimated Extent of Dam Influence
Aluminum City in Northborough	0.06	0.39	4	about 0.1 mile in Northborough
Allen Street Dam in Northborough	0.55	6.9	8	about 0.6 miles to River Street in Northborough
Hudson Dam in Hudson	0.77	21.9	10	about 1.2 miles to Chapin Road in Hudson
Gleasondale Dam in Stow	0.61	13.6	11	about 1.5 miles to Cox Road in Hudson
Ben Smith Dam in Maynard	2.15	145.8	11	about 5 miles to Route 62 in Stow
Powdermill Dam in Acton	0.74	27.2	8	about 1 mile to Crane Ave in Maynard

Dam Safety

In Massachusetts the Office of Dam Safety, Department of Conservation and Recreation (DCR) is responsible for overseeing the safety of the dams. State Law requires the dam owners to be responsible for completing periodic inspections of their dams and implementing any required maintenance or repair.

Hazard Ratings for each of the dams were obtained from DCR and are shown in Table 5 for information purposes only.

Table 5. Dam Safety Hazard Rating

Dam Name	**Town**	**DCR DAM ID**	**DCR – Dam Hazard Rating**
Aluminum City	Northborough	MA02843	not available
Allen Street	Northborough	MA00995	S
Hudson	Hudson	MA00447	S
Gleasondale	Stow	MA00820	L
Ben Smith	Maynard	MA00752	S
Powdermill	Acton	MA00128	S

H = High Hazard Potential dam refers to dams located where failure will likely cause loss of life and serious damage to home(s), industrial or commercial facilities, important public utilities, main highway(s) or railroad(s).
S = Significant Hazard Potential dam refers to dams located where failure may cause loss of life and damage home(s), industrial or commercial facilities, secondary highway(s) or railroad(s) or cause interruption of use or service of relatively important facilities.
L= Low Hazard Potential dam refers to dams located where failure may cause minimal property damage to others. Loss of life is not expected.

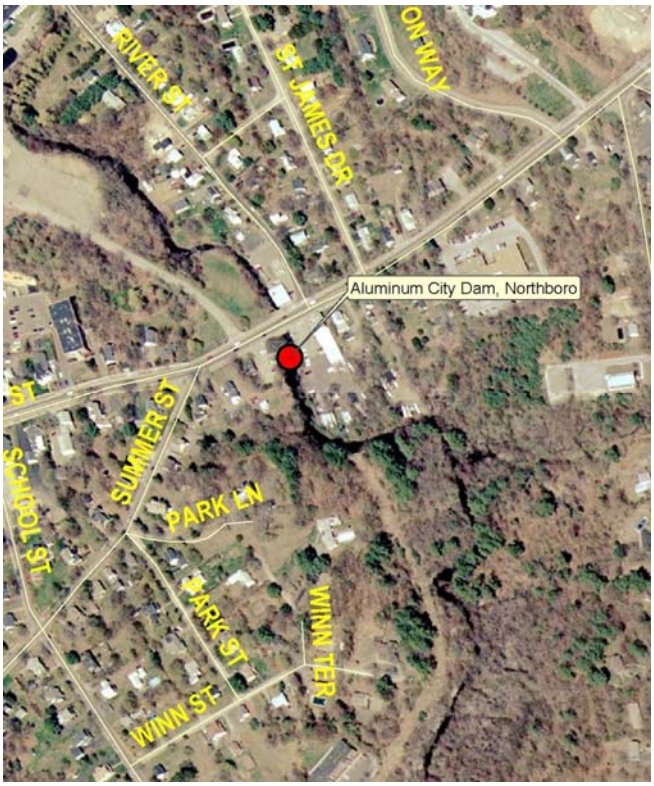
Existing Uses

The dams have been in place for many years and uses have changed over time, from their original purpose as mill dams. However, the dams and impoundments are still valued by locals for recreation and visual impacts, and as a potential source of water and for hydropower

generation. Existing uses of the dams and impoundments were identified through meetings with the dam owners and observations during field visits and these uses are discussed below. A detailed user survey or water supply investigation was not conducted as part of this study.

ALUMINUM CITY DAM

Recreation, Land Use and Viewscape. The impoundment has no developed or informal canoe or boat access. The land adjacent to the river in this area is in private ownership. Land use adjacent to the impoundment is commercial and residential. The river flows through the Juniper Hills golf course not far upstream of the impoundment. The dam is visible from the buildings adjacent to the river.



Water Supply and Hydroelectric Power. The impoundment is not currently used for water supply or hydropower generation. The potential for future use appears low.

ALLEN STREET DAM

Recreation, Land Use and Viewscape. The impoundment has no developed boat access. The river, however, is readily accessible from Hudson Street, near the Wachusett Aqueduct.

Discarded lures and line indicate the site is fished to some extent. There are several private canoe launch points located upstream of the Allen Street impoundment.



The impoundment is visible from Hudson Street and Allen Street and has aesthetic appeal due to the reflection of the archways of the Wachusett Aqueduct over the impoundment. Dense growth of duckweed and mats of filamentous algae likely detract from the aesthetic appeal of the site during summer months.

The historic mill building at the dam has been converted to an apartment complex entitled "Residence at the Falls". There may be some appeal to renters to be located adjacent to flowing waters. It is expected that improvements in water quality would benefit this asset. However, it is not currently known if a natural fall exists at the site or if dam removal would eliminate the "falls" setting.

Water Supply and Hydroelectric Power. The impoundment is not used for water supply or hydropower generation. The potential for future use appears low.

HUSDON DAM

Recreation, Land Use and Viewscape. Land use includes commercial, residential, and public properties. About 75 percent of the impoundment shoreline between the dam and the Taylor Memorial Bridge (footbridge) is privately owned. Public land along this reach includes conservation land, town park land, and the Hudson Town Library.



Between the Taylor Memorial Bridge and Chapin Road, the riparian corridor is largely owned by the Town of Hudson or private organizations (The Elks Club, Yankee Golden Retriever Rescue, and the Portuguese Club). This includes town parkland (Wood Park, Apsley Park and Riverside Park), conservation land, active and passive recreation land, and Hudson High School. The Taylor Bridge is an impressive double arch pedestrian structure and connects Wood and Apsley parks.

The Town of Hudson Recreation Department hopes to work with private organizations and owners to develop a walking trail along both sides of the river from the Taylor Memorial Bridge to Riverside Park at Chapin Street. (See Appendix A, Plate 3 to view this area)

There are several public boat launches on the river. These include a put-in at the Maynard town park at Ice House Landing, and at a boat ramp at White Pond Road. There are also some private access points along the lower impoundment. Dense growth of duckweed and other submerged aquatic vegetation impedes recreation use of the impoundment during summer months.

Popular fishing sites include Taylor Memorial Bridge, Chapin St. Bridge, and Route 85 bridges downstream of the dam. Canoe fishing is also popular. Motorboat use of the impoundment is permitted but rare. During winter the impoundment is a popular ice fishing location.

Water Supply and Hydroelectric Power. The impoundment is not used for hydropower generation. The town has no plans to use this site for hydroelectric generation in the future. At the dam, there appears to be a water intake for possibly fire protection of a nearby building, however more research is needed to verify status.

GLEASONDALE DAM

Recreation, Land Use and Viewscape. Land use is a mix of industrial (at the mill), residential, recreation (Stow Acres golf course), and farmland (Orchard Hill). Nearly all of the impoundment shoreline between the dam and the Hudson Town Line is privately owned. Public open space is limited to a small lot on Route 62 near the Gleasondale Dam.

The nearest public canoe access is at the Cox Street Bridge in Hudson, about 1.5 miles upstream of Gleasondale Dam. There is no public boat access near the dam where fringing wetlands and currents pose a challenge for those trying to portage around the dam. Dense growth of duckweed and submerged aquatic vegetation impedes recreational use of the impoundment during summer months. Duck blinds located on the northern embayment suggest hunters use the site. The nearby Orchard Hill provides 100 acres of grassland habitat for bobolink (McAdow, 2000).

The river and dam are part of the view from several private homes along Route 62, the Gleasondale Mill Complex, the Orchard Hill farm, and the Stow Acres Golf Course (Lambert Hill). From the river, there are dramatic views of Orchard Hill, a steeply sloped, grassy glacial drumlin that rises 130 feet above the impoundment. Grazing horses are often visible on the hill.

An impressive horse barn and farmhouse are visible from the river near the dam.



Water Supply. The old tail race (sluiceway) feeding from the dam to the mill complex is used for fire suppression water supply purposes by both the mill owner and the Town of Stow.

The sluiceway feeds a cistern that has the intake for the mill sprinkler system. Water is pumped from this cistern to holding tanks. Water in these tanks is needed to feed the sprinkler system during a fire. If the dam is removed, there needs to be features incorporated to provide for water supply for the mill sprinkler system.

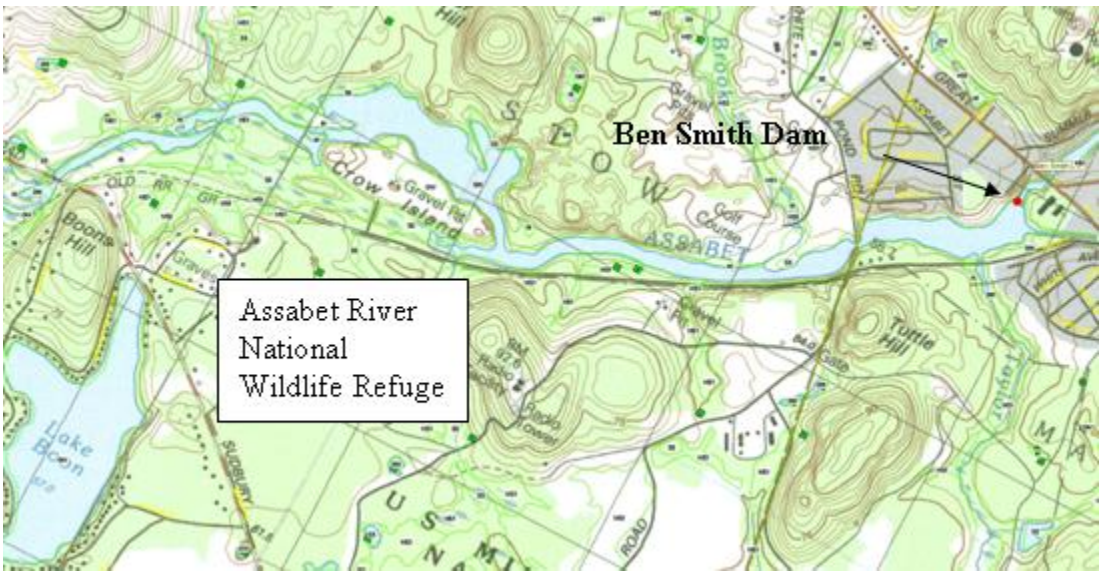
As reported by the Chief of the Stow Fire Department, the sluiceway is the main source of water for the Department in case of a fire at the Gleasondale Mill building and the surrounding community. Stow does not have a public water supply system. The Fire Department backs their trucks up to the sluiceway to fill the trucks with water. If the dam were removed the design would need to incorporate features to allow the Stow Fire Department to continue to fill their fire trucks.

Hydroelectric Power. The impoundment is not currently used for hydropower generation. The old power wheels have been removed and there are no plans to reactivate hydropower at this site.

BEN SMITH IMPOUNDMENT (INCLUDING CLOCK TOWER POND)

Recreation, Land Use and Viewscape. Land use is a mix of commercial, residential, and open space. Adjacent to the impoundment, much of the shoreline between White Pond Road and Sudbury Road is protected open space. The Assabet River National Wildlife Refuge borders the river for about 1.5 miles along this reach and the Stow Town Forest is located on the other side of the river. Refuge trails currently do not approach the Ben Smith Impoundment. There are, however, plans to construct a rail trail along the river. The trail would follow the impoundment from Route 117 to Sudbury Road. A general map of the refuge is included in Appendix I.

Canoe access is available at Route 62, at Sudbury Road, at White Pond Road, and near the Ben Smith Dam via the adjacent building parking lot.



The Clock Tower mill ponds and Clock Tower Place and the dam are privately owned. Boating on the pond by the public is not permitted. The mill pond shoreline is available to the work force at Clock Tower Place for walking. A large parking lot for Clock Tower Place is located adjacent to the pond.

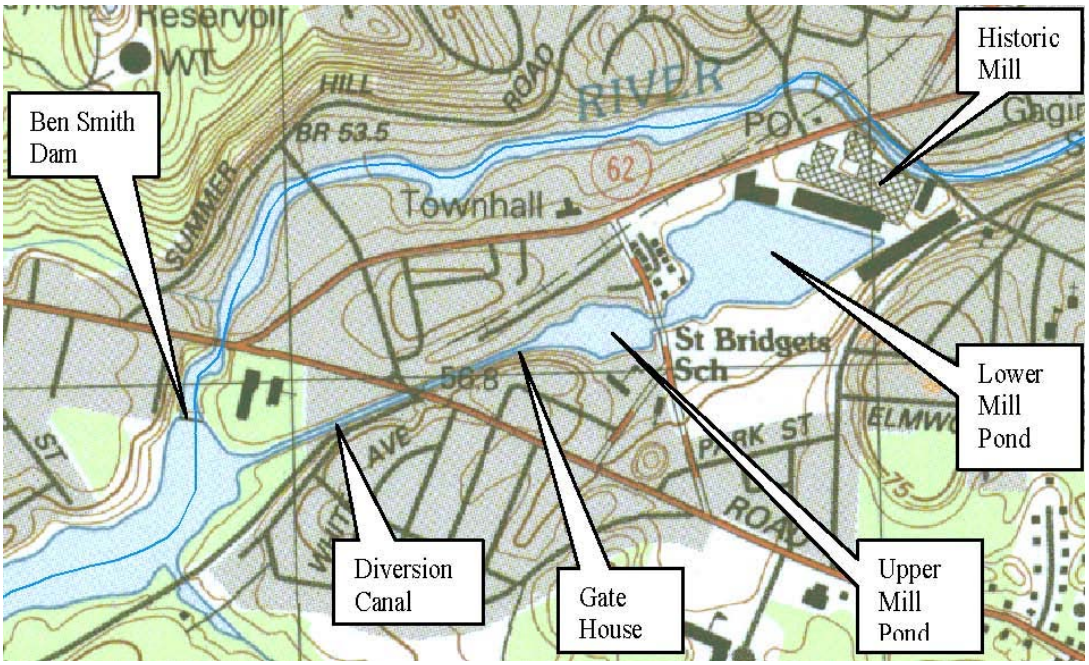


Hydroelectric Power. There is an exiting hydropower[4] project at Clock Tower Place. In 1983 the project was granted an exemption from licensing from FERC. The generator has not operated since 1998. The current owner (Wellesley Rosewood Maynard Mills L.P.) assumed ownership of the facility in 1998 and decided at that time to decommission the hydroelectric project. The surrender of the license exemption was accepted by FERC in 2004. Since 2004, the Dam owner has re-evaluated their decision and is currently considering operating a hydroelectric project at

[4] The powerhouse contains a 125-kW turbine generator.

the site using the existing dam. The project proposes an installed capacity of 290 kw.

The Assabet River and the Mill Ponds. Under the 2004 FERC order new gates were installed on the diversion canal to the mill ponds that are to be operated as a fixed weir during low flow periods. For flows at or below 39 cfs in the river, no flow would go to the mill ponds. These lower daily flows normally occur on days in the months of July through October.

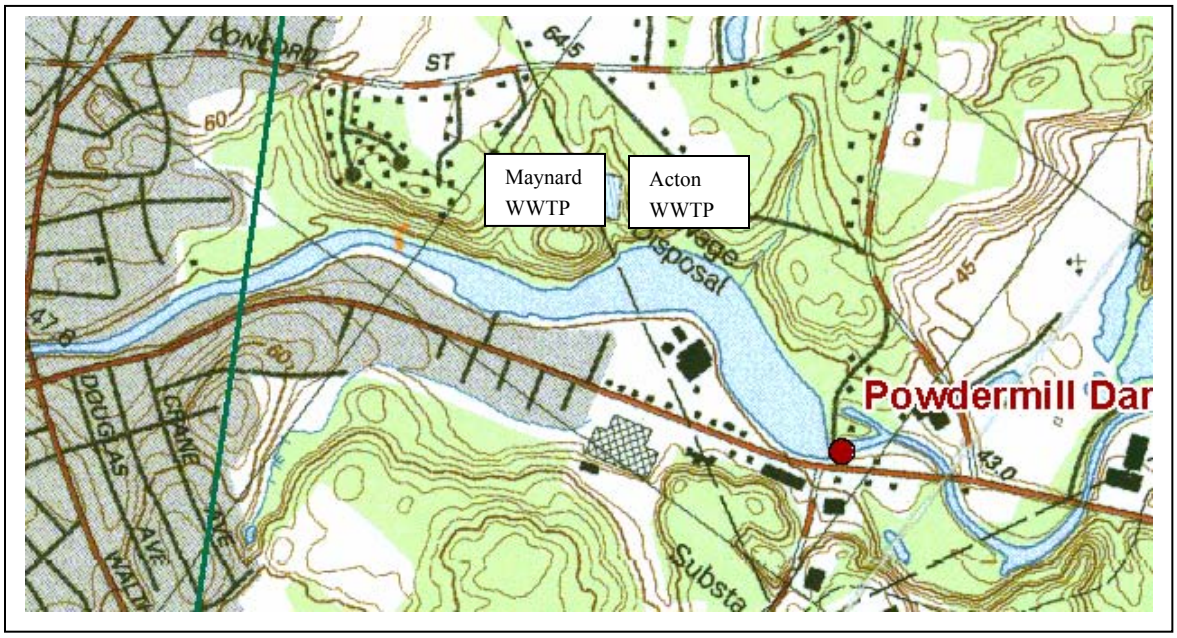


Water Supply. The lower mill pond is a source of water for the Clock Tower Place emergency sprinkler system and an emergency source of water for the Maynard Fire Department.
In addition, the Stow Fire department relies on the Assabet River impoundment above the Ben Smith Dam as a source of water for fire suppression. The Fire Chief in a letter dated November 5, 2007 expressed the concern that removal of Ben Smith Dam will make the Assabet an unusable water source for the Town of Stow for fire suppression needs and also that if the Assabet is an unusable source it could endanger lives and property to the citizens and firefighters of Stow. The Town of Stow does not have a municipal water supply.

POWDERMILL DAM

Recreation, Land Use and Viewscape. Land use near the dam is primarily commercial. Areas upstream of the dam include residential and public uses. Public land includes a parcel of

conservation land and land associated with Acton and Maynard wastewater treatment facilities. There are no public boat launches near the Powdermill Dam.



Water Supply. The impoundment is not used for water supply.

Hydroelectric Power. The dam will be used for hydropower generation. The hydropower generating unit is planned to operate as a run of river facility primarily in the fall and spring by a private owner, Acton Hydropower, Inc. Authorized capacity is 178 kw. A FERC exemption issued for the project requires instantaneous discharge of 40 cubic feet per second, or inflow, whichever is less, and installation of fish passage facilities when anadromous fish restoration efforts reach this site. The owner has stated he plans to install a Denil fishway at the dam when required by FERC to allow for upstream passage of anadromous fish such as alewife.


HIGH ST
OLD HIGH ST
Powdermill Dam
ROUTE 62

ENGINEERING CONSIDERATION FOR DAM REMOVALS

Sediment Quantities

Sediment management is an important component of any dam removal project. Management of sediment accumulations behind a dam can be a significant component of the dam removal costs. In designing the dam removal project the quantity and physical and chemical characteristics of the sediment behind the dam is considered. Based on data collected a decision is then made with involved regulatory agencies as to whether it will be necessary to require removal of the sediments to prevent them from moving downstream.

The Assabet River Study Dams have been in place since the late 1800s and early 1900s and as a result sediments have accumulated behind these dams. If the dams are removed some of this material will reposition within the channel and some will move downstream.

For planning purposes, the amount of sediment that would be transported downstream in a relatively short period of time following dam removal was estimated by CDM for the Assabet Study. The methodology applied is detailed in the CDM, "Assabet River Sediment Management Plan" dated December 2008. The estimated sediment quantity is listed in Table 6.

Table 6. Estimated Sediment Volumes to be Dredged

Impoundment	Volume to be Dredged (yd^3)
Aluminum City	1,300*
Allen Street	2,230
Hudson	71,560
Gleasondale	27,860
Ben Smith	67,600
Powdermill	65,830

* within Aluminum City impoundment area.

Sediment Quality

In 2003, the USGS conducted a survey of sediment distribution and chemistry of the six impoundments along the Assabet River. The USGS study included, approximately 180 sediment cores collected at 57 sampling sites within the impoundments. The cores were analyzed for metals, reactive sulfide, volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), organochlorine pesticides, and extractable petroleum hydrocarbons (EPH). However, the analyses of VOCs were inconclusive due to matrix interference at the laboratory. The metals that were analyzed included those typically considered for sediment characterization studies with the exception of mercury[5].

For purposes of evaluating the quality of the sediments and to aid in understanding the potential sediment disposal options the USGS data and additional sieve analysis data was assessed and results are presented in the CDM "Assabet River Sediment Management Plan", dated December 2008. Based on the assessment, it was concluded that regulatory agencies will likely require additional chemical and physical testing of sediments that may be exposed, dredged, or mobilized as a result of removing the Assabet River dams.

Table 7. Summary of RCS-1 and Landfill Reuse Exceedances *(USGS data from 2003, data published in USGS 2005 report)*

Impoundment	Soil Category RCS-1 Exceedances	In-State Landfill Reuse Exceedances
Aluminum City	Cadmium, Chromium, Nickel	Chromium (1 sample)
Allen Street	Cadmium, Chromium, Nickel	No observed exceedances
Hudson	Arsenic, Cadmium, Chromium, Lead, Nickel	Arsenic
Gleasondale	Arsenic, Cadmium, Chromium, Nickel, PCBs	Arsenic, PCBs
Ben Smith	Arsenic, Cadmium, Chromium, Lead, Nickel	Arsenic, Lead
Powdermill	Arsenic, Cadmium, Chromium, Lead, Copper, Nickel, PAHs	Arsenic, Chromium, PAHs

[5] Mercury was not analyzed by USGS due to storage and analyses requirements

A sampling plan for each impoundment was developed and is included in the CDM December 2008 report. Table 7 above shows by impoundment where one or more samples in the proposed dredge areas were observed to exceed either the RCS – 1[6] level or the landfill reuse level.

Costs Estimates For Dam Removal

Construction Costs. Planning level construction cost estimates for dam removal were developed by CDM for this report based on anticipated construction activities. (See Appendix B for construction activities and Appendix C for cost estimates.) A summary of the estimated construction costs are provided in Table 8 below. Estimates for dam removal and dredging include contractor overhead (16%), profit (10%), bond and insurance cost (5%) and a contingency of 25%. The hauling and disposal costs for the dredged material were also developed by CDM and were based on per ton unit cost. These are included in Appendix C.

Table 8. Estimated Dam Removal and Sediment Management Construction Cost Estimates *(Planning level information)*

Dam Name	Dam Removal Only	Dam Removal and Dredging	Add Hauling and Disposal of Dredged Material	Dam Removal, Dredging, Hauling, and Disposal
	($)	($)	($)	($)
Aluminum City	639,490	924,330	86,000	1,010,330
Allen Street	1,007,780	1,637,380	136,000	1,773,380
Hudson	1,440,640	4,677,000	4,727,000	9,404,000
Gleasondale	2,428,450	4,027,950	1,855,000	5,882,950
Ben Smith	4,559,430	7,759,300	5,081,000	12,840,300
Powdermill	1,764,890	4,841,180	6,961,000	11,802,180
Total All Six Dams	11,840,680	23,867,140	18,846,000	42,713,140
Total Hudson, Gleasondale, and Ben Smith	8,428,520	16,464,250	11,663,000	28,127,250

[6] *310 CMR 40.1600 MCP Reportable Concentrations Soil Category RCS-1.* The Massachusetts Contingency Plan (MCP) does not have notification thresholds for contaminants in sediment.

Dam removal costs do not include cost for any desired planting and or contouring of the project area above the dams. Future detailed design of dam removals should consider these features.

The total construction cost estimate for a "six dam removal project" is about $42.7 million, for a "Ben Smith, Gleasondale and Hudson" project at about $28.1 million, and for a "Ben Smith Dam alone" project about $12.8 million.

The percent of the total cost that applies to the sediment management costs (dredging, dewatering, hauling, and disposal) ranges from 37% for Aluminum City Dam to about 85 % of the construction cost for Powdermill and Hudson dams. (See Table 9.) Modeling at these sites demonstrated that a significant quantity of material will move downstream in a short period of time following dam removal.

Table 9. Dam Removal Construction Cost versus Sediment Management Cost.

Dam Name	Dam Removal Construction Cost %	Sediment Management Cost %
Aluminum City	63%	37%
Allen Street	57%	43%
Hudson	15%	85%
Gleasondale	41%	59%
Ben Smith	36%	64%
Powdermill	15%	85%

CDM's study of the sediment identified the need for additional testing of the sediment behind the dams during design to further define the quality of the sediments and verify the extent of sediment removal that will be required by the regulatory agencies prior to dam removal. If more sediment can be left in the river or if less costly disposal options are identified then this will decrease the overall construction costs of the dam removals.

Design and Management Costs.

In addition to construction costs additional cost will be incurred during implementation including additional sediment sampling, design of the dam removal projects, permitting, and project management. Design, permitting, and project management costs are not estimated at this time and will vary depending on the entity that implements the project. Also there may be real estate costs associated with implementation including items such as cost of the purchase of the dam, permanent or temporary construction easements, and purchase of land in fee as determined to be needed for the project.

TARGET FISH COMMUNITY ANALYSIS

A target fish community (TFC) can be used as a guide to identify the composition of a healthy fish community for large streams and small rivers in the New England region and can guide and evaluate river rehabilitation. This approach was applied to the Assabet River and is detailed and discussed in Appendix E. Appendix E also addresses the anadromous fish restoration efforts on the river.

The existing fish community (EFC) in the Assabet is not consistent with the target fish community (TFC) proposed for the river. Current fish species composition consists primarily of microhabitat generalists and pollution tolerant species. Figure 4 displays the existing fish species in the river and Table 10 compares the TFC to the EFC.

Figure 4. Assabet River Existing Fish Community

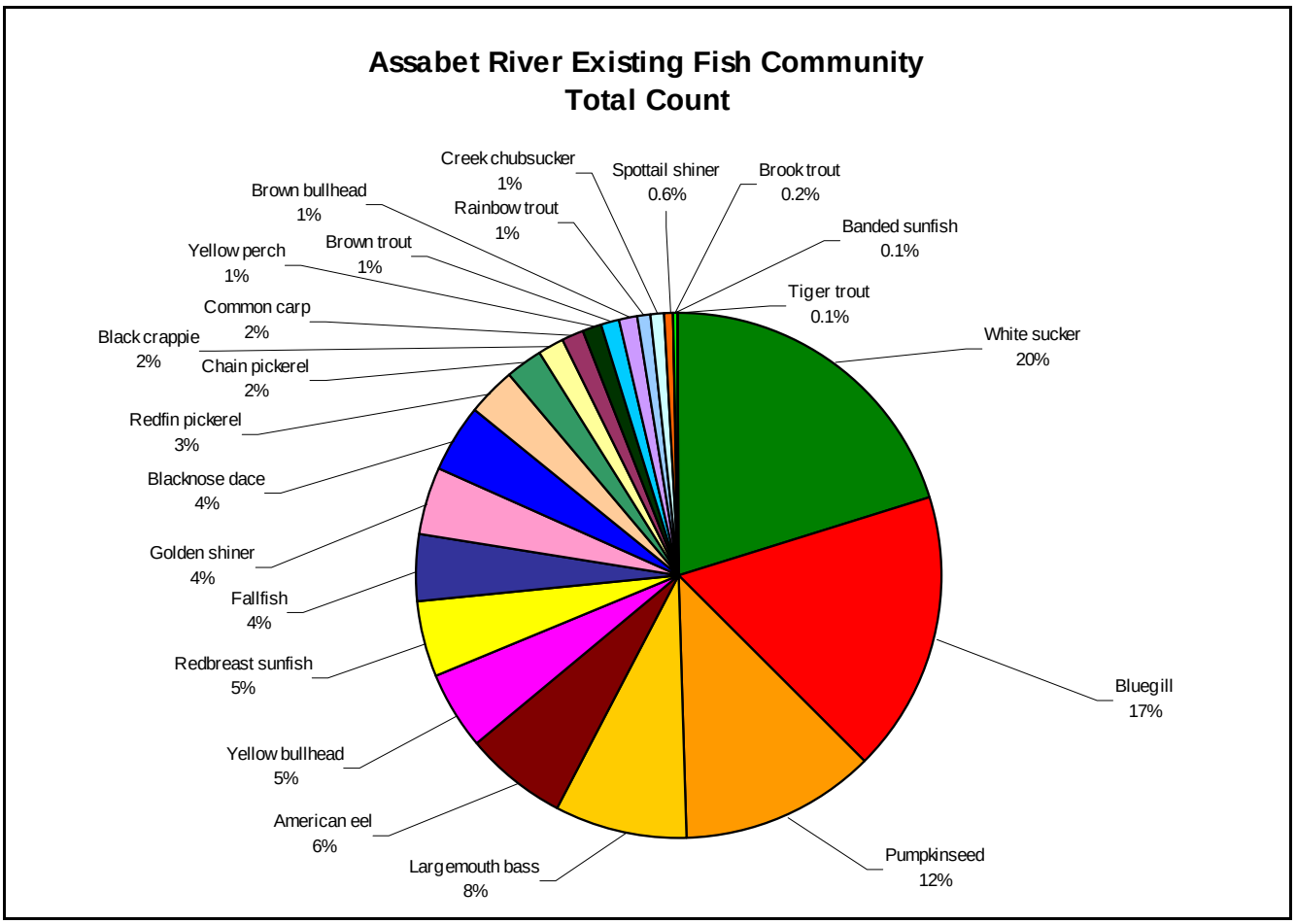


Table 10. Assabet River Fish Community Analysis

Comparison of the Target Fish Community (TFC) and Existing Fish Communities (EFC) Based on Habitat-Use and Pollution Tolerance Classification Guilds

	%	%	%	%
Habitat-Use Class	**Expected TFC**	**Total Existing Fish Community**	**Impoundment Only**	**Riverine Only**
Fluvial Specialist	45.8	11.2	0	17.8
Fluvial Dependent	28	20.3	10.3	26.2
Macrohabitat Generalist	26.4	68.5	89.7	56
Pollution Tolerance	**Expected TFC**	**Total Existing Fish Community**	**Impoundment Only**	**Riverine Only**
Intolerant	7.7	2.9	0	4.6
Moderate	75.4	35.6	39.4	33.4
Tolerant	17.1	61.5	60.6	62

The overall dominance of macrohabitat generalists and lack of fluvial specialist is directly related to the effect of the dams and the creation of impoundments in what naturally would be free flowing stretches of river. The dominance of the current fish population by more pollution tolerant species (e.g. white sucker and bluegill) indicates that the Assabet River ecosystem is degraded.

It is expected that removing dams on the Assabet River and improving water quality will improve the aquatic habitat and support the increase in fluvial dependent and fluvial specialist species consistent with the proposed target fish community (TFC) for this river.

Over the long term, removing dams on the Assabet would also provide for the future restoration of the migratory corridor on the Assabet and provide access to spawning grounds and nursery habitat for river herring when passage is provided at the Talbot Dam in Billerica. In the short term, American eel would likely benefit from removal of obstructions such as dams that impede upstream and downstream passage and make their migration more difficult. American eel is the only migrating species that is currently able to access the Assabet due to their ability to pass over or around dams.

DAM REMOVAL ASSESSMENTS

Impact of Dam Removal on Water Surface Elevations

Computer modeling of the Assabet River included an examination of the effect of dam removals on water surface elevations. Effects were calculated using the HEC-RAS computer model developed for the study. (CDM, Modeling Report, June 2008.) The HEC-RAS model results indicate that dam removals will significantly lower the water surface elevations for the 7Q10, summer average flow, 10-year flood, and the 100-year flood flow conditions. The largest change in water surface elevation occurs for the lower flow conditions, 7Q10 and summer average flows, except for the Allen Street and Gleasondale sites. The change in depth behind each of the dams for the four flow conditions is presented in Table 11. Changes in depth noted in Table 11 are directly upstream of the dam. Changes decrease with distance upstream from a dam as shown in Figure 5 below.

Table 11. Change in Water Surface Elevation for Various Flows Scenarios

Flow Scenario	**7Q10**	**Summer Average**	**10 year**	**100 year**
Dam Removed	**Estimated change in WSEL in feet just upstream of dam**			
Aluminum City	-4.9	-4.8	-4.2	-0.6
Allen Street	-3.4	-3.5	-4.7	-5.6
Hudson	-7.0	-6.9	-5.4	-3.4
Gleasondale	-4.7	-4.5	-4.6	-5.1
Ben Smith	-7.4	-7.4	-5.6	-4.0
Powdermill	-7.8	-7.6	-7.2	-7.1

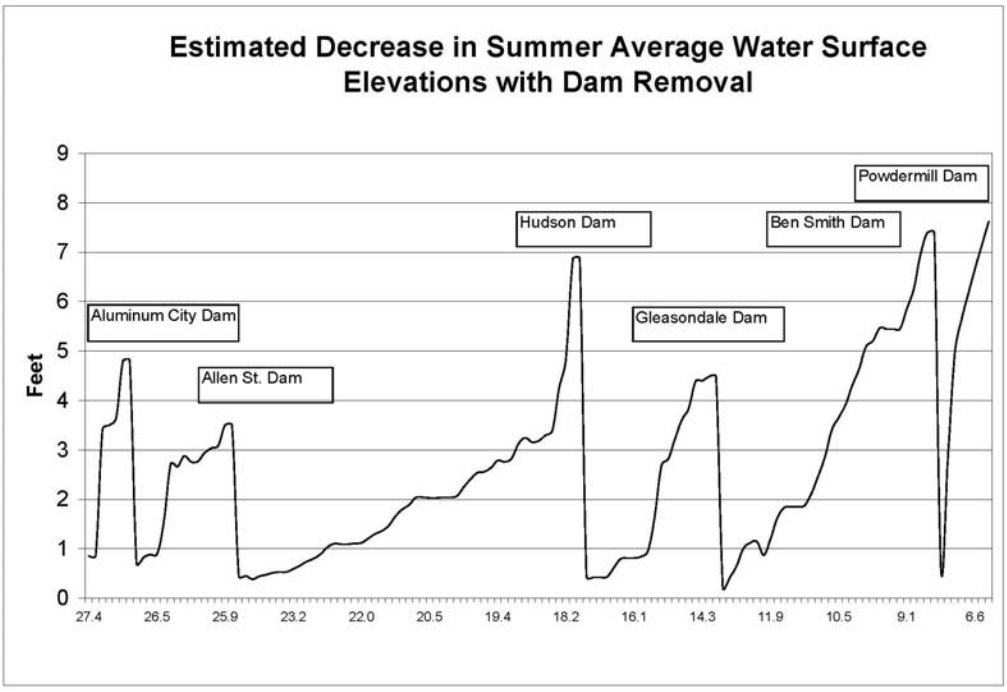


Figure 5. Assabet River Change in Water Surface Elevation[7]

Decreasing water surface elevations with dam removals will impact uses that rely on the pools (water levels) maintained by the dams. Decreased water surface elevation will result in a change in wetlands along the river (See Appendix D Figures 1 to 3) and may affect any riparian landowners that have come to depend on the impoundments as a source of water. The change in the amount of time the river would be available for canoeing and kayaking will depend on the season, the flow conditions in a given year, and will vary by area along the river. Water depths will be deeper under higher river flow conditions and shallow (one to two feet) under low flow conditions. (Detailed data on Assabet River Water surface profiles is provided in Appendix F of the CDM modeling report dated June 2008.)

[7] Flows used for the summer average water surface elevation calculations were 13 cfs at Northborough to 64 cfs at Maynard.

Impact of Dam Removal on the Mill Ponds at Clock Tower Place

CDM reviewed the situation that would exist if Ben Smith Dam were removed and how this would affect the flow of water to the Mill Ponds at Clock Tower Place. CDM determined that the Assabet River water level at the current canal intake point would drop such that water would no longer flow by gravity into the Mill Ponds at Clock Tower Place.

In order to direct water into the Mill Ponds by gravity, the intake location would need to be moved upstream on the Assabet (i.e., to remain higher than the Mill Ponds normal pool elevation). However, due to the mild slope of the river upstream of Ben Smith Dam, an intake along the Assabet River channel is likely not feasible. Another option is to pump water from the Assabet River into the Mill Ponds to maintain a small pool of open water. This might include allowing wetlands to fill in some of the shallower areas. It may be possible to create an open space with wetlands that would be both aesthetically pleasing and still reflect the historic mill pond function of the site. (CDM memorandum June 8, 2007.)

Impact of Dam Removal on Groundwater Levels Adjacent to the River

Surface water levels in the river will generally be lower after dam removal. The impact of lower river water levels on the adjacent groundwater levels was not included in this study, but could be considered during future dam removal studies if desired. Any impact will decrease with distance from the river.

Impact of Dam Removal on Water Supply for Fire Protection

Initial planning level review indicated that dam removal could impact water supply for fire protection purposes at the Gleasondale Mill, the water supply for fire protection for the Town of Stow for the Gleasondale and Ben Smith Dam removals (Town of Stow uses the Assabet River for fire truck water supply), and fire protection source water from the Ben Smith Lower Mill Pond at Clock Tower Place. During dam removal design these uses can be investigated further and mitigations plans developed as appropriate.

Flood Levels

Summary. Removing dams will lower water levels in the Assabet River. Storage behind the dams is small and will not be entirely lost when the dams are removed, because the dams are located at natural restrictions in the river, so effects of dam removal on downstream peak flows will be small. Future studies will determine if it is necessary to leave part of the abutments in

place to further restrict flood flows such that there is no increase in downstream peak discharges; however, the elimination of the pools behind the dams will mean that the same storage as before dam removal can be achieved at a lower water level. On the other hand, because storage behind the dams amounts to only a small amount of runoff from the watershed, no significant reduction in downstream peak flows can be achieved utilizing the extra storage made available by removing the dams and lowering the water levels behind them.

Surcharge Storage. That removing a dam will lower the water level behind it is intuitive, but there are concerns that the loss of surcharge storage will increase peak flows downstream and, therefore, the risk of flooding. "Surcharge storage" is that which occurs when flow increases causing the level of the water over the spillway to rise, which also causes the water level in the pool behind the dam to rise. The increased volume of water behind the dam and above the level of the spillway crest is the surcharge storage. If the pool behind the dam is large enough compared to the size of the watershed, the surcharge storage can significantly reduce peak downstream flows. However, the storage behind these dams amounts to only a small amount of runoff. Total surcharge storage behind the three dams whose removal would most benefit water quality in the Assabet River – Ben Smith, Gleasondale, and Hudson – is 3,850 acre-feet, which is equivalent to 0.6 inches of runoff from their 114 square mile drainage area. While this is not a large amount of storage, most of it will be retained through natural channel storage and the actual loss of storage will be much smaller.

Channel Storage. For practical reasons, dams are built at natural channel restrictions, and even with a dam completely removed, water can still backup behind that point with much the same effect as surcharge storage. At the Ben Smith Dam site, for example, HEC-RAS backwater analyses show that surcharge storage during the 100-year flood is 1,220 acre-feet with the dam in place and 1,140 acre-feet with it removed, a difference of 110 acre-feet, which is equivalent to less than 0.02 inches of runoff from the watershed. Total surcharge storage during the 100-year flood behind Ben Smith, Gleasondale, and Hudson Dams is 3,850 acre-feet with the dams in place and 3,560 acre-feet with them removed; the lost storage due to removal of these dams is 290 acre-feet, which is equivalent to less than 0.05 inches of runoff from the upstream watershed. By comparison, the 100-year 24-hour rainfall for this area is about 6.5 inches according to the "Rainfall Frequency Atlas of the United States" (1961), and 7 inches according to "Atlas of Precipitation Extremes for the Northeastern United States and Southeastern Canada" (1993).

Additional Studies. Although the loss of storage due to removal of three dams (Ben Smith, Gleasondale, and Hudson) is very small, it may be necessary during design of the dam removals

to consider leaving part of the abutments at one or more dam sites in place to restrict high flows such that there is not even a small increase in downstream peak flood flows. Dam removal will mean that the storage below the former spillway crest will now be available for channel surcharge storage. Consequently, it will be possible to retain the full surcharge storage at a lower water elevation. For this feasibility study, only backwater analyses were performed. If dam removals are pursued then, future studies should include routings of flood hydrographs to determine if any channel restrictions are needed at the sites where dams are removed.

Wetlands

Wetlands and Riparian Vegetation

Hundreds of acres of vegetated wetlands occur along the Assabet River. The extent of wetlands along the river varies greatly. In areas where the river is affected by development there may be only a narrow fringe of vegetated wetland or none at all. In some impoundments, wetlands extend hundreds of feet from the river. Many of the wetlands along the Assabet River exist because of the water backed up by the dams.

Wetlands within the Assabet River watershed have been mapped and classified by the Massachusetts Wetlands Conservancy Program. The mapping is based on interpretation of 2001-color aerial photography. Fieldwork conducted by the Corps in 2005 indicated that these maps were accurate enough for the planning purposes of this study, except for Powdermill where the dam was partially breached in April 2004 and the wetland plant community is adjusting to new hydrologic conditions. Other sources of information include maps of aquatic vegetation at impoundments prepared by ENSR (2001) and OAR (2006).

The Ben Smith impoundment supports the most wetland and open water aquatic habitat, followed by Gleasondale, Hudson, Powdermill, Allen Street, and Aluminum City Dams. A description of wetland communities along the Assabet is provided in Appendix D.

Impacts of Dam Removals on Wetlands

Wetland changes following dam removal were estimated for each impoundment. See Table 1 Appendix D. Table 1 shows existing conditions, the predicted acreage for each wetland type after dam removal, the change in the amount of each wetland type, and the amount of wetlands expected to transition to upland. The planning level analysis determined that there would be both changes in wetland types and a loss of wetlands as a result of dam removal.

Invasive Species

Invasive species are non-native plants that threaten native habitats by spreading so prolifically that they crowd out native species in sensitive forest, wetland and aquatic habitats. Common invasive emergent plants within the Assabet River study area include reed canary grass, which often forms semi-floating mats that are loosely anchored to the bottom and float up and down with changing water levels. Purple loosestrife, a ubiquitous invader, is also found in emergent wetlands and scrub-shrub wetlands along the Assabet River. Purple loosestrife would likely rapidly colonize exposed areas with saturated soils following a draw down for dam removal. Oriental knotweed could colonize exposed areas at higher elevations. Norway maple, Tree of heaven, Japanese barberry, European buckthorn, Japanese honeysuckle, and multiflora rose are also found in tree and shrub communities. Phragmites and yellow iris do not seem to be widespread in Assabet River wetlands. However, non-native invasive species are opportunistic invaders in disturbed habitats, have prolific reproductive capabilities and the ability to out-compete native vegetation. Therefore, it is prudent to develop a vegetation management plan in conjunction with dam removal to avoid the spread of these species to newly exposed areas. A post dam removal monitoring and control program could prevent initial invasion and long-term establishment of these noxious species.

Invasive aquatic plants occurring in the study area include water chestnut, fanwort, and curly pondweed. Generally, these species are associated with the lacustrine environment (sluggish flows and soft substrate) and will not survive in a riverine system due to increase water velocities and inadequate substrates.

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Mitigation for Loss of Wetlands

There is a history of dam building in the eastern United States to provide water-based power for various industrial purposes, most commonly mills, as well as flood control and hydroelectric power. As noted previously, the Assabet River has nine dams on the river, starting in Westborough at the George H. Nichols Dam constructed by the Natural Resources Conservation Service (NRCS)(formerly the Soil Conservation Service) in 1968 for flood prevention and fish and wildlife habitat. Downstream from this are seven old mill dams and one additional flood control dam the Tyler Dam, a “dry bed” flood control facility constructed in1965 by NRCS. Increasingly, dam removal is being considered a viable alternative to costly repairs or rehabilitation to deal with the problem of aging or unsafe dams or to address environmental degradation.

The benefits to stream or river restoration are widely recognized by the environmental community. Water movement through impounded areas is slow, allowing the retention of sediments, chemical and nutrient contamination which can lead to degraded water quality, eutrophication and warming. As well, fish passage and movement of other aquatic species up and down the river are restricted. Many opportunities exist in the Assabet River study area for aquatic ecosystem restoration and improvement through the removal of obsolete dams. These benefits include improved water quality, fisheries and wildlife habitat and the restoration of a self-maintained and sustainable riverine system.

Massachusetts recently published guidance designed to encourage environmental improvements through dam removal projects. (Massachusetts Executive Office of Energy and Environmental Affairs, 2007) Under the Wetland Protection Act (310 CMR 10.53(4)), dam removal may be considered a limited project and as such, the assignment of traditional mitigation requirements is discretional for the local conservation commission (the responsible permitting board). The benefits of dam removal, such as long term water quality and wildlife habitat benefits may be recognized as mitigation as long as the net benefits of dam removal are clearly demonstrated. These inherent benefits are likely to outweigh the short term impacts to water quality (turbidity) and loss of wetland resources. The U. S. Army Corps of Engineers, the agency responsible for the administration of Section 404 of the Clean Water Act, also has some flexibility in accounting for the benefits of river restoration projects and applying mitigation requirements. The evaluation of a "proactive project", as referred to in the Massachusetts General Programmatic Permit (GPP), requires consultation with the Corps, State and Federal agencies "to determine that net adverse effects are not more than minimal."

Dam Removal Considerations for All Project Areas

Newly exposed riparian areas and transitional upland areas should be protected to preserve the open space, wildlife, water quality and flood storage benefits of the land. Development of transitional upland areas would be considered cumulative impacts under The Council on Environmental Quality (CEQ)[8] which defines cumulative impact as found in 40 Code of Federal Regulation (CFR) section 1508.7 as "the impact on the environment which results from the

[8] The Council on Environmental Quality coordinates federal environmental efforts and works closely with agencies and other White House offices in the development of environmental policies and initiatives.

incremental impact of the action when added to other past, present and reasonably foreseeable future actions regardless of what agency (Federal or nonfederal) or persons undertakes such other acts." Transitional upland areas will need to be identified prior to dam removal and a mechanism implemented to prevent suburban/urban development of these areas in order to avoid potential cumulative impacts.

Increased water velocities within the river channel after removal of the dam will likely limit invasive species infestations, such as reed canary grass, fanwort, water chestnut, yellow flag, etc. by preventing rooting or by flushing unanchored vegetation downstream. However, the presence of purple loosestrife in many areas is of particular concern because of its ability for prolific growth and rapid reproductive capabilities in exposed wet soils and shallow aquatic sites.

Following dam removal, newly exposed banks will be highly susceptible to purple loosestrife infestation. The focus of management after dam removal should be to prevent the further spread of purple loosestrife by encouraging the growth of a healthy zone of native vegetation. A vegetation seeding plan should be implemented to provide an initially quick vegetative cover for exposed soils to prevent purple loosestrife seeds from making contact with exposed soils and the maintenance of a dense and durable vegetative cover over the long-term. This may require multiple seeding with different seed mixes depending on the time of year seeding is conducted.

Wildlife and Rare Species

The purpose of this Section is to generally describe the wildlife and rare species associated with the Assabet River and the six study dams and their impoundments to provide information on existing resources.

Habitat

Development along the Assabet River varies considerably as it passes through lightly developed riparian corridors punctuated by more heavily developed village or town centers. In many areas the river remains well buffered by broad floodplain wetlands that have precluded development. Development tends to be most extensive near dams and downstream of dams and increases markedly downstream of the Ben Smith Dam.

The river shoreline has notable protected open space. This includes a 1.5-mile reach along the Assabet River National Wildlife refuge in Stow and many smaller locally protected parcels.

Non-impounded sections of the river are protected from further development by the Massachusetts River Protection Act, which provides regulatory oversight and added scrutiny for development projects within 200 feet of the normal high water level, except in urbanized areas where the protected zone may be reduced in width to 25 ft.

Hundreds of acres of vegetated wetlands occur along the Assabet River (see Wetlands discussion above). The extent of wetlands along the river varies greatly. In areas where the river is affected by development there may be only a narrow fringe of vegetated wetland or none at all. In some impoundments, expansive mosaics of floodplain wetlands extend hundreds of feet from the river. Shoreline along most impoundments is largely undeveloped. There are typically long reaches where broad areas of emergent and scrub-shrub wetland lie between open water and upland habitat. Most impoundments also contain areas with well defined banks where open water transitions abruptly to forested wetland or upland**.**

Wildlife

Wildlife habitat within the Assabet River riparian corridor includes shallow open water areas, emergent, scrub-shrub, and forested wetlands and upland forest. These diverse communities provide valuable habitat for a variety of invertebrates, amphibians, reptiles, birds, and mammals. The river and adjacent riparian habitat also provide travel corridors which allow wildlife to safely move between habitat areas.

Mammals strongly associated with riverine habitat and likely to occur in the Assabet study area include northern short-tailed shrew, beaver, mink, and river otter. Many other mammals utilize riparian upland or wetland habitats. These include star-nosed mole, meadow vole, bats, raccoon, weasel, muskrat, Virginia opossum, white-tailed deer, coyote, and others. Moose occur as occasional transients.

Reptiles and amphibians strongly associated with riverine habitat or impoundments include snapping turtle, painted turtle, and musk turtle. Others that inhabit riparian wetlands along the Assabet include bullfrog, leopard frog, spotted turtle, northern water snake, and ribbon snake. Vernal pools near the river provide breeding habitat for wood frogs, mole salamanders, and other amphibians.

The 1974 to1979 and 2007 to 2011 Massachusetts Breeding Bird Atlas have identified numerous breeding birds from the Assabet River watershed.
(See http://www.massaudubon.org/birdatlas/bba2/)

Many of these species are likely to utilize riparian habitat along the Assabet River. Waterfowl commonly breeding on the Assabet include mallard, wood duck, and Canada goose. Uncommon nesters include American black duck (a declining species), green and blue winged teal, and hooded merganser. The Assabet River also provides wintering habitat for American black duck, mallard, and Canada goose. The Sudbury, Assabet, Concord, Nashua, and Blackstone Rivers of central Massachusetts are designated as an "Inland River Focus Area" in the Atlantic Coast Joint Venture Waterfowl Implementation Plan (ACJV, 2005).

Riparian wetlands also provide habitat for numerous species of resident and migratory songbirds, including marsh wren, song sparrow, veery, catbird, common yellowthroat, yellow warbler, tufted titmouse, red winged blackbird, American goldfinch, and tree swallow.

Wading birds seen on the Assabet, Sudbury and Concord rivers include sora and Virginia rail, black crowned night heron, great blue heron, and bitterns (ACJV, 2005). Osprey and belted kingfisher are often seen fishing in the river or its impoundments. Mudflats and decomposing floating mats of duckweed and filamentous algae provide forging areas for migratory shorebirds such as spotted sandpiper. More than 120 species of birds are reported in the Assabet River National Wildlife Refuge (USFWS 2003), including many that may at least occasionally use riparian habitat.

Rare Species and Critical Habitat Areas

The Massachusetts Natural Heritage Program has identified numerous areas within the Assabet River watershed as potential habitat for rare species. See Figure 6. Three areas on the Assabet River are or were recently mapped as estimated habitat for rare wildlife. These include an area in Northborough mapped as blue-spotted salamander habitat, an area in Stow along the upper reaches of the Ben Smith impoundment mapped as spotted turtle habitat (note: the spotted turtle was removed from the Massachusetts rare species list as of 2007), and an area downstream of Powdermill Dam in Acton and Concord mapped as habitat for Blanding's turtle, and two freshwater mussels (triangle floater and eastern pond mussel). Blanding's turtle is a threatened species in Massachusetts. Transient bald eagle are occasionally seen along the Assabet River.

The entire reach of the Assabet River downstream of Powdermill Dam to the Concord River confluence is mapped as 'Living Waters Core Habitat" by the MA NHESP. Living Waters Core Habitat represents the lakes, ponds, rivers, and streams that provide habitat for rare freshwater species, or that are known to be exemplary aquatic habitat. The key reason for designating the

Assabet as Living Waters Core Habitat is the occurrence of triangle floater and the eastern pond mussel mentioned above.

An area of the Assabet River watershed downstream of the Lake Boone in Stow is mapped as Living Waters "Critical Supporting Watershed". The area includes most of the Ben Smith impoundment and the Powdermill impoundment. "Critical Supporting Watershed" represents the area within which conservation actions, such as improved land management, decreased water use, and land protection, is likely to make the greatest contribution toward protecting the freshwater species living in the Living Waters Core Habitat.

The Massachusetts Bio-Map identifies critical upland and wetland habitat needed to maintain biodiversity. Areas classified as "Core" Bio-Map habitat consist of the most viable habitat for rare plants, animals, and natural communities. "Supporting Natural Landscape" consist of buffer areas around Core habitat and large un-fragmented areas and undeveloped watersheds.

Two areas on or near the Assabet River are designated Bio-Map habitat. A large area south of the Ben Smith impoundment, including much of the Assabet River National Wildlife Refuge, is classified as Supporting Natural Habitat. The Assabet River in Concord downstream of Route 2 is within a large Core area that provides habitat for numerous rare plants and animals, and includes examples of a rare floodplain forest community.

The SuAsCo Biodiversity Protection and Stewardship Plan (Clark 2000) identified numerous "biodiversity sites" within the Assabet watershed. The Ben Smith impoundment includes portions of three biodiversity sites: the Assabet Marshes, Crow Island and Gardner Hill, and Assabet River National Wildlife Refuge. The Assabet Marshes, located upstream of the Ben Smith dam, were noted as an excellent example of marsh habitat along the river which provides excellent habitat for migrating waterfowl, bank swallows, otter, swamp sparrow, and other wildlife.

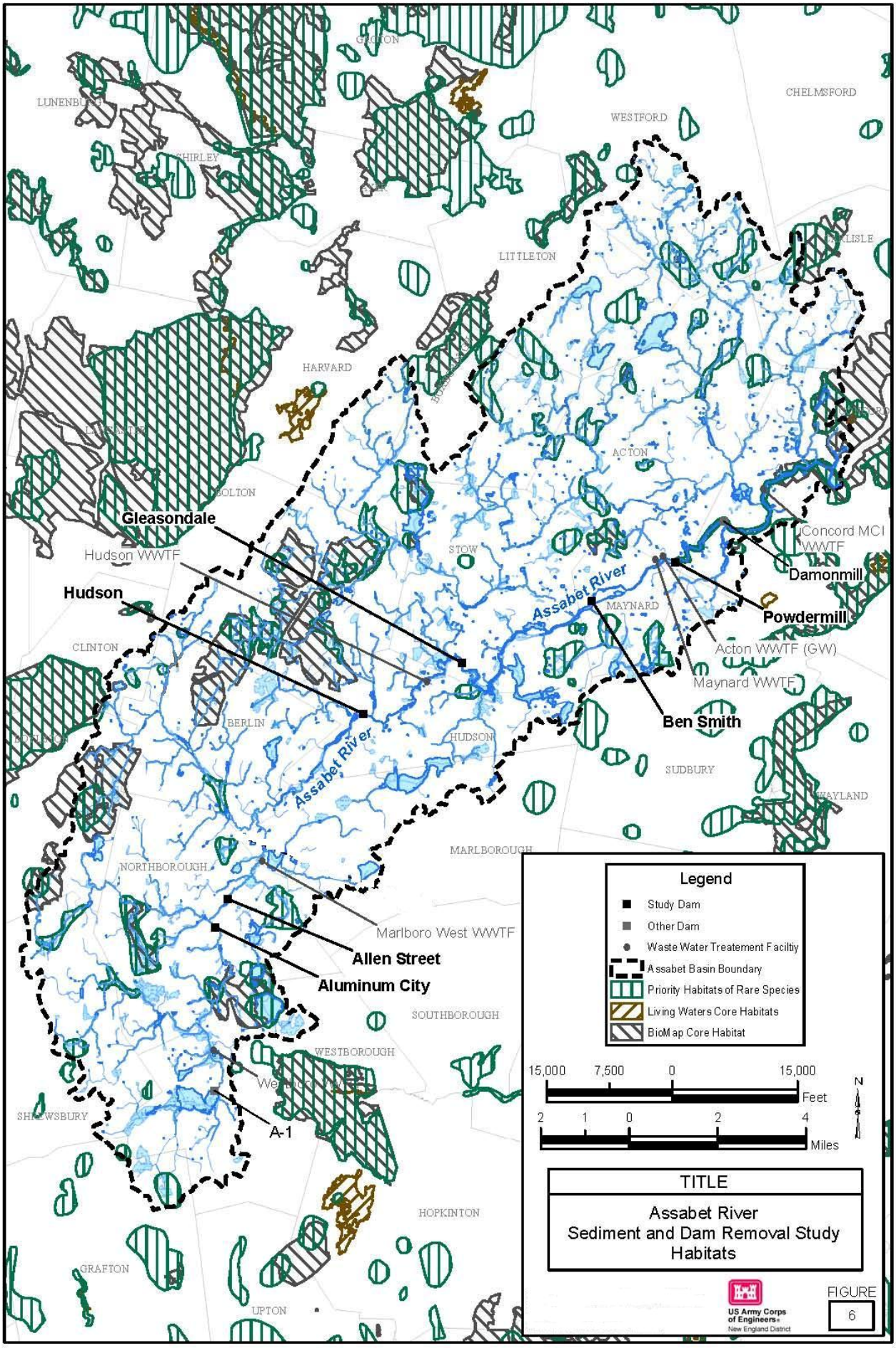
Aquatic Invertebrates

The DEP has sampled stream invertebrates at several locations on the Assabet River as part of a bio-monitoring program (DEP, 2004). Samples are collected only in riffle areas, which are uncommon in the Assabet River. Many of the Assabet River stations are located downstream of dams. The DEP considers all stations on the Assabet River impaired due to reduced species diversity and dominance of caddisflies, an indicator of organic enrichment.

Six of the twelve freshwater mussels occurring in Massachusetts are known to occur in the Assabet River (MA NHESP, 2004) These include three rare species which occur downstream of the Powdermill Dam. These are the triangle floater, the Eastern pond mussel, and Eastern lamp mussel. These mussels are found partially buried in sediment within moderately flowing reaches of the river (MA NHESP, 2004).

Summary Wildlife and Rare Species

None of the impoundments in the study are known to provide habitat for any federally identified rare or endangered species. Based on current information, restoration (dam removal and sediment removal) does not appear to directly impact rare species habitat at the impoundments. However, restoration activities could mobilize sediment and potentially adversely effect rare freshwater mussels downstream of Powdermill Dam. Work should be designed to minimize sediment transport downstream of Powdermill. Also, dam removal will change the wetlands communities and the effect of these changes on wildlife communities will need to be considered during the environmental assessment process in compliance with applicable Environmental Regulations.


Gleasondale
Hudson WWTF
Hudson
Assabet River
Concord MCI WWTF
Damonmill
Powdermill
Acton WWTF (GW)
Maynard WWTF
Ben Smith
Marlboro West WWTF
Allen Street
Aluminum City
A-1
LITTLETON
WESTFORD
CHELMSFORD
HARVARD
ACTON
BOLTON
STOW
MAYNARD
CLINTON
BERLIN
HUDSON
SUDBURY
WAYLAND
MARLBOROUGH
NORTHBOROUGH
SOUTHBOROUGH
WESTBOROUGH
SHREWSBURY
HOPKINTON
GRAFTON
UPTON
Legend
Study Dam
Other Dam
Waste Water Treatement Facilty
Assabet Basin Boundary
Priority Habitats of Rare Species
Living Waters Core Habitats
BioMap Core Habitat
15,000 7,500 0 15,000
Feet
2 1 0 2 4
Miles
N
TITLE
Assabet River
Sediment and Dam Removal Study
Habitats
US Army Corps of Engineers
New England District
FIGURE
6

Cultural Resources

Prehistoric Resources

Massachusetts Historical Commission (MHC) Reconnaissance Survey Reports for each town in which the Assabet River traverses, note that these towns were known for aboriginal settlement and activity along rivers as well as ponds, and wetland areas. Prehistoric sites are most often found on terraces overlooking waterbodies. Identified sites represent all phases of New England prehistory from the PaleoIndian Period (12,500 – 10,000 BP [Before Present] to the Contact Period (450 – 300 BP/A.D. 1500 – 1620). These sites include short-term hunting or fishing stations or campsites, fish weirs, seasonal camps, and lithic production or repair sites.

The Sudbury-Assabet-Concord River drainage is an area that has been heavily studied by avocational archaeologists and has also been documented by professional cultural resource management investigations. (See Appendix F for specific site discussions.) Based on the existing documentation, it appears that the Assabet River was moderately used by prehistoric groups for resource procurement, and seasonal or short-term settlement. The potential exists for other prehistoric sites to be identified in the floodplain, on terraces or surrounding wetlands adjacent to the river. Further archaeological studies will be needed as part of environmental assessments of a dam removal project.

Historic Resources

The historic inventories for each town were examined for all of the dams being considered for possible removal. Some towns have very detailed, up to date inventories, while others have little or no information on the historic resources of the respective community. All of the dams are listed in the MHC Historic Inventory in their respective towns, with the exception of the Aluminum City Dam in Northborough. While National Register of Historic Places (NR) eligibility has not been determined for most of these structures, many of the dams can be considered contributing elements of larger, historic areas and potentially historic districts. NR eligibility determinations will need to be made as part of the environmental compliance process, in consultation with the Massachusetts State Historic Preservation office. More information on the Historic sites is provided in Appendix F.

Known historic structures, which may be eligible for the National Register of Historic Places were identified with a recommendation that a formal determination of eligibility should be made

when an alternative is selected and that the determination be coordinated with the Massachusetts State Historic Preservation Officer (MA SHPO) for their concurrence.

The Corps conducted preliminary coordination with the MHC and received a letter dated July 25, 2008 that indicated that this is a highly sensitive area for significant historical and archaeological resources and general concurrence that additional studies and coordination will be needed for dam removals.

Dam removals will also be subject to consultation and review with the Wampanoag Tribe of Gay Head (Aquinnah) Tribal Historic Preservation Officer (THPO), as well as the Mashpee Wampanoag THPO. This coordination can be undertaken by the project sponsor/partners once a decision is made to proceed further with the investigation of dam removal.

Aluminum City Dam. The Aluminum City Dam in Northborough does not appear to be eligible for the NR. While there is a possibility that the dam is associated with an adjacent structure, the structure has been extensively modified as has the area surrounding the dam. However, dam removal, dredging, and possible staging areas all have the potential to affect archaeological resources.

An archaeological reconnaissance survey is recommended if any alternatives are chosen that would impact this site.

Allen St. Dam. The Allen Street Dam, as part of the Woodside Area appears to be potentially eligible for the NR. An intensive archaeological survey is recommended if dam removal and/or dredging are planned for this structure. There are visible stone foundations most likely relating to earlier industries at this area.

Photographic and historic documentation of the dam, factory, and surrounding village will most likely be necessary if removal of the dam is considered. An updated MHC Inventory Form will also need to be prepared in order to get concurrence with the determination of NR eligibility from the MA SHPO.

There is also the possibility that intact pre-contact archaeological resources may be present.

Hudson Dam. The Route 85 Dam in Hudson, also known as the Washington Street Dam is a contributing structure to the Silas Felton Historic District. Dam removal will have an adverse effect on the NR district.

Pre-contact and industrial archaeological resources could also potentially be affected by dam removal. Historic, photographic, and archaeological documentation may be necessary prior to any work at this site. The determination of effect will be coordinated with the SHPO and the THPOs as part of any future studies.

Gleasondale Dam. The Massachusetts Historical Commission Inventory lists the village of Gleasondale, the Gleasondale Mill, and the Gleasondale milldam and canal as historic resources within the town of Stow. Although a formal determination of eligibility has not been made for the dam, mill or surrounding village, it appears that the dam is a contributing element of a NR eligible historic district, so removal would be considered an adverse effect on the village of Gleasondale.

It is likely that archaeological resources (pre-contact and post-contact) would also be impacted by dam removal. An intensive archaeological survey is recommended prior to any work at this site. An updated MHC Inventory Form will also need to be prepared in order to get concurrence with the determination of NR eligibility from the MA SHPO.

Ben Smith Dam. The Ben Smith Dam in Maynard has been determined individually eligible for the NR as well as a contributing element of the Assabet Mills Historic District. The dam is historically important to the development of Maynard's industry as well as the development of the town itself.

Removal of the dam would constitute an adverse effect to a NR eligible historic resource and an adverse effect on the Assabet Mills Historic District, and perhaps other districts, sites or structures associated with the mills. Archaeological resources could be affected by the associated drawdown of the impoundment after dam removal. Removal of the Ben Smith Dam would have the largest negative impact on the historic industrial resources along the Assabet River.

Table 12. Cultural Resource Eligibility for National Register

Site	**Findings relative to the National Register (NR) of Historic Places**	**Recommended Next Steps for Dam Removal Assessment of Cultural Resources**
Aluminum City Dam	Does not appear to be eligible for the NR.	Conduct archaeological reconnaissance survey of area.
Allen St. Dam	Appears to be potentially eligible for the NR.	Conduct an intensive archaeological survey of area.
Hudson Dam	Dam is a contributing structure to the Silas Felton Historic District. Dam removal will have an adverse effect on the NR district	Conduct an intensive archaeological survey of area.
Gleasondale Dam	Dam is a contributing element of a NR eligible historic district, village of Gleasondale. Dam removal will have an adverse effect on the NR eligible district	Conduct an intensive archaeological survey of area.
Ben Smith Dam	Removal of the dam would constitute an adverse effect to a NR eligible historic resource and an adverse effect on the Assabet Mills Historic District	Conduct an intensive archaeological survey of area.
Powdermill Dam	Powdermill Dam is located at the site of historic manufacturing activity, so removal of the dam could possibly effect significant historic or archaeological resource	Owner has modified dam and will be generating power at site. No further cultural resources studies are suggested as dam removal is unlikely.

ADDITIONAL INFORMATION

Comparative Value of Dam Removals

In order to provide guidance to the Assabet River stakeholders in the selection of the dam removals to pursue further, the construction costs of the dam removals are compared against two metrics. The metrics used are the decrease in impoundment river miles and the reduction in sediment P-flux. The impoundmnet river mile metric was selected as removing a dam decreases the river channel bed area exposed to open water and thus reduces the recycling of phosphorus from the sediments and restores the free flowing river; improving the aquatic habitat for the target fish communities. The value used for the decrease in the impoundment river mile (DIRM) was the observed impoundment length. The reduction in P-flux metric was selected as this is one of the goals of the TMDL. The data used for this metric are from the CDM report "Assabet River Sediment and Dam Removal Study, Modeling Report", June 2008. The value used was the reduction in sediment P-Load (RPL) calculated from Table 2 of the Modeling Report.

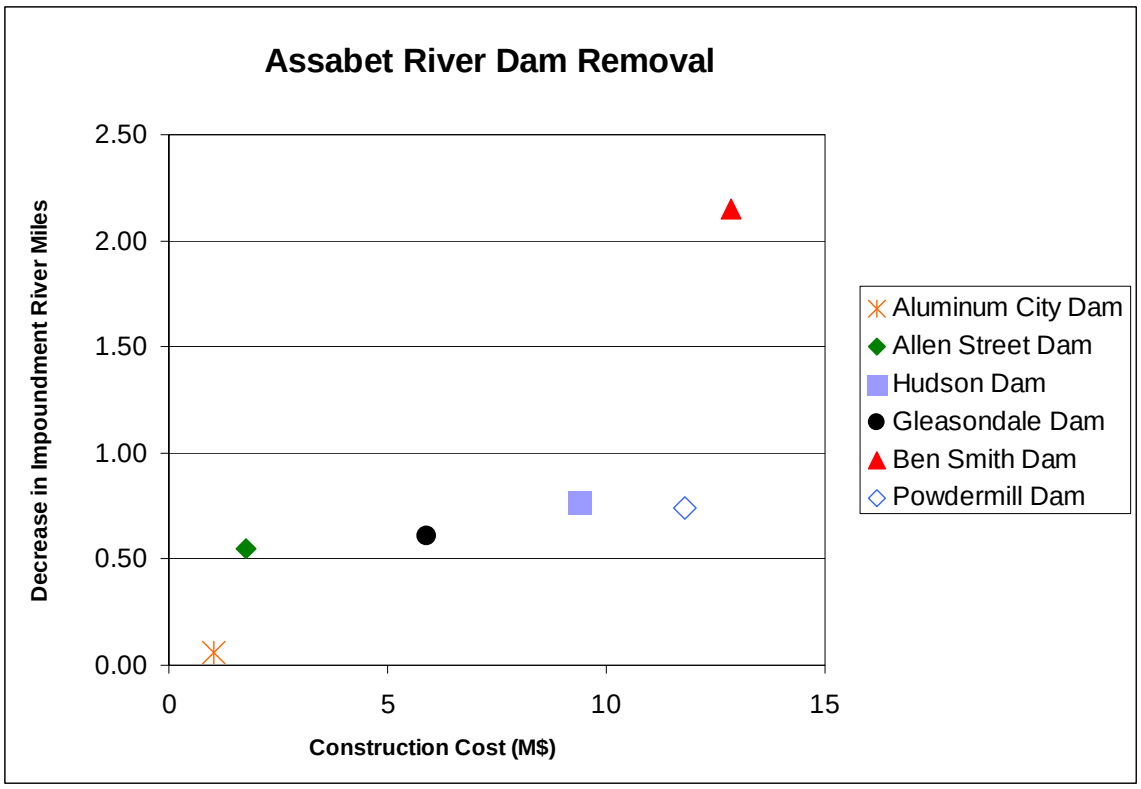
Decrease in Impoundment River Mile

Dam removal construction costs versus DIRM are presented in Table 13 and Figure 7. This information demonstrates that although the Ben Smith Dam removal is one of the more costly alternatives it provides the largest decrease in impoundment river miles. The Allen Street Dam has the lowest cost per DIRM. Although the Allen Street Dam removal has a lower cost per DIRM than the Ben Smith Dam, it has a smaller overall benefit. The largest cost per DIRM removals are for Aluminum City and Powdermill dams.

Table 13. Construction Cost versus DIRM

Dam Name	Decrease in impoundment River Mile (DIRM)	Construction Cost for Dam Removal with sediment disposal (M$)	Cost M$/DIRM
Aluminum City Dam	0.06	$ 1.0	$ 16.8
Allen Street Dam	0.55	$ 1.8	$ 3.2
Hudson Dam	0.77	$ 9.4	$ 12.2
Gleasondale Dam	0.61	$ 5.9	$ 9.6
Ben Smith Dam	2.15	$ 12.8	$ 6.0
Powdermill Dam	0.74	$ 11.8	$ 15.9
TOTAL	4.88	$ 42.7	$ 8.8

Figure 7. Construction Costs versus Decrease in Impoundment River Miles



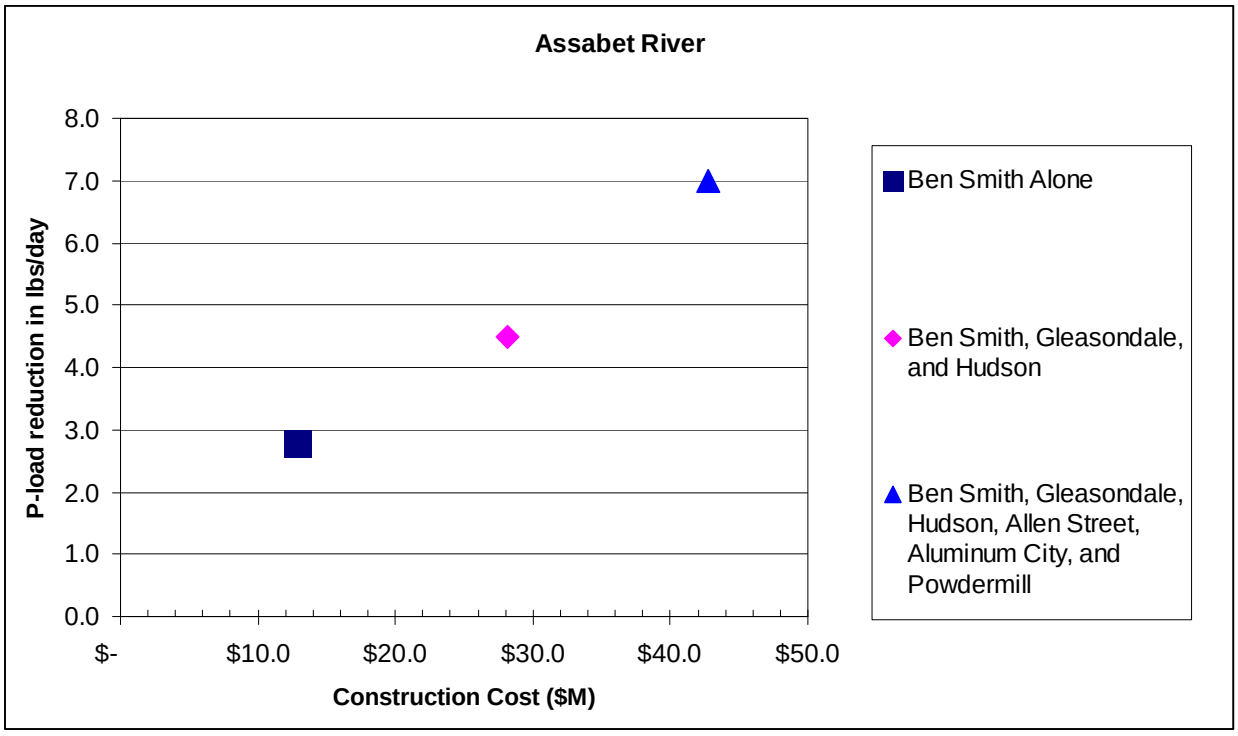
Reduced P-load

The next comparison made was to compare the estimated reduction in sediment P-load (RPL) from the combination of dam removals considered in the modeling phase of the study with construction costs. The RPL is the difference between existing conditions (planned WWTF improvements) and the dam removal alternative. This analysis is presented in Table 14 below. As can be seen from Table 14, the "best dollar value" is Ben Smith Dam removal, when the other dams are added to increase the reduction the average unit cost increases. When all six dam are considered the average unit cost decreases.

Table 14. Construction Costs versus Reduction in P-Load *(planning level information only)*

Dam Name	Sediment P Load (lbs/day)	Construction Cost Estimate ($M)	RPL (Reduction in P Load in lbs/day)	Cost ($M)/RPL
Base Condition	28.0			
Planned WWTF Improvements	11.2	Not available	16.8	Not available
Ben Smith Alone	8.4	12.8	2.8	4.6
Ben Smith, Gleasondale, and Hudson	6.7	28.1	4.5	6.2
Ben Smith, Gleasondale, Hudson, Allen Street, Aluminum City, and Powdermill	4.2	42.7	7.0	6.1

Figure 8. Construction Cost versus Reduction in P-load



Real Estate Information

Preliminary research was made into the listed owner of each dam for planning purposes. (See Appendix G.) Below is a summary of the listed dam owners based on a review of public records. All but one of the dams (Hudson Dam) are in private ownership. Dam removal would require the cooperation and willingness of these owners. The Acton Hydro Company, owner of the Powdermill Dam, has indicated that they are not interested in removing the dam as they are rebuilding the dam for hydroelectric power generation.

The dam removal project sponsor will also need to consider the land ownership of abutters along the dam impoundments and identify those areas where the project work area is on private property and either obtain the appropriate right of entry or real estate interest in these properties.

Also further investigation is needed to determine ownership and access to land previously submerged that will be exposed due to dam removal.

When the Corps of Engineers is involved in a dam removal project, the Corps requires that the project sponsor obtain and hold all lands, easement, and right of ways needed to proceed with dam removal. This includes the dam, construction staging areas and work areas, and sediment dewatering and upland disposal areas. The sediment management plan include preliminary identification of areas that might be considered for sediment management purposes.

Table 15. Dam Owners on Record

Dam	**Town**	**Listed Owner**
Aluminum City Dam	Northborough	86-88 Main Street LLC.
Allen Street Dam	Northborough	Montrose Northborough LLC.
Hudson Dam	Hudson	Town of Hudson
Gleasondale Dam	Stow	F L B, Inc.
Ben Smith Dam	Maynard	Wellesley/Rosewood/Maynard Mills Limited
Powdermill Dam	Acton	Acton Hydro Company, Inc.

Depictions of Dam Removals

At the request of the Study Coordination Team planning level depictions of dam removal projects were prepared for 5 of the six dams by CDM. Depictions were not prepared for Powdermill as the dam was undergoing re-construction for hydroelectric power generation during the study. Dam removal depictions are included in Appendix H. An artistic depiction of what the Ben Smith Impoundment may look like after dam removal is provided below.



Figure 9. Ben Smith Impoundment Before and After Dam Removal

CONCLUSION

In general, dam removal will benefit the Assabet River aquatic ecosystem in at least four ways:

- Dam removal will decrease the sediment phosphorus loading from the impoundments. This reduction is due to the decrease in bed area associated with dam removal, the decrease in biomass growth and settling, and less phosphorus cycling though the sediments. Another benefit from dam removal is increased reaeration in the shallower water depths with increased water velocity. Increased reaeration will improve dissolved oxygen conditions in the river.

- Reduced phosphorus flux from the sediments will reduce the excessive nuisance aquatic vegetation and improve recreational use of the river and aesthetic values.

- Water quality improvements will provide improved aquatic habitat for fluvial specialists and fluvial dependent freshwater species.

- Dam removal will improve the efficiency of American eel migration, a species that is currently found in the Assabet River.

- Dam removal will restore the river for future river herring migration.

Dam removal would address major environmental problems identified in the study area. These include highly variable dissolved oxygen levels in surface waters, poor sediment quality, and lack of riverine habitat and fish passage. Dam removal is an effective means of achieving both water quality and ecosystem restoration goals. It will also eliminate river fragmentation, improving ecosystem connectivity.

It is recommended that further efforts be pursued on the Assabet River to remove the old mill dams. An analysis of cost versus benefits indicates that although Ben Smith Dam is one of the more costly dams to remove, due to large sediment management and disposal costs, it provides the greatest benefit in that it reduces impoundment river miles by about 2 miles and provides for a 2.8 lbs/day decrease in P loading to the river. Benefits would also accrue from removal of Hudson Dam, Gleasondale Dam, Allen Street Dam, and Aluminum City Dam and these should be considered for removal as resources allow. The Hudson Dam due to the large amount of sediment accumulation is the most costly of the four with Aluminum City Dam as the least costly. Powdermill Dam was also considered for removal but as the current owner is planning to

generate hydropower at the facility and the costs for removal are more costly with fewer benefits than some of the other dams, this project is considered the lowest priority.

Phosphorus discharge (WWTFs and non-point sources) in the winter appears to be an important part of the year round phosphorus budget in the Assabet River and this possibility was previously recognized in the TMDL and monitoring required. Future water quality and biomass monitoring is needed to evaluate the effectiveness of measures undertaken and to provide information for the adaptive management of the river to meet water quality goals.

Studies of the dam removals presented in this report provided information on construction costs and impacts of the dam removals. One of the significant costs identified in this study is the cost of sediment management associated with each dam removal. This study identified the need for additional testing of the sediment behind the dams during design to provide information to further define the quality of the sediments and verify the extent of sediment removal that will be required by the regulatory agencies prior to dam removal. If more sediment can be left in the river or if less expensive disposal options are identified through further study of the impoundments then this will decrease the overall construction costs of the dam removals.

Removing the dams will change the existing water levels in the river. Many of the wetlands along the Assabet River exist because of the water backed up by the dam. The extent of wetlands along the river varies greatly and in some areas there may be only a narrow fringe of vegetated wetland or none at all while in others floodplain wetlands extend hundreds of feet from the river. The largest changes in wetlands will occur for the Ben Smith, Gleasondale, and Hudson dam removal projects.

Decreased water levels may also affect recreational uses of the river such as canoeing and kayaking when flows in the river are low. Decreased water levels may also affect direct withdrawals from the river depending on elevation of the intake structure. The Town of Stow uses the river as water source for fire suppression and providing adequate access to river water for this use will need to be considered through consultation with the Stow Fire Department during designs for removal of the Gleasondale and Ben Smith Dams.

All of the dams have identified cultural resource value. Ben Smith, Gleasondale, Hudson, and Allen Street Dams are contributing elements to historic districts that are eligible for or listed with the National Register of Historic Places and removal would be an adverse impact and require further studies and documentation of the resources. Further study will also be required of Aluminum City to determine significance. Also, all removals will require further consideration

of archaeological resources as areas in the vicinity of the river were used prior to European settlement by native groups dating back to 8,000 BP.

All dam removal projects will be subject to consultation and review by the Massachusetts State Historic Preservation Officer and the Wampanoag Tribe of Gay Head (Aquinnah) Tribal Historic Preservation Officer (THPO), as well as the Mashpee Wampanoag THPO.

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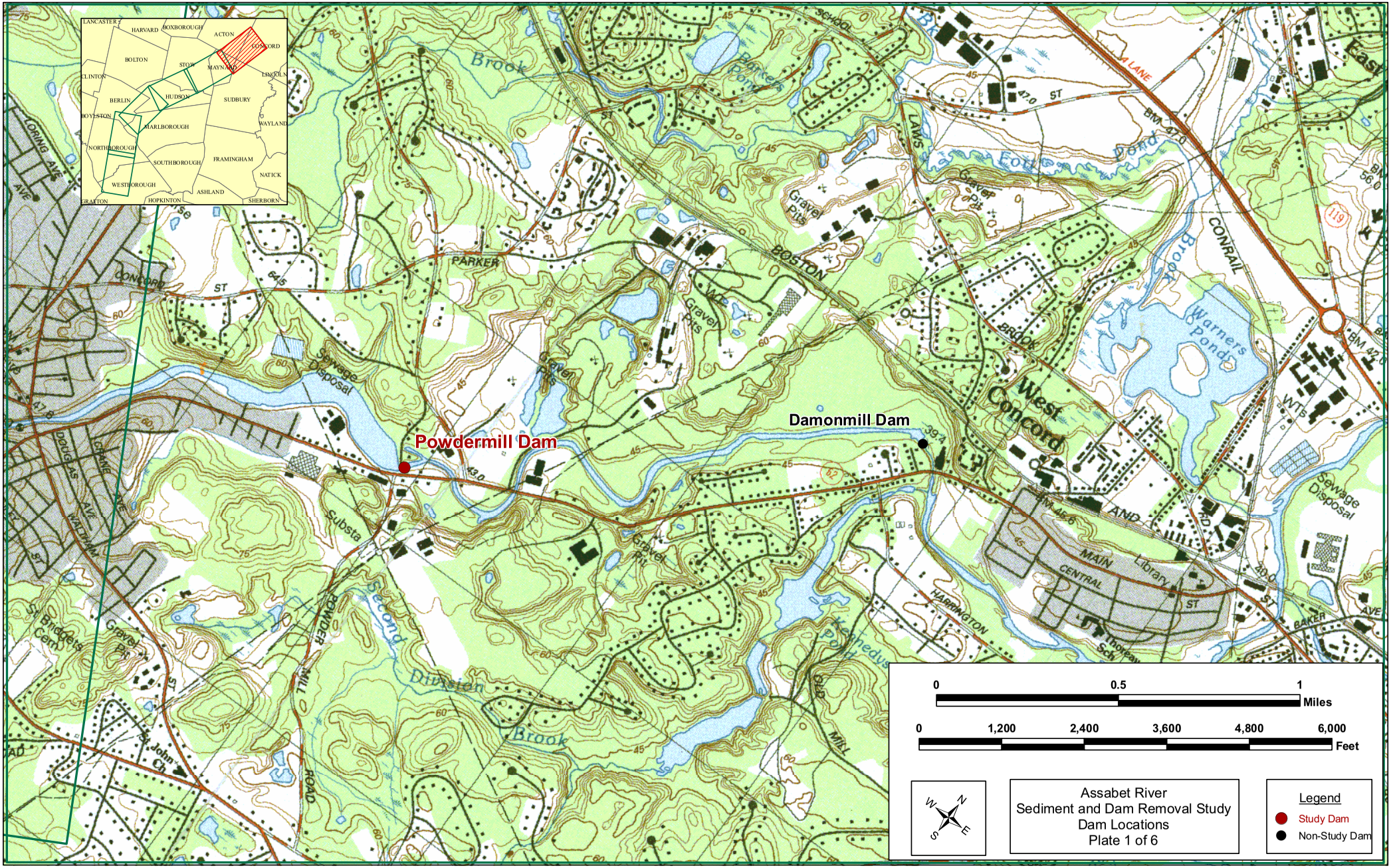
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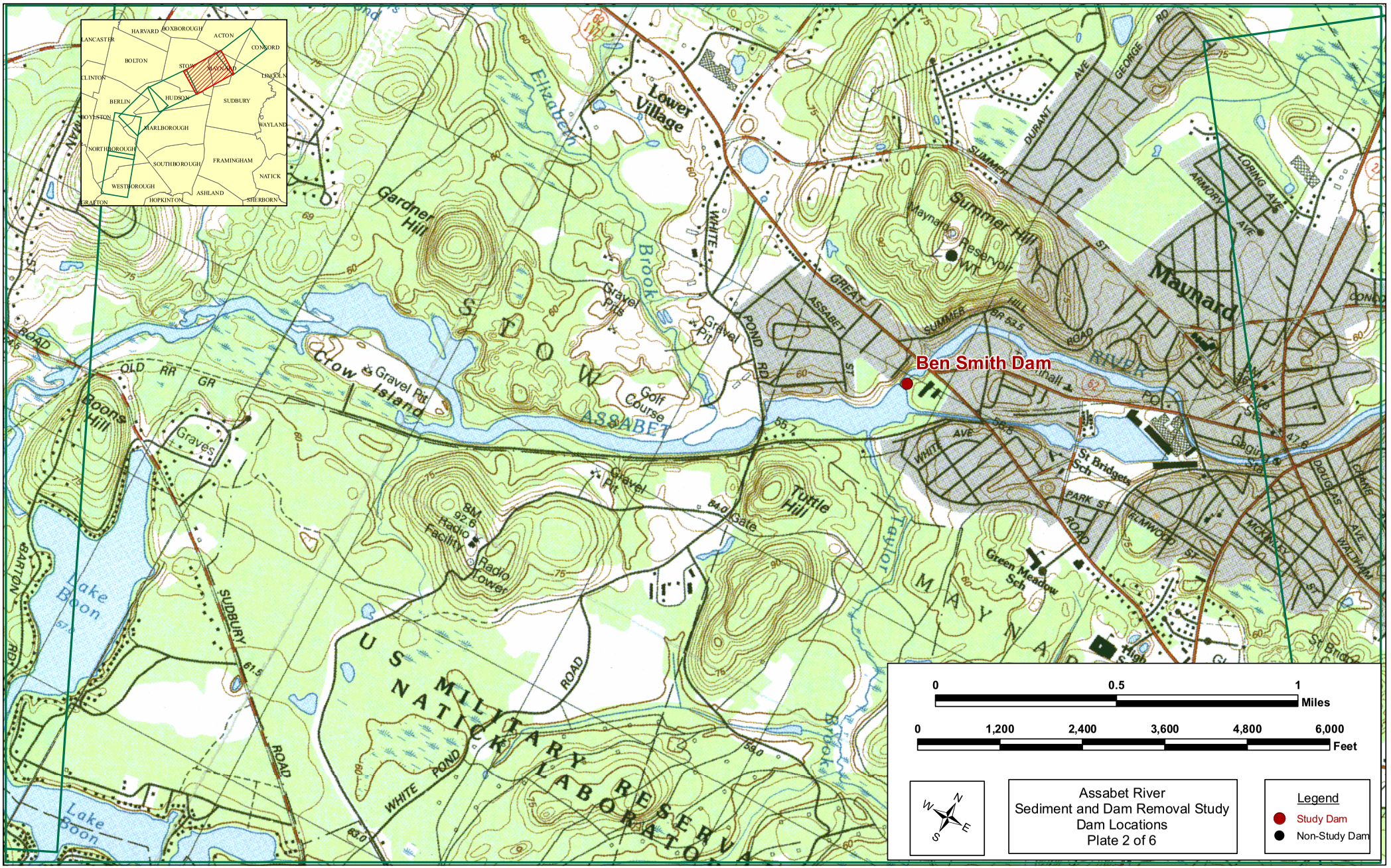
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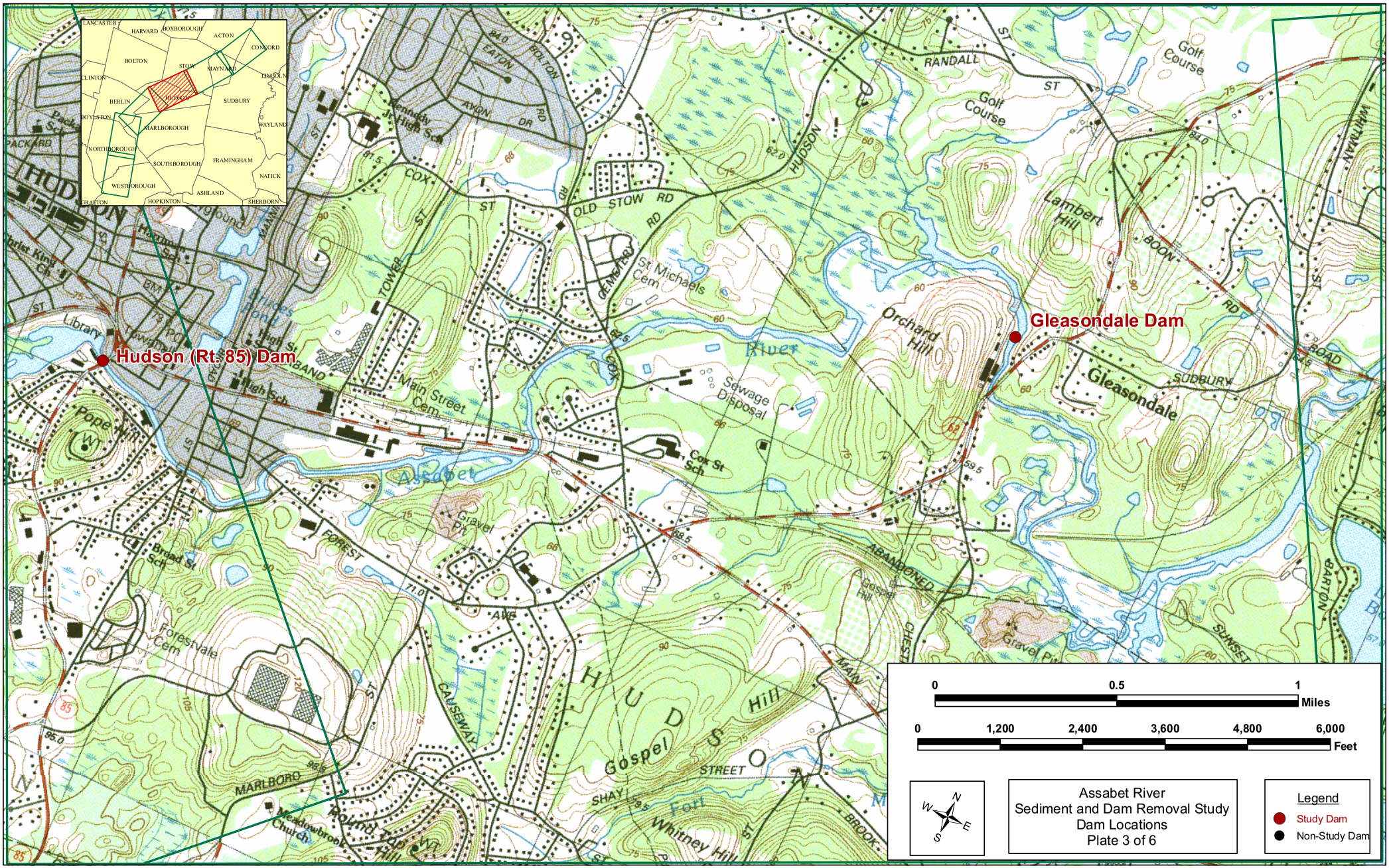
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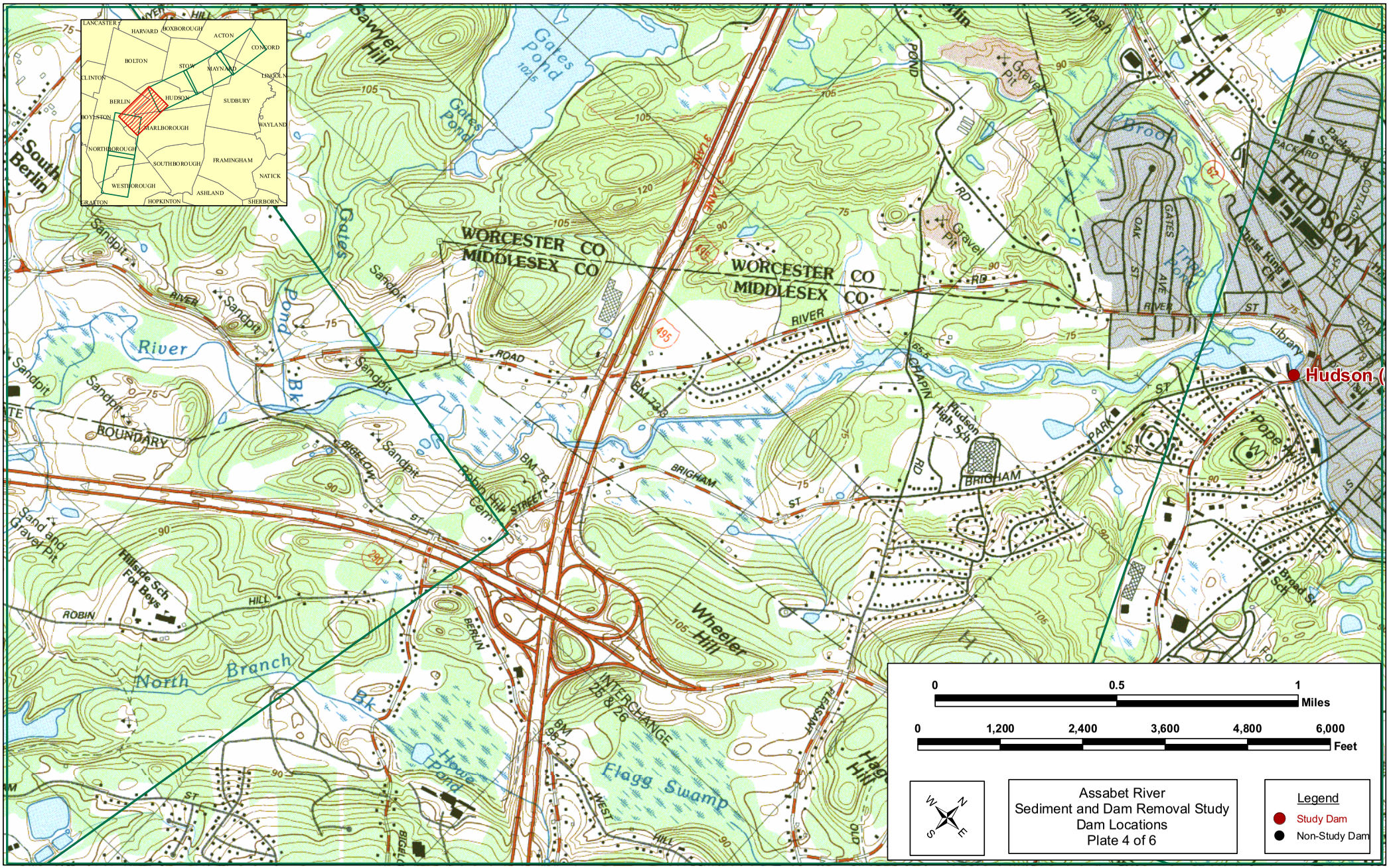
APPENDIX A

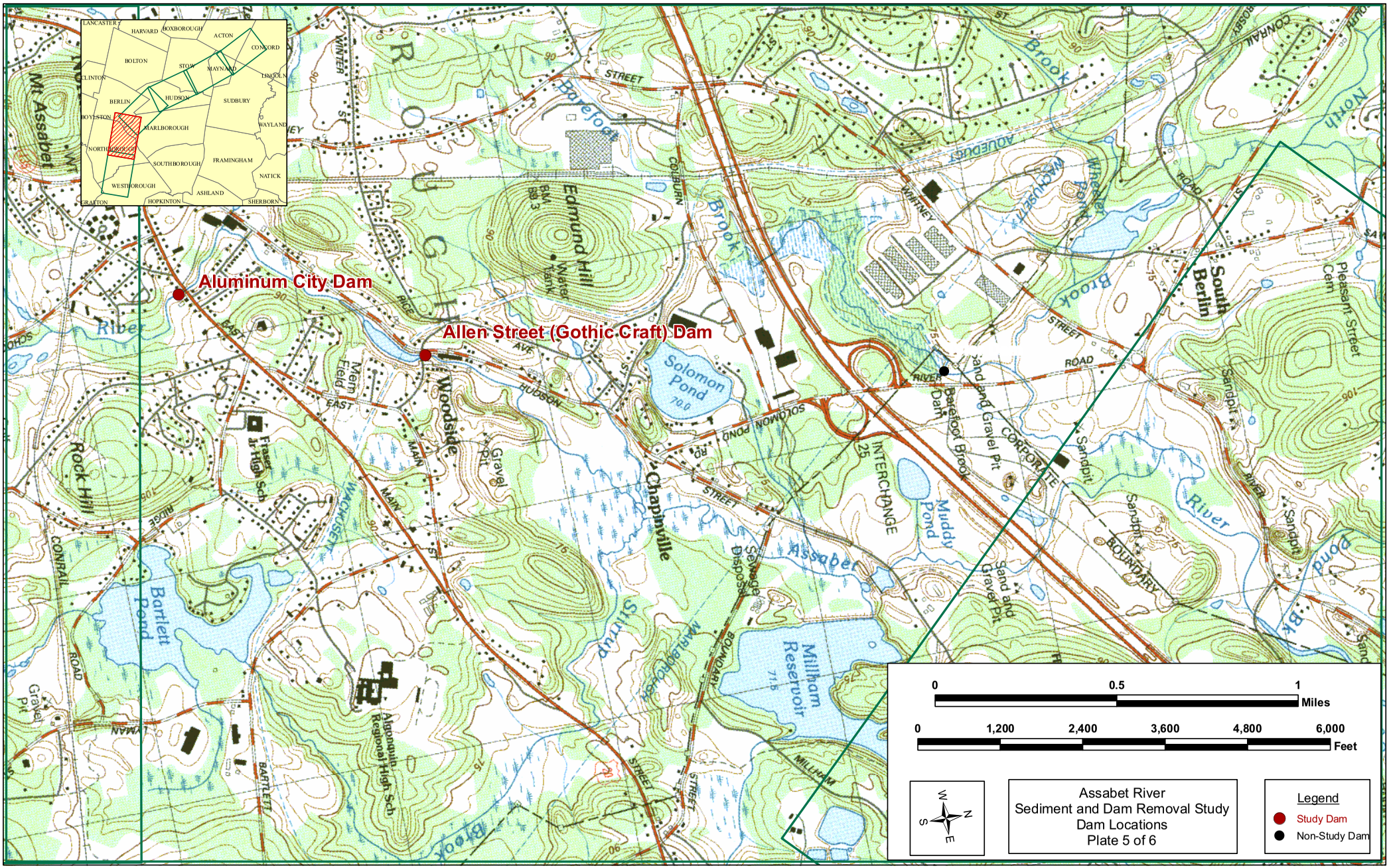
ASSABET RIVER DAM LOCATIONS

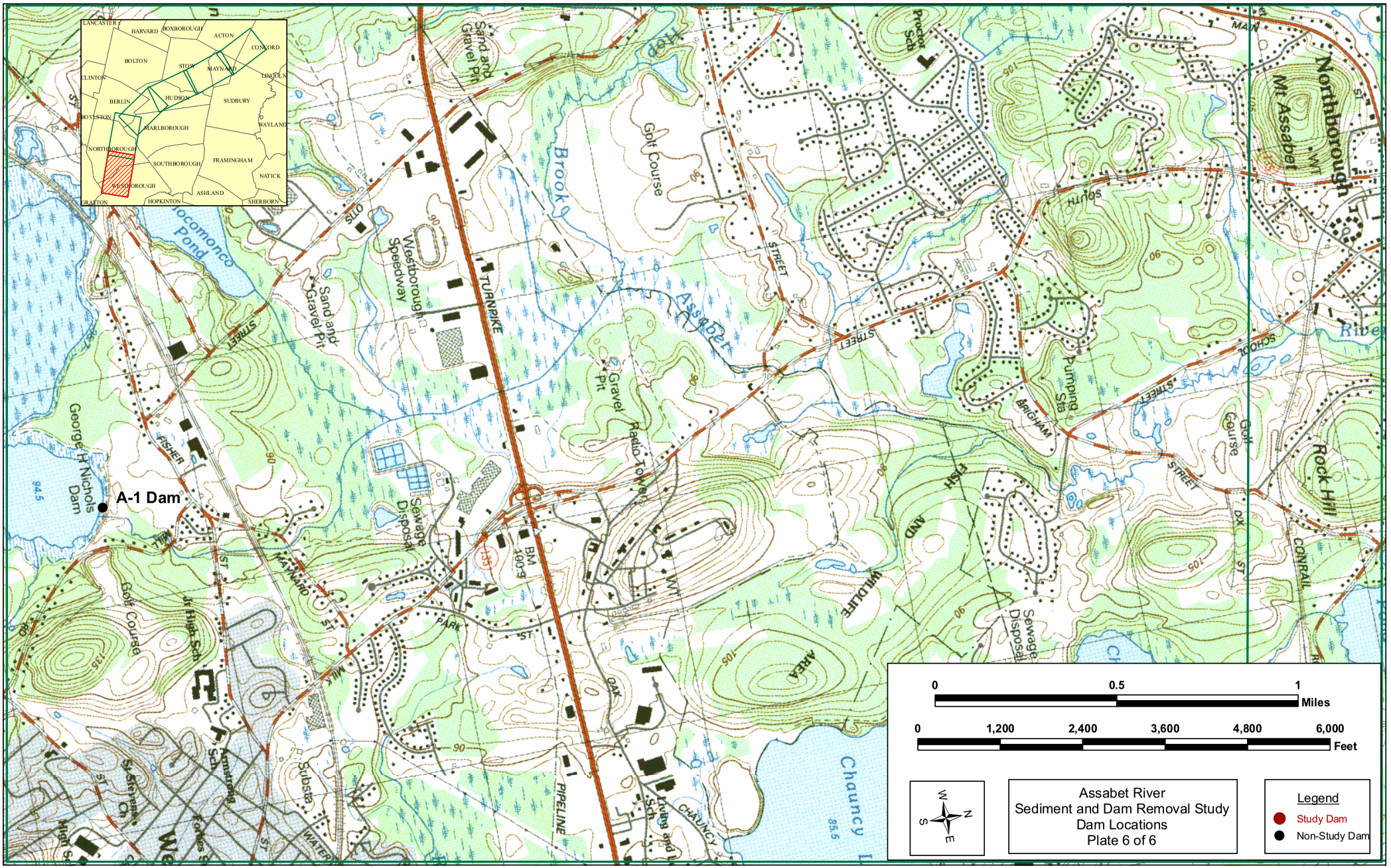

Powdermill Dam
Damonmill Dam
Warners Pond
West Concord
Second Division Brook
Gravel Pits
Sewage Disposal
CONRAIL
BOSTON POST ROAD
PARKER ST
CONCORD AVE
WALTHAM AVE
DOUGLAS AVE
MAIN ST
CENTRAL AVE
HARRINGTON AVE
BAKER AVE
LAWS BROOK
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Assabet River
Sediment and Dam Removal Study
Dam Locations
Plate 1 of 6
Legend
Study Dam
Non-Study Dam


Ben Smith Dam
Maynard
STOW
ASSABET
RIVER
Lower Village
Gardner Hill
Summer Hill
Maynard Reservoir
Elizabeth Brook
Crow Island
Gravel Pit
Golf Course
Boons Hill
Graves
Turtle Hill
Taylor Brook
Lake Boon
U S MILITARY RESERVATION
NATICK LABORATORIES
WHITE POND
Green Meadow Sch
St Bridgets Sch
Radio Tower
Radio Facility
BM 92.6
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OLD RR GR
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POND RD
GREAT ASSABET ST
SUMMER HILL RD
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Study Dam
Non-Study Dam


Hudson (Rt. 85) Dam
Gleasondale Dam
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BOLTON
STOW
MAYNARD
LINCOLN
CLINTON
BERLIN
HUDSON
SUDBURY
BOYLSTON
MARLBOROUGH
WAYLAND
NORTHBOROUGH
SOUTHBOROUGH
FRAMINGHAM
NATICK
WESTBOROUGH
ASHLAND
GRAFTON
HOPKINTON
SHERBORN
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Dam Locations
Plate 3 of 6
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NATICK
WESTBOROUGH
ASHLAND
GRAFTON
HOPKINTON
SHERBORN
Sawyer Hill
Gates Pond
South Berlin
Sandpit
River
Pond
Bk
WORCESTER CO
MIDDLESEX CO
ROAD
BOUNDARY
BIGELOW
Robin Hill Cem
STREET
BM 76.1
BRIGHAM
Hillside Sch For Boys
HILL
ROBIN
North Branch
Howe Pond
BERLIN
INTERCHANGE 25 & 26
BM 96.2
Flagg Swamp
Wheeler Hill
WEST
OLD
PLEASANT
Hag Hill
Gravel Pit
POND
RD
CHAPIN
Hudson High Sch
PARK
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Pope Pond
Brook
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Assabet River
Sediment and Dam Removal Study
Dam Locations
Plate 4 of 6
Legend
Study Dam
Non-Study Dam


Aluminum City Dam
Allen Street (Gothic Craft) Dam
Solomon Pond
Muddy Pond
Millham Reservoir
Bartlett Pond
Chapinville
Woodside
Edmund Hill
Barefoot Brook
Assabet River
Mt Assabet
Rock Hill
South Berlin
Pleasant Street Cem
Algonquin Regional High Sch
Fraser Jr High Sch
Mem Field
Water Tank
Gravel Pit
Sandpit
Sand and Gravel Pit
Sewage Disposal
Barefoot Dam
INTERCHANGE 25
CONRAIL
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Sediment and Dam Removal Study
Dam Locations
Plate 5 of 6
Legend
Study Dam
Non-Study Dam


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Sediment and Dam Removal Study
Dam Locations
Plate 6 of 6
Legend
Study Dam
Non-Study Dam

APPENDIX B

DAM REMOVAL ENGINEERING CONSIDERATIONS

Aluminum City Dam (Old Mill Pond Dam)

1.0 General Information [1]

Aluminum City Dam is situated on the southerly side of Route 20 (Main Street) in Northborough, Massachusetts. Figure 1 shows the location of Aluminum City Dam. The dam is listed in the National Inventory of Dams (NID) as ID No. MA 02843. According to the NID, the dam was constructed in 1925. According to the cultural resources review the dam site is likely to date from pre-1900.

The existing structure appears to be an earth fill dam with stone and granite masonry. The nature of the earth fill material and/or the presence of an impervious core are unknown. The dam has a structural height of 8.5[2] feet and a crest width of 60 feet. The west abutment is stone and granite block and appears to be connected to the foundation of the existing residential wood-frame building adjacent to the dam. The east abutment also appears to be stone and granite and is now part of the existing retaining wall for the parking lot at E.L Stone/Aluminum City. The foundation of the present dam and abutments is unknown, but it is assumed that it is founded on the remnants of the previous dams located within the existing channels that preceded the existing dam. Based on visual observations, the dam is generally in poor condition.

It is apparent that at one time the dam had an outlet that went under the Aluminum City parking lot, across Route 20 and under the front portion of the Stone Motorcycle Company's property. According to owner of E.L. Stone/Aluminum City, the conduit was approximately 3' x 3' and was blocked both upstream of the dam and under Route 20 in front of the Stone Motorcycle Company's building. The outlet to the Assabet River was not located, but personal communication with the owner of Stone Motorcycle Company indicates this outlet is blocked at the Assabet River.

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[1] Information provided in Sections 1, 2 and 3 on the dam and construction activities were prepared by CDM for planning purposes and provide to the Corps in CDM in memo dated March 14, 2008.

[2] Fuss & O'Neill, Letter to Dam Safety Office dated November 17, 2006.



Location of Old Mill Pond Dam (Aluminum City Dam)



Dam and Left Abutment



Route 20 Bridge Just Downstream of Dam



Support Walls Just Downstream of Route 20 Bridge

2.0 Proposed Construction Activities

The proposed construction activities necessary for removal of Aluminum City Dam include the following:

- Remove existing sediment upstream of the dam
- Demolition of the dam
- Channel improvements and repairs to downstream building foundation
- Channel improvements and stabilization between the dam and the bridge at Route 20 and repairs to the foundation of the downstream building
- Modifications (filling) to the existing outlet conduit as necessary
- Site restoration

2.1 Sediment Removal

Sediment removal behind the dam will be needed as part of the dam removal project. The estimated quantity of sediment, quality, and additional sediment sampling needs and dredging and dewatering are discussed in the report prepared by CDM entitled the "Assabet River Sediment Management Plan", December 2008.

For the Aluminum City impoundment, site preparation would include setting up for mechanical dredging operations. With maximum water depths of about 3.5 feet and channel widths of 30 to 65 feet, it may be possible to access the impoundment with low pressure backhoes and similar excavating equipment. If the Aluminum City dam can be removed in controlled increments, the water level in the impoundment can be lowered which would allow standard ground equipment to access the impoundment.

2.2 Dam Demolition

It is anticipated that only the spillway portion of the dam will be removed. Access and work areas for contractors for the demolition of the spillway will be primarily from the east side of the dam. Access will be from the Aluminum City parking lot. The existing residential building on the west side of the river limits access to the dam. There is limited

space available in the existing parking lot. In addition to parking for customers and employees, there are several residential trailers located on the site and the rear of the parking lot is used for vehicle storage. Close coordination with the owner and tenants of E.L. Stone/Aluminum City will be required by the contractor.

Removal of the spillway portion of the dam can be accomplished using conventional construction equipment. Temporary cofferdams will be required to divert flows both upstream and downstream during a sequenced removal of the spillway. For the purposes of the planning-level cost estimate, it was assumed that prior to removal of the spillway; repairs will be required to the foundation of the adjacent residential building. Similarly, the retaining wall along the E.L. Stone/Aluminum City parking lot will be repaired and stabilized. Spillway removal will extend to the natural channel bottom or bedrock, if any. Due to the proximity of the adjacent residential building and the unknown condition of the outlet conduit, blasting is not recommended.

As part of the demolition process, all stone and granite pieces that have been either displaced from the dam, or were deposited during the dam's construction should be removed. These are all located in the channel immediately downstream of the spillway.

The stone and granite masonry should be trucked from the site. The impact of this truck traffic on the businesses located in the E.L. Stone/Aluminum City building and the impact to traffic on Route 20 should be evaluated during final design. The smaller material will be utilized as part of the final channel improvements and stabilization. Given the large size of the stone and granite masonry pieces, and the limited space, on-site crushing of these pieces into graded gravel products is not anticipated.

2.3 Channel Improvements and Repairs to Downstream Building Foundation

Downstream channel improvements will include removal of sediment and vegetation that have deposited in and along the channel over time and re-establishing a cross sectional area of the channel. The channel improvements are required to reduce the impacts of the temporary increased flows through the channel that will result as part of the construction activities. As such, it is anticipated that these improvements will be performed prior to the removal of the spillway. Temporary cofferdams and proper operation of the dam

should allow work to be safely performed in the channel. Access to the channel will be from the same location as the access to the spillway.

Scour protection at the abutments to the bridge at Route 20 will be required prior to removal of the spillway. Work will be primarily repair to existing concrete. Access will be from the channel and the parking lot.

It is anticipated that repairs will be required to the Stone Motorcycle Company building's foundation. These repairs primarily will be re-pointing the stone foundation, replacing missing stones and repairing existing concrete. These repairs will extend downstream of the building to include repairs to the stone and concrete retaining wall along the building's rear parking lot.

Channel improvements in this area will include removal of accumulated sediment and vegetation to re-establish the channel cross-section. Access for the work within the channel and repairs to the foundation and retaining wall will be from the parking lot in the rear of the Stone Motorcycle Company building. This work will be performed prior to spillway removal.

2.4 Streambank Erosion/Stabilization Required

The locations and extent of streambank stabilization were determined based on CDM site visits in 2007 and analysis of HEC- RAS and HEC-6 model results by CDM.

1) East Main Street/Route 20 Bridge – Streambank stabilization and/or channel bed modifications will be required from downstream of the East Main Street/Route 20 Bridge for approximately 1300 feet.

2) River Street Bridge - Streambank stabilization and/or channel bed modifications will be required from downstream of the River Street Bridge for approximately 1600 feet.

2.5 Modifications to the Existing Outlet Conduit

It is anticipated that the existing outlet conduit will be filled as part of this project. As indicated earlier, currently the conduit is blocked in several locations. However, the condition of the remaining conduit is unknown. The conduit is under the parking lot and crosses under Route 20, a heavily traveled roadway in Northborough. The conduit is relatively short, approximately 200 feet long. The conduit is relatively deep and filling the conduit with a concrete fill material can be accomplished with an excavation within the Aluminum City parking lot.

2.6 Site Restoration

Site restoration will be conducted to restore the site and any areas used for temporary access or staging, to their original conditions. For purposes of the planning-level cost estimate, minimal landscaping was assumed as part of the site restoration. The extent and type of landscaping should be evaluated as part of the design phase.

2.7 Additional Considerations

It is recommended that the existing bridge at River Street be reviewed in more detail during final design. The existing bridge is located approximately 1,600 feet downstream of the Aluminum City dam. The existing bridge appears to be supported on timber columns. These should be evaluated in detail prior to any planned temporary, or permanent, increase in flow rate within the River. Also scour protection may be needed at the Route 20 Bridge just downstream of the dam.

3.0 Proposed Sequence of Construction Activities

For the purposes of developing the planning-level cost estimate, a proposed sequence of construction activities was developed. The overall construction period is estimated at 20 months. This is based on limiting construction within the Assabet River to the period May through December. It is anticipated that construction during the peak winter months and during the traditional high flow periods will not be feasible.

The major activity during the first calendar year is the sediment removal upstream of the dam. Other construction during the first calendar year will be limited to mobilization; cleaning and stabilizing the river downstream of the dam; stabilizing the existing walls and foundation of the adjacent residential building and the E.L. Stone/Aluminum City parking lot; stabilizing the walls and building foundation downstream of Route 20 and providing scour protection at the Route 20 Bridge. These later activities are performed in preparation of the dam removal.

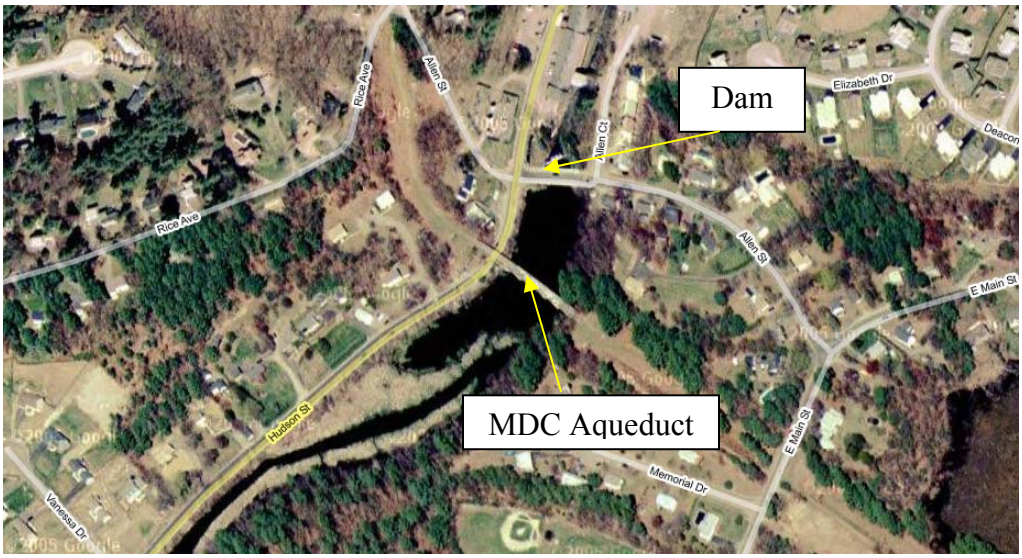
During the second calendar year, work on the demolition of the dam will be performed. Other activities will include the filling of the existing outlet conduit and site restoration.

ALLEN STREET DAM

1.0 Existing Structure Description[1]

The Allen Street Dam is located just north and approximately 30 feet downstream of Allen Street in Northborough, MA. Figure 1 shows the location of the dam. The Allen Street Dam in Northborough (also known as the Gothic Craft or Woodside Dam) is listed in the MHC Historic Inventory as the Assabet River Bridge and Dam.

The bridge and dam are part of the Woodside Area, earlier known as Davisville, which has been a mill site since c. 1720. There is an old factory building downstream that has been turned into apartments. The dam is listed in the National Inventory of Dams (NID) as ID No. MA 00995. The MDC Aqueduct is located about 100 yards upstream of the dam.



Location of Allen St. Dam

[1] Information provided in Section 1, 2 and 3 on the dam and construction activities was prepared by CDM for planning purposes and provide to the Corps in CDM memo dated March 14, 2008.



Allen Street Dam Impoundment



Allen Street Dam

Design plans and construction notes were not readily available in conducting this analysis. The discussion of proposed construction methods and the planning-level cost estimates are based on visual observations of the dam (August 2007 by CDM) and the information provided in the previous studies obtained by USACE and CDM.

The existing structure appears to be an earth fill dam with stone and granite masonry. The nature of the earth fill material and/or the presence of an impervious core are unknown.

The spillway is 70 feet long with a structural height of 12 feet. The abutments are stone and granite block. The foundation of the present dam and abutments is unknown.

The dam has a 9’ x 3’ foot outlet (culvert) under Allen Street, just west of the dam. The outlet discharges to an open channel immediately adjacent to Hudson Street. Flow returns to the Assabet River through a 4’ wide x 6’ foot concrete raceway with two vertical drops. Flow through the outlet is controlled by stop logs at the concrete raceway. The stop logs were missing at the time of CDM’s site visit (August 2007).



Apartment Unit Walkway Downstream of Assabet River Dam



MDC Aqueduct Upstream of Assabet River Dam

2.0 Proposed Construction Activities

The proposed construction activities necessary for removal of Allen Street Dam include the following:

- Sediment removal
- Demolition of the dam
- Channel improvements and stabilization downstream the dam and repairs to the foundation of the apartment building downstream of the dam
- Modifications (filling) the existing outlet culvert, open channel and concrete raceway
- Site restoration

A proposed construction sequence is presented in Section 3.0 of this document.

2.1 Sediment Removal

Sediment removal behind the dam will be needed as part of the dam removal project. The estimated quantity of sediment, quality, and additional sediment sampling needs and dredging and dewatering are discussed in the report prepared by CDM entitled the "Assabet River Sediment Management Plan", December 2008.

For the Allen Street impoundment, site preparation would include setting up for hydraulic dredging operations, including performing a pilot study prior to full scale production. Additional

site preparation includes removing oversized debris around the dam and any other areas, clearing and grubbing, establishing access and haul roads, and preparing the dewatering area.

The dredging estimate is based on hydraulic dredging using relatively small (500 gpm) equipment. If it is not possible to reach the river banks using hydraulic dredge equipment, then as suggested previously, another option would be to remove the Allen Street dam in controlled increments. This would lower the water level, which would allow standard ground equipment to access the impoundment. A 1 to 2 month lag in dewatering and disposal may be estimated based on the amount of water to be treated, time to dewater and solidify/bulk the sediment, and time to haul the sediment off site. Sediment in the Allen Street impoundment may be dredged and disposed of in one construction season.

2.2 Dam Demolition

It is anticipated that only the spillway and the east abutment of the dam will be removed. Access and work area for contractors for demolition will be primarily from Allen Court on the east side of the dam. Access will require tree removal and clearing. There appears to be adequate room for the contractor's operation. However, there is insufficient room in the area of the dam for the staging area. One possible location for the staging area is on the private property of the business at the end of Allen Court.

Removal of the spillway and abutment can be accomplished using conventional construction equipment. Temporary cofferdams will be required to divert flows both upstream and downstream during a sequenced removal of the dam. For the purposes of the cost estimate, it was assumed that repairs will be required to the foundation of the downstream apartment building and stabilization of the existing channel before any work can begin on the removal of the spillway. Removal will extend to the natural channel bottom or bedrock, if any.

It is important to note that the existing abutment of the Allen Street Bridge appears to be directly bearing on the dam's westerly abutment, which is a major concern regarding removal of the dam. The bridge has been recently rebuilt (completed in 2007), but the abutment was not modified. This must be investigated in detail prior to demolition of any portion of the dam.

As part of the dam removal process, all stone and granite pieces that either have been displaced from the dam, or were deposited during the dam's construction should be removed. These are all located in the channel immediately downstream of the dam. Existing ledge outcroppings should remain.

The stone and granite masonry should be trucked from the site. The smaller material from the dam and immediately downstream of the dam should be utilized as part of the final channel improvements and stabilization. The larger pieces of granite will be trucked from the site. Due to the limited work area at the dam site, on-site crushing of these pieces into graded gravel products is not anticipated.

2.3 Channel Improvements and Associated Structure Repairs

Downstream channel improvements will include removal of sediment and vegetation that have deposited in and along the channel over time and re-establishing the cross sectional area of the channel. The channel improvements are required to reduce the impacts of the temporary increased flows through the channel that could result as part of the construction activities. As such, it is anticipated that these improvements will be performed prior to the removal of the dam. Temporary cofferdams and proper operation of the dam should allow work to be safely performed in the channel. Access to the channel will be from Allen Court.

It is anticipated that repairs will be made to the foundation of the apartment building immediately downstream of the dam. These repairs primarily will be re-pointing the stone foundation, replacing missing stones and repairing existing concrete. Also of concern is the enclosed walkway spanning the river that connects the main building to an existing apartment unit on Allen Court. Repairs to the foundation of the apartment unit on Allen Court are anticipated.

2.4 Modifications to the Existing Outlet, Open Channel and Concrete Raceway

It is anticipated that the existing outlet culvert and open channel along Hudson Street will be filled as part of the dam removal project. Similarly, the existing concrete raceway will be removed and the land filled and re-graded as part of this project.

2.5 Site Restoration

Site restoration will be conducted to restore the site and any areas used for temporary access or staging, to their original conditions. For purposes of the planning-level cost estimate, minimal landscaping was assumed as part of the site restoration. The extent and type of landscaping should be evaluated as part of the design phase.

2.6 Additional Considerations

It is recommended that the existing bridge at Boundary Street be reviewed. A portion of the existing bridge appears to be closed to traffic indicating concerns about the safety of the existing bridge.

Steam bank stabilization and or channel bed modifications may be required downstream of the dam removal.

3.0 Proposed Sequence of Construction Activities

For the purposes of developing the planning-level cost estimate, a proposed sequence of construction activities with schedule was developed. The overall construction period is estimated to be 20 months. This is based on limiting construction within the Assabet River to the period May through December. It is anticipated that construction during the winter months and during the traditional high flow periods will not be feasible.

The major activity during the first calendar year is the sediment removal upstream of the dam. Other construction during the first calendar year will be limited to mobilization; cleaning and stabilizing the Assabet River downstream of the dam; and stabilizing the existing walls and foundation of the apartment buildings. These later activities are performed in preparation of the dam removal.

During the second calendar year, work on the demolition of the dam will be performed. Other activities will include the removal and filling of the existing outlet channel and site restoration. Depending on actual weather conditions, landscaping and planting associated with the site restoration may extend into the following calendar year.

HUDSON DAM (WASHINGTON STREET OR ROUTE 85 DAM)

1.0 Existing Structure Description [1]

Hudson Dam is situated on upsteam of the of Route 85 bridge in Hudson, Massachusetts. The dam exists in a narrow river channel through the downtown area. The dam is listed in the National Inventory of Dams (NID) as ID No. MA 00447.



Location of Hudson Dam

The Hudson Dam was first constructed c. 1866, and was most recently repaired in 1987. It is likely, however, that earlier dams may have been constructed at this site. A gristmill was built at

[1] Information provided in Sections 1, 2 and 3 on the dam and construction activities were prepared by CDM for planning purposes and provide to the Corps in CDM in memo dated March 14, 2008.

the natural falls at this location c. 1698, and the first bridge over the Assabet River was built just downstream of the dam by the Town of Marlborough (of which Hudson was once a part) in 1699.

Design plans and construction notes on the original dam were not readily available in conducting this analysis. The discussion of the construction methods and the planning-level cost estimates are based on visual observations of the dam (August 2007) and the information provided in previous reports obtained by the USACE and CDM.

The total extent of the existing dam is not evident from visual inspection. It appears that only the spillway portion of the dam can be seen. Development on both sides of the dam obscures the remainder of the original dam. Visual inspection also indicates that there may have been up to four buildings or mills on Washington Street in the immediate vicinity that may have used the water or water power from the dam. These building have all been replaced by existing structures. The existence of any conduits or raceways to these buildings is not evident. The existing foundation to Ace Hardware shows evident of an intake and outlet that has been blocked by concrete. The extent of that raceway and its condition are unknown, although the Phase I Inspection Report by USACE reports that there is no basement under the Ace Hardware building. The existence of any conduits to other buildings, if any, is not evident based on visual inspection.

The existing spillway structure appears to be earth fill with stone and granite masonry. The granite and stone face has mortared joints. The nature of the earth fill material and/or the presence of an impervious core are unknown. The spillway has a crest length of 66 feet with a structural height of 15 feet.

The spillway is bounded to the south by the foundation wall for the Ace Hardware building. This foundation is built of the same stone and granite block construction. The wall has several openings that have been blocked. The spillway in the vicinity of this foundation wall has a slight bend. The origin of this bend is unknown.

The spillway is bounded to the north by a concrete wall founded on a stone and granite masonry wall. This wall acts as a training wall for the spillway. The current outlet is located adjacent to this training wall. This 6’ x 8’ concrete outlet structure houses the 3’ x 4’ wood sluice gate. The gate’s operator is mounted above the gate. Adjacent to the outlet structure is a fire line intake.



Hudson Dam



Gated Outlet Works for Hudson Dam



Aerial Photograph of Hudson Dam

Immediately downstream of the dam is the Washington Street/Route 85 Bridge. The present bridge appears to be steel and concrete built over the original stone arch bridge.
The structural connection between the original dam and the stone arch bridge is a concern that will require additional investigation during the design phase. Similarly, downstream of the bridge are concrete walls which appear to be founded on stone and granite Masonry. This masonry appears consistent with the construction upstream of the dam and also needs to be evaluated in more detail during the design phase.



Hudson Bridge and Old Arch Stone Culvert Bridge



Channel Downstream of Hudson Dam

2.0 Proposed Construction Activities

The proposed construction activities necessary for removal of the Hudson Dam include the following:

- Sediment removal
- Demolition of the dam/spillway and outlet structure
- Channel improvements and stabilization and repairs to the foundation of the hardware building and gas station
- Repairs to the stone arch portion of the bridge, scour protection and removal of sediment in the River
- Repairs and stabilization of the walls downstream of the bridge
- Replacing the fire protection intake
- Site restoration

A proposed construction sequence is presented in Section 3.0 of this document.

2.1 Sediment Removal

Sediment removal behind the dam will be needed as part of the dam removal project. The estimated quantity of sediment, quality, and additional sediment sampling needs and dredging and dewatering are discussed in the report prepared by CDM entitled the "Assabet River Sediment Management Plan", December 2008.

For the Hudson impoundment, site preparation would include setting up for hydraulic dredging operations, including performing a pilot study prior to full scale production. Additional site preparation includes removing oversized debris around the dam and any other areas, clearing and grubbing, establishing access and haul roads, and preparing the dewatering area. The dredging would be by hydraulic dredging. If it is not possible to reach the river banks using hydraulic dredge equipment, then another option would be to remove the Hudson dam in controlled increments. This would lower the water level which would allow standard ground equipment to access the impoundment. A 1 to 3 month lag in dewatering and disposal may be estimated based on the amount of water to be treated, time to dewater and solidify/bulk the sediment, and time to haul the sediment off site. Sediment in the Hudson impoundment may be dredged and disposed of in two to three construction seasons.

2.2 Demolition of the Dam

Only the spillway of the dam is proposed for removal. It is anticipated that access for the demolition work will be from the water from the west. The best recommended access point is from the driveway and parking area of the existing gas station immediately north of the dam. The area is currently used by the existing gas station and a taxicab business. There appears to be approximately 25 feet between the retaining wall and the gas station's building. However, the presence of overhead power lines in this vicinity limits the use of this space and would make operation of heavy construction equipment extremely difficult. Thus, it is anticipated that work will proceed from the west.

Access to the water will be from the parking lot behind the town library and firehouse off Route 62. There appears to be adequate room in this parking lot for the contractor's operation and staging area. A traffic signal on Route 62 that is used by the firehouse will provide safe egress from the work site onto the busy street for all trucking activities.

For the purposes of the planning-level cost estimate, it was assumed that prior to removal of the spillway; repairs will be made to the walls both upstream and downstream of the dam and to the arch portion of the Washington Street Bridge, and stabilization of the existing channel. For the work downstream of the dam, temporary cofferdams will be required to divert flow to permit work in the dry. Work upstream of the dam will require the temporary lowering of the water level in the impoundment area. This will require opening the sluice gates in combination with the use of temporary cofferdams.

Demolition of the spillway and outlet structure can be accomplished using conventional construction equipment and techniques. Lowering of the water level in the impoundment area

will be required. Depending on the resulting level of water remaining behind the spillway and the bearing capacity of the remaining soils, the equipment will be operated from temporary barges or work mats. It is anticipated that all material to be removed will be "double-handled" prior to being placed in trucks and removed from the site. Because of concerns with the condition of the walls adjacent to the spillway and the downstream bridge, blasting is not recommended.

The stone and granite masonry will be trucked from the site. The smaller material can be utilized as part of the final channel improvements and stabilization. However, the larger pieces of granite will be trucked from the site. On-site crushing of stone and granite into graded gravel products should be investigated in the future.

2.3 Channel Improvements and Stabilization and Repairs to Structures

Downstream channel improvements will include removal of sediment and vegetation that has deposited in and along the channel upstream of the dam and immediately downstream of the dam. The channel improvements are required to reduce the impacts of any temporary increase in flow rates through the channel that could result as part of the construction activities. As previously indicated, it is anticipated that these improvements will be performed prior to the removal of the spillway and that the water level in the impoundment must be lowered. Lowering of the water will require opening the sluice gate in combination with the use of temporary cofferdams. Pumping within the cofferdams is anticipated. Repairs to walls included re-pointing the stone foundation, replacing missing stones and repairing existing concrete.

2.4 Repairs to the Bridge, Scour Protection and Removal of Sediment in the River

It is anticipated that repairs to the stone arches, scour protection and removal of existing sediment at the bridge will be completed prior to demolition of the spillway and outlet structure. This work will require temporary cofferdams to control flow within the channel. The repairs to the stone arches of the Washington Street/Route 85 bridge include re-pointing and replacing missing stones. Scour protection will include repairs to existing concrete at the abutments. Removal of sediment and vegetation in the channel is also anticipated.

2.5 Repairs and Stabilization of the Walls Downstream of the Bridge

It is anticipated that while the work on the bridge and stabilization of the channel is proceeding, repairs to the existing walls downstream of the bridge can be performed. For the purposes of cost estimating, it is assumed that the concrete work above the stone/granite wall is in good condition and that the work will involve stabilizing the area in and around the remaining stone masonry. Re-pointing and replacing missing stones are anticipated. Additional stabilization can be

provided by providing a new concrete toe. This should be investigated as part of the design phase.

2.6 Replacing the Fire Protection Inlet

Following removal of the spillway and outlet structure, the fire protection inlet may be replaced if needed.

2.7 Site Restoration

Site restoration will be conducted to restore the site and any areas used for temporary access or staging, to their original conditions. For purposes of the planning-level cost estimate, minimal landscaping was assumed as part of the site restoration. The extent and type of landscaping should be evaluated as part of the design phase.

2.8 Additional Considerations

The existing bridge at Houghton Street is currently closed to traffic and in need of repair. Any work at the dam should be coordinated with efforts by Hudson and the state regarding plans to repair/replace this bridge.

The existing foundation to the former mill building off Houghton Street should be evaluated in more detail prior to any planned temporary release of waters. This building is currently used as temporary storage and appears to be well maintained.

There are other sites downstream on the river that may need scour protection once the dam is removed. Also stream bank stabilization and or channel bed modifications may also be needed downstream of the dam removal project. These items will need to be considered in design.

The existing spillway from Tripp Pond should be evaluated prior to the removal of the Hudson Dam. The pond is controlled by a 5' wide stop log structure immediately north of Route 62. A low level outlet is provided by a gate valve. The outlet from the pond passes via an open cannel under an existing building prior to release to the Hudson Dam impoundment area. Although the elevation of the Tripp Pond outlet appears to be significantly above the level of the impoundment, the existence of any hydraulic control should be investigated further.

3.0 Proposed Sequence of Construction Activities

For the purposes of developing the planning-level cost estimate, a proposed sequence of construction activities was developed. The overall construction period is estimated at 20 months.

This is based on limiting construction within the Assabet River to the period May through December. It is anticipated that construction on the spillway during the peak winter months and during the traditional high flow periods will not be feasible with the exception of the sediment removal activities.

The major activity during the first calendar year is the sediment removal upstream of the dam. It is anticipated that the first several months of sediment removal will be dedicated to providing access to the river and for preparation of the drying areas. Once sediment removal commences, it is anticipated to take approximately six months. It is important to note that several of the construction activities in and around the spillway and foundations and walls upstream of the spillway will require periodic lowering of the water levels in the river. This may have an impact on the type and size of equipment used for sediment removal.

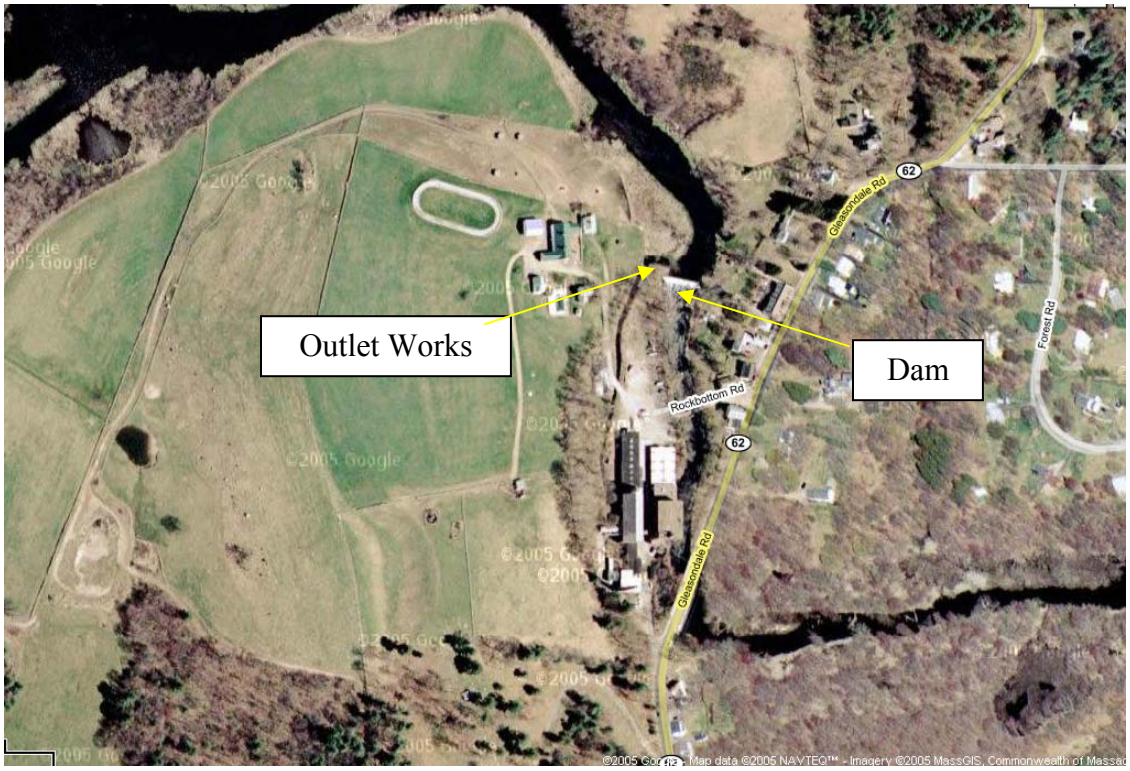
Other construction during the first calendar year will be limited to mobilization; repairing the existing sluice gate, stabilizing and repairing the Ace Hardware building's foundation and the retaining wall upstream of the dam, providing scour protection at the Washington Street bridge; cleaning and stabilizing the river downstream of the dam; and stabilizing the existing wall downstream of the dam. These later activities will be performed in preparation of the dam removal.

During the second calendar year, work on the demolition of the dam will be performed. Site restoration will proceed early in the second year and will be carried on through the remainder of the year. Depending on the weather at the end of the construction period, landscaping and planting associated with the site restoration may extend into the third construction season.

GLEASONDALE DAM

1.0 Existing Structure Description[1]

Gleasondale Dam is situated on the westerly side of Route 62 (Gleasondale Road) in Stow, Massachusetts. The dam exists in a narrow river channel and has masonry abutments on both sides. The dam is listed in the National Inventory of Dams (NID) as ID No. MA 00820.



The current dam, called the "stone dam" is the third dam at this location. The first dam constructed here was built c. 1735, and the second c. 1836 along with the canal, which extended under the mill building. The current dam was built in 1883 and connected to the existing canal, with a canal gate and overflow spillway to service the C.W. Gleason's Sons textile mill. Work on the Dam may have been done in 1924 as this is the date provided in the NID.

Design plans and construction notes were not readily available in conducting this analysis. The discussion of construction methods and the planning-level cost estimates are based on visual observations of the dam (August 2007) and the information provided in previous studies obtained by USACE and CDM.

[1] Information provided in Section 1, 2 and 3 on the dam and construction activities was prepared by CDM for planning purposes and provide to the Corps in CDM memo dated March 14, 2008.

The existing Gleasondale dam structure appears to be an earth fill dam with stone and granite masonry. The nature of the earth fill material and/or the presence of an impervious core are unknown. The dam has a crest length of 95 feet and a structural height of 12 feet. The abutments are of similar stone and granite block construction. The foundation of the existing dam and abutments is unknown.



Gleasondale Dam

The dam has a rectangular shaped outlet channel east of the dam. The outlet channel continues south along the west side of the property via an earth open channel approximately 600 feet long. At this point the channel enters a pipe. The size of the pipe could not be determined. The pipe ends at a cistern style structure on the west side of the Mill Building. The flow passes through an opening under the building to a chase that eventually passes under the Mill building and the Mill complex's driveway before returning to the Assabet River.

Flow in the outlet pipe is controlled by a sluice gate. According to one of the dam's owners, the sluice gate has not been operated in many years. The sluice gate appears to be in poor condition. Immediately downstream of the sluice gate, there is an earth channel from the outlet channel to the Assabet River. This earth channel appears to be hand-dug and lacks a stabilized channel configuration. Early signs of erosion are visible particularly along the south face of the dam's west abutment.

Flow in the outlet channel currently serves as a critical component of the fire protection system for the Mill Complex. Presently, water is pumped from the cistern to three storage tanks located on top of the adjacent hill east of the Mill complex. Currently, only the 50,000 gallon tank is

used. The tanks feed the Mill complex's building sprinkler system and yard hydrant. Since there are no existing water mains in the vicinity of the Mill Complex, this fire protection system is critical to the Mill complex and neighboring homes.

2.0 Proposed Construction Activities

The proposed construction activities necessary for the removal of Gleasondale Dam are summarized as follows:

- Sediment removal
- Demolition of the dam
- Channel improvements and stabilization
- Scour protection and sediment removal
- Outlet channel removal
- Fire protection system replacement
- Site restoration

A proposed sequence of construction activities is included in Section 3.0 of this document.

2.1 Sediment Removal

Sediment removal behind the dam will be needed as part of the dam removal project. The estimated quantity of sediment, quality, and additional sediment sampling needs and dredging and dewatering are discussed in the report prepared by CDM entitled the "Assabet River Sediment Management Plan", December 2008.

For the Gleasondale impoundment, site preparation would include setting up for hydraulic dredging operations, including performing a pilot study prior to full scale production. Additional site preparation includes removing oversized debris around the dam and any other areas, clearing and grubbing, establishing access and haul roads, and preparing the dewatering area.
The dredging estimates are based on hydraulic dredging.

If it is not possible to reach the river banks using hydraulic dredge equipment, then another option would be to remove the Gleasondale dam in controlled increments. This would lower the water level which would allow standard ground equipment to access the impoundment. A 1 to 2 month lag in dewatering and disposal may be estimated based on the amount of water to be treated, time to dewater and solidify/bulk the sediment, and time to haul the sediment off site. Sediment in the Gleasondale impoundment may be dredged and disposed of in one to two construction seasons.

2.2 Dam Demolition

It is anticipated that only the spillway portion of the dam will be demolished and removed. The existing east abutment will remain. The existing west abutment will be stabilized and remain.

Removal of the spillway can be accomplished using conventional construction equipment. Temporary cofferdams will be required to divert flows both upstream and downstream during a sequenced removal of the dam. The flow can be diverted through the existing outlet structures and back to the Assabet River through the hand-dug channel. The hand dug channel will require stabilization prior to its use. Reuse of the entire open channel and chase under the building is not recommended due to the age and unknown condition of the portion of the chase under the building and driveway. However, the channel needs to be modified to allow flow to maintain the existing fire protection system.

For the purposes of this evaluation it is assumed that prior to removal of the spillway, repairs will be required to the foundation of the mill buildings together with removal of debris and stabilization of the river bank in this vicinity. Spillway removal will extend to the natural channel bottom or bedrock, if any.

As part of the spillway removal process, all stone and granite pieces that either have been displaced from the spillway, or were deposited during the dam's construction should be removed.

The stone and granite masonry will be trucked from the site. The smaller material from the dam and immediately downstream of the dam can be utilized as part of the final channel improvements and stabilization. However, the larger pieces of granite will be trucked from the site. On-site crushing of stone into graded gravel products should be evaluated during the design phase. Since it is anticipated that the existing abutments are to remain, blasting is not recommended.

Access and work area for contractors for the demolition will be from the open area to the rear of the Mill complex. There appears to be adequate room for the contractors' operation and staging area in this area. Some tree removal and clearing will be required. A second access to the dam is available from an existing right-of-way behind the properties to the east of the dam.

It is recommended that a new, temporary bridge be installed over the Assabet River in the same location at the existing, abandoned bridge. This temporary bridge will provide the access off Route 62 onto the site. The existing access to the area to the rear of the Mill complex off Route 62 is via the Mill's driveway. This driveway is narrow, has a dangerous traffic movement onto

on Route 62, and is the only access/egress to the Mill. This driveway is also the only access to the Rock Bottom farm located to the rear of the complex. Movement of construction equipment on this driveway will be a constant impediment to the Mill's tenants. Additionally, the existing chase and the septic system for the complex are located under the driveway. The condition of both is unknown.

2.3 Channel Improvements and Stabilization

Channel improvements, together with stabilization and repairs to the foundation of the Mill buildings downstream of the dam will be required as part of removing Gleasondale Dam. Downstream channel improvements will include removal of sediment and vegetation that have deposited in and along the channel. The channel improvements are required to reduce the impacts of the temporary increased flows through the channel that could result as part of the construction activities. As such, it is anticipated that these improvements will be performed prior to the removal of the dam. Temporary cofferdams and proper operation of the dam will allow work to be safely performed in the channel. Access to the channel will be from the contractor's work area to the rear of the Mill complex.

It is also anticipated that repairs will be made to the Mill building's foundation. These repairs primarily will be re-pointing the stone foundation, replacing missing stones and repairing existing concrete.

2.4 Scour Protection and Sediment Removal

It is anticipated that scour protection and removal of existing sediment at the Route 62 bridge will be completed prior to demolition of the spillway. The existing bridge has three spans. Currently, flow in the Assabet River flows through only the center span and a limited portion of a second span. Considerable sediment and vegetation have accumulated which should be removed prior to the temporary release of additional flows. Similarly, scour protection should be provided to the two middle abutments of the existing bridge.

2.5 Outlet Channel Removal

It is anticipated that the existing outlet culvert and open channel will be removed and filled. This channel must remain in operation until the new pump station and force main are operational. This work will include removal of the stone outlet walls, removal of the concrete sluice gate structure, filling and re-grading the outlet and open channel, removal of the small bridge to the small mill building and the driveway for Rock Bottom Farm and removal of the pipe section immediately upstream of the cistern.

It is also recommended that the existing chase and outlet structure be abandoned and filled. The condition of both is unknown and they no longer serve the intended purpose. These are potential safety concerns to the building, the complex's driveway and the Town's fire fighting capabilities.

2.6 Fire Protection System Replacement

It is anticipated that a new submersible pump within a precast well will be constructed immediately adjacent to the Assabet River in the vicinity of the existing chase's outlet. The precast well will be preceded by a fabricated bar rack for protection from large solids and debris. A new force main will also be installed and connected to the existing main to the tanks.

2.7 Site Restoration

Site restoration will be conducted to restore the site and any areas used for temporary access or staging, to their original conditions. For purposes of the planning-level cost estimate, minimal landscaping was assumed as part of the site restoration. The extent and type of landscaping should be evaluated as part of the design phase.

3.0 Proposed Sequence of Construction Activities

For the purposes of developing the planning-level cost estimate, a proposed sequence of construction activities with schedule was developed. The overall construction period is estimated at 27 months. This is based on limiting construction within the Assabet River to the period May through December. It is anticipated that construction on the spillway and in the Assabet River during the peak winter months and during the traditional high flow periods will not be feasible. Construction activities off the river will continue during these periods.

The major activity during the first calendar year is the installation of the temporary bridge across the river to provide the access to the site from Route 62. The other major activity during the first year is sediment removal upstream of the dam. It is anticipated that the first several months of sediment removal will be dedicated to providing access to the river and for preparation of the drying areas. Once sediment removal commences, it is anticipated to be completed by the end of the first calendar year.

Other construction during the first calendar year will be limited to mobilization; modifications to the outlet channel to divert most of the flow back to the river while maintaining the required flow for the fire protection system; stabilizing and repairing the Mill building's foundation; cleaning

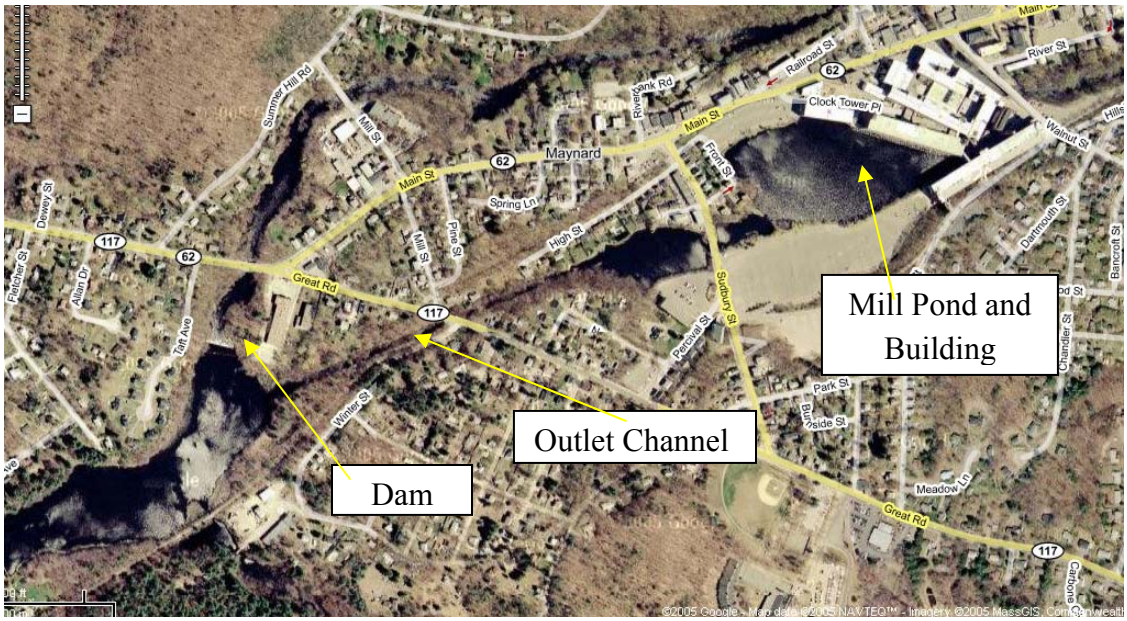
and stabilizing the river downstream of the dam; and providing scour protection at the Route 62 bridge. These later activities are performed in preparation of removing the spillway.

During the second calendar year, work on the demolition of the spillway will be performed. Work on the pump station and force main will commence as will work on site remediation. Both activities will be carried on through the remainder of the year into the third calendar year. Work during the third calendar year will complete all miscellaneous, but necessary construction activities including the completion of site remediation activities.

BEN SMITH DAM

1.0 Existing Structure Description [1]

Ben Smith Dam is situated on the southerly side of Route 117 (Great Road) in Maynard, Massachusetts. The dam exists in a narrow river channel with a mix of stone and concrete abutments. The dam is listed in the National Inventory of Dams (NID) as ID No. MA 00752.



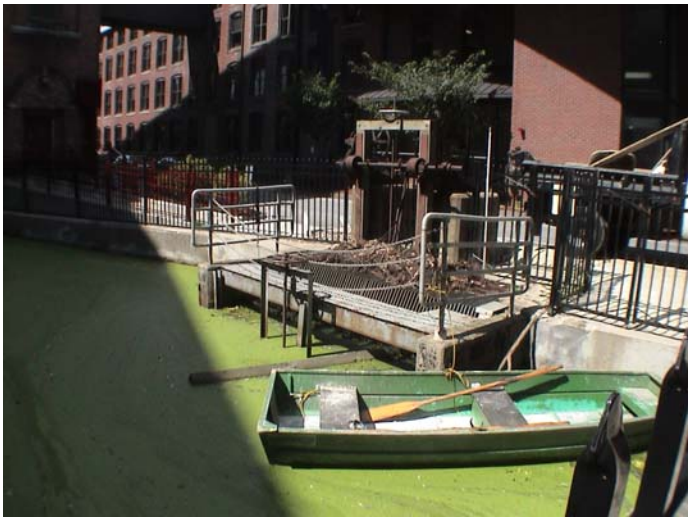
Location of Ben Smith Dam

Ben Smith Dam was constructed across the Assabet River in 1847 to establish a mill for the manufacture of carpets and carpet yarn. In order to power the mill, a canal was dug to channel a portion of the river into what is called Mill Pond. The mill changed hands several times over the years and was converted to hydroelectric power in 1902. While the mill ceased operation in 1950, the buildings remain and the mill complex, currently known as Clock Tower Place, currently houses numerous businesses. Power generation was discontinued in the early 1990s.

[1] Information provided in Sections 1, 2 and 3 on the dam and construction activities were prepared by CDM for planning purposes and provide to the Corps in CDM in memo dated March 14, 2008.



Ben Smith Dam



Hydropower Intakes at Mill Complex

Design plans and construction notes for Ben Smith dam were not readily available in conducting this analysis. The discussion of construction methods and the planning-level cost estimate are based on visual observations of the dam (August 2007) and the information provided in previous studies obtained by USACE and CDM.

The Ben Smith Dam was constructed in 1847 of large, dry-laid granite blocks, 1.5 to 2 ft. in depth and 4 to 6 ft. long. The Ben Smith dam is 170 feet long. The crest of the spillway is approximately two feet wide and the base of the dam is reported to be six to seven feet wide. The dam crest elevation is 174.9 feet above mean sea level. The dam varies in height from

approximately three feet on the east bank to approximately nine feet on the west bank and approximately nine feet in the primary channel section.

A canal leading to the Upper and Lower Mill Ponds is located approximately 350 feet south east of the dam. The canal extends approximately 1,800 feet to the Upper Mill Pond and appears to be dug by hand with minimal horse or mule equipment. The canal begins as a 58' wide channel on the northeast shore of the Ben Smith impoundment, quickly narrowing to a relatively uniform width of approximately 40 feet . When the water level in the Ben Smith impoundment is at the crest of the dam, water depths within the canal range from 2 feet at the diversion intake to 5 feet in the narrower portion of the channel.

A gate house, located two-thirds of the way between the Ben Smith impoundment and Upper Mill Pond, controls the flow of water entering the ponds with two 6-foot wide manually controlled gates. The sluice gates are operational and were closed at the time of the August 2007 field observations to allow for work in the Lower Pond. Water exits Lower Mill Pond through the powerhouse, passing through twin tailrace tunnels before rejoining the Assabet River about 5,400 feet downstream of Ben Smith Dam.

The Lower Mill Pond is located across the bridge on Sudbury Road. The two ponds are used for aesthetic and recreational purposes for the Mill complex. The two ponds also serve as part of the fire protection system for the Mill complex.

2.0 Proposed Construction Activities

The proposed construction activities necessary for the removal of Ben Smith Dam are summarized as follows, and described subsequent sections.

- Sediment removal
- Dam demolition
- Channel improvements and stabilization
- Pump station and force main (to maintain water levels in the Upper and Lower Mill Ponds)
- Remove gate house and abandon the canal to the Mill Ponds
- Site restoration

A proposed sequence of construction activities is presented in Section 3.0 of this document.

2.1 Sediment Removal

Sediment removal behind the dam will be needed as part of the dam removal project. The estimated quantity of sediment, quality, and additional sediment sampling needs and dredging and dewatering are discussed in the report prepared by CDM entitled the "Assabet River Sediment Management Plan", December 2008.

For the Ben Smith impoundment, site preparation would include setting up for hydraulic dredging operations, including performing a pilot study prior to full scale production. Additional site preparation includes removing oversized debris around the dam and any other areas, clearing and grubbing, establishing access and haul roads, and preparing the dewatering area.
The dredging cost estimate is based on hydraulic dredging. If it is not possible to reach the river banks using hydraulic dredge equipment, then another option would be to remove the Ben Smith dam in controlled increments. This would lower the water level which would allow standard ground equipment to access the impoundment. A 1 to 3 month lag in dewatering and disposal may be estimated based on the amount of water to be treated, time to dewater and solidify/bulk the sediment, and time to haul the sediment off site. Sediment in the Ben Smith impoundment may be dredged and disposed of in two to three construction seasons.

2.2 Dam Demolition

Removal of the Ben Smith dam can be accomplished using conventional construction equipment. Portable, temporary cofferdams will be required to divert flows both upstream and downstream during a sequenced removal of the dam.

The dam is assumed to be founded on the existing bedrock. Dam removal will extend to the natural channel bottom or bedrock. No blasting is anticipated. Since it is anticipated that removal of the dam will extend to bedrock, little or no permanent channel stabilization is anticipated to be required in the immediate area of the new channel bottom. Establishing new channel slopes will be required. Given the slope of the existing bank on the west, it is anticipated that the channel will resume its original pre-dam route in this area.

As part of the dam removal process, some granite pieces that either have been displaced from the dam, or were deposited during the dam's construction, should be removed. These are all located immediately downstream of the dam. All rock outcroppings that extend into the channel should remain.

The granite masonry will be trucked from the site. The smaller material will be utilized as part of the final channel improvements and stabilization. Given the large size of the granite masonry pieces, it appears unlikely that these can be used as part of the final stabilization work.

Access and work area for contractors will be primarily from the east side of the dam. Access will be from the Mill Pond Building off Route 117. The steepness of the slope makes access from Taft Avenue to the west extremely difficult and cost prohibitive. Vehicle and equipment access will be from the driveway of the Mill Pond Building. Currently, a one-way traffic pattern exists around the building with parking along the driveway. Modifications to the traffic pattern would be required during construction. There is adequate space available in the existing parking lot in the rear of the building for a staging area. Tree removal and site clearing will be required on the private property for access to the dam and to provide an adequate work area.

2.3 Channel Improvements and Stabilization

Channel improvements and stabilization will be required between the dam and the bridge at Route 117, including scour protection at the bridge at Route 117. Downstream channel improvements will include removal of sediment and vegetation that have deposited in and along the channel over the years and re-establishing a cross- sectional area of the channel. The channel improvements are required to reduce the impacts of the temporary increased flows through the channel that could result as part of the construction activities. As such, it is anticipated that these improvements will be performed prior to the removal of the dam. Temporary cofferdams and proper operation of the dam should allow work to be safely performed in the channel. Access to the channel will be from the same location as the access to the dam.

Scour protection at the abutments to the bridge at Route 117 will be required prior to removal of the dam. Work will be primarily removal of the accumulated debris in the channel bed, repair to existing concrete and improvements to the existing granite block foundation and abutments. Access will be from the channel. However, some work from Route 117 will be required. Interference to traffic should be minimal as the temporary closing of one lane to traffic is not anticipated.

2.4 Pump Station and Force Main

A critical element in removing Ben Smith dam will be maintaining the water surface elevations in the Lower and Upper Mill Pond. A previous study indicated that pumping water from the Assabet River to the Mill Ponds is required if the Ben Smith Dam is removed. This requirement is based on the need to maintain minimum water surface elevations and maintain flow in the ponds for water quality, aesthetic and fire protection purposes. The study addressed the need for

pumping only. The required rate of pumping to maintain proper flows will need to be determined with additional analyses of the Mill Pond system during future phases of this study.

Construction of a pump station upstream of the present location of the Ben Smith Dam appears to be the most feasible option to supply appropriate flow to the Mill Ponds. Several locations for this pump station were evaluated including on the private property off Winter Street and on the property immediately adjacent to the Town's Public Work's yard. Both options would require a long suction line into the Assabet River and a long force main to the Upper Mill Pond.

For the purposes of this study and to prepare the planning-level cost estimate, a 400-foot long suction line and a 2,600-foot force main are anticipated. The force main route would be constructed within and along the existing bed of the canal feeding the Mill Ponds. Based on this evaluation, there do not appear to be any significant foundation or construction issues associated with the pump station, suction line and force main. It is anticipated that excavation of existing bedrock will be required.

A third potential pump station location was also evaluated. Locating the pump station within the lower level of one of the Mill buildings could also be considered as a viable option for evaluation in future phases of this study. Locating the pump station within one of the Mill buildings would significantly reduce the size of the pump station, and reduce the length of the suction line and force main. This should significantly reduce both overall construction and operation cost of the system.

It is anticipated that the pump station, suction line and force main will be constructed prior to the demolition of the dam. Temporary cofferdams will be required at the Mill Ponds and at the entrance to the canal until the work abandoning the canal is complete.

2.5 Gatehouse Removal and Canal Abandonment

The elevation of the canal feeding the Mill Ponds is very close (approximately one to two feet lower) than the elevation of the crest of the Ben Smith Dam. Upon removal of the dam, flow will no longer enter the canal from the west from the Assabet River. To assure proper operation of the Mill Ponds and to prevent water in the Mill Ponds from flowing back into the canal, it is recommended that the canal be re-graded at both the impoundment end and at the Upper Mill Pond. Similarly, it is recommended that the canal be filled and/or re-graded to prevent a new impounded area from forming in which local surface runoff could accumulate. It is also recommended that the existing gatehouse be removed since its original purpose is no longer needed.

Access for this portion of the construction will be from Route 117 and High Street along the channel and Sudbury Road from the east.

2.6 Site Restoration

Site restoration will be conducted to restore the site and any areas used for temporary access or staging, to their original conditions. For purposes of the planning-level cost estimate, minimal landscaping was assumed as part of the site restoration. The extent and type of landscaping should be reevaluated as part of the design phase.

2.7 Additional Considerations

There will be significant truck traffic associated with the construction activities required to remove Ben Smith dam. The impact of this increased traffic in this congested needs to be addressed during future phases of this study.

The three bridges along the Assabet River downstream of Ben Smith Dam all appear to be adequately sized to convey any temporary increase in flow during construction. As discussed in Section 2.3, channel improvements are recommended upstream of the bridge and scour protection is recommended for the bridge at Route 117.

More details on the extent of downstream scour protection and streambank stabilization will need to be considered in design. Channel bed improvements (e.g. drop structures) might be considered downstream of Ben Smith dam, which could minimize the extent of streambank stabilization required.

It is recommended that the existing sediment and vegetation be removed along the channel section immediately adjacent to the Mill Buildings and Route 62.

3.0 Proposed Sequence of Construction Activities

For the purposes of developing the planning-level cost estimate, a proposed sequence of construction activities was developed. The overall construction period is estimated to be 20 months. This is based on limiting construction within the Assabet River to the period May through December. It is anticipated that construction in the river during the peak winter months and during the traditional high flow periods will not be feasible. Construction activities off the river will continue during these periods.

The major activity during the first calendar is the sediment removal upstream of the dam. Other construction during the first calendar year will be limited to mobilization; cleaning and stabilizing the river downstream of the dam; and providing scour protection at the Route 62/117 Bridge. These later activities are performed in preparation of removing the spillway.

The construction on the pumping station and force main can begin during the first calendar year. Construction can continue uninterrupted over the winter and spring until completed and operational.

During the second calendar year, work on the demolition of the dam will be performed. Site restoration will performed the second calendar year and should be completed by year end.

POWDERMILL DAM

1.0 Existing Structure Description [1]

Powdermill Dam is situated on the northerly side of Route 62 (Powdermill Road) in Acton, Massachusetts. The dam is part of a small hydropower facility owned by Acton Hydro Company. The dam is listed in the National Inventory of Dams (NID) as ID No. MA 00128.

Based on the information provided in the previous reports, the dam was built around 1921 but has undergone repair in the past and was undergoing reconstruction at the time of this study.

The discussion of proposed construction methods and the planning-level cost estimates are based on visual observations of the dam (August 2007) and the information provided by the dam owner to USACE regarding the ongoing construction project.



[1] Information provided in Sections 1, 2 and 3 on the dam and construction activities were prepared by CDM for planning purposes and provide to the Corps in CDM in memo dated March 14, 2008.

The dam is built of stone masonry on a natural ledge with a timber crib structure to raise the freeboard height for hydropower purposes.

The existing dam appears to be built of stone masonry on existing ledge and till. A timber crib structure was built on the stone masonry presumably to raise the water level in the impoundment area as part of the hydroelectric plant's operation. This timber crib structure is being removed and replaced as part of the ongoing construction. The timber crib is being replaced with hinged flashboards.

The length of the dam is approximately 150 feet, not including an additional 250 feet along Route 62. The dam has a structural height of 13. The current spillway has a crest length of 105 feet.

The intake to the power facility is located approximately 40 feet north of the spillway. The intake is twin 7 ft diameter concrete pipes. Currently, flow to the intake pipes is controlled by wood stop logs. This is being updated as part of the ongoing work.



Aerial showing lower impoundment level due to failed outlet works



Aerial view of dam prior to reconstruction

The outlet to the dam is twin 6 ft diameter corrugated metal pipes located approximately 180 feet north of the existing powerhouse. It appears that flow through the outlet pipes was controlled by gate valves. These valves were removed prior to the August 2007 site visit. The existing outlet will be filled and taken out of service as part of the ongoing repairs. It appears that the newly constrructed hinged flashboards will be lowered to provide a temporary outlet from the impoundment when required.

Immediately upstream of the existing spillway is the Old High Street Bridge. This bridge is currently closed to traffic and appears to be abandoned. The demolition of the existing spillway must be coordinated with the Town of Action and the Commonwealth regarding any plans to repair/replace the bridge.

The foundation wall for an existing building is located approximately 90 feet downstream of the spillway. This foundation is built of the same stone construction and appears to be in poor condition. The channel downstream of the spillway has evidence of significant erosion and

damage. Plans for demolition of the spillway must include provisions for stabilizing the foundation and channel.

2.0 Proposed Construction Activities

The proposed work necessary for removal of the Powdermill Dam includes the following:

- Sediment removal
- Demolition of the spillway structure
- Channel improvements and stabilization and repairs to the building foundation and channel downstream of the spillway
- Closing of the intake to the power facility
- Site restoration

2.1 Sediment Removal

Sediment removal behind the dam will be needed as part of the dam removal project. The estimated quantity of sediment, quality, and additional sediment sampling needs and dredging and dewatering are discussed in the report prepared by CDM entitled the "Assabet River Sediment Management Plan", December 2008.

For the Powdermill impoundment, site preparation would include setting up for hydraulic dredging operations, including performing a pilot study prior to full scale production. Additional site preparation includes removing oversized debris around the dam and any other areas, clearing and grubbing, establishing access and haul roads, and preparing the dewatering area.

The dredging cost estimate is based on hydraulic dredging. If it is not possible to reach the river banks using hydraulic dredge equipment, then as suggested previously, another option would be to remove the Powdermill dam in controlled increments. This would lower the water level which would allow standard ground equipment to access the impoundment. A 1 to 3 month lag in dewatering and disposal may be estimated based on the amount of water to be treated, time to dewater and solidify/bulk the sediment, and time to haul the sediment off site. Sediment in the Powdermill impoundment may be dredged and disposed of in two to three construction seasons.

2.2 Demolition of the Dam

Only the spillway structure portion of the dam will be demolished. It is anticipated that contractor access for the demolition work will be from Old High Street to the north. Old High Street appears to be capable of accommodating anticipated truck and equipment traffic. The street accesses Route 62 via High Street. The contractors' staging area will be the lower portion of Old High Street. The street is currently blocked to traffic and fenced by the current contractor. There is an existing building within the fenced area that is currently being used for the contractors' and dam operator's office. It is anticipated that similar arrangements will be available in the future.

For the purposes of the planning-level cost estimate, it is assumed that prior to removal of the spillway; repairs will be made to the existing foundation and channel downstream of the spillway. Following these repairs, the current outlet pipes need to be put back in service. Re-establishing this outlet will allow all flow to be diverted around the spillway. This will permit the construction to be performed in dry conditions.

Demolition of the dam can be accomplished using conventional construction equipment and techniques. However, because of limited space, it is anticipated that all material to be removed will be "double-handled" prior to being placed in trucks and removed from the site. Because of concerns with the condition of the adjacent dam and the dam/retaining wall along Route 62, blasting is not recommended.

The smaller material from the spillway and immediately downstream of the dam will be utilized as part of the final channel improvements and stabilization. However, the larger pieces of stone will be trucked from the site. On-site crushing of stone and granite into graded gravel products is not anticipated.

2.3 Channel Improvements and Stabilization and Repairs to the Building Foundation and Channel Downstream of the Spillway

Downstream improvements will include removal of stones, sediment and vegetation that has deposited in and along the channel downstream of the spillway. The placement of a stone and riprap channel section are required to stabilize the channel for the anticipated increase in flow during construction and to repair existing damage due to erosion. This erosion is particularly evident along the earthen channels immediately downstream of the existing outlet from dam and the tailway from the hydroelectric facility. Channel repairs are assumed to extend the entire length of the channel to the bridge at Route 62.

Repairs to the building will include the replacement of a major section of the west and north side foundation wall. Temporary support of the building will be required to replace the foundation. The building appears to be founded on the same material as the dam; therefore problems with bearing capacities are not anticipated.

The work on the foundation and within the channel will require the use of temporary cofferdams around the work areas.

2.4 Closing of the Intake to the Power Facility

Closing the intake to the dam includes the removal of the wood stop logs and intake structure and filling the twin pipes with concrete. This work should be performed during the same period that the flow in the Assabet River is being diverted through the outlet pipes.

2.5 Site Restoration

Site restoration will be conducted to restore the site and any areas used for temporary access or staging, to their original conditions. For purposes of the planning-level cost estimate, minimal landscaping was assumed as part of the site restoration. The extent and type of landscaping should be evaluated as part of the design phase.

2.6 Additional Considerations

Scour protection at the existing bridge at Route 62 downstream of the dam will need to be evaluated during the design phase.

The existing retaining wall along Route 62 should be evaluated further during the design phase. Based on the visual inspections during the August 2007 field visit, it was not completely evident whether the wall is part of the dam. If so, the impact on this retaining wall from the removal of the spillway needs to be determined.

It is assumed that the abandoned bridge on Old High Street will remain or will be removed by others. However, this assumption needs to be evaluated in terms of the final planning for the re-channelization of the Assabet River in this area. As a minimum, the old abandoned piles adjacent to the dam should be removed for visual effect and to prevent buildup of debris.

The removal of the power facility is also assumed to be performed by others and is not part of this project. That assumption needs to be re-considered as part of the future phases of this project.

3.0 Proposed Sequence of Construction Activities

For the purposes of developing the planning-level cost estimate, a proposed sequence of construction activities was developed. The overall construction period is estimated at 20 months. This is based on limiting construction within the Assabet River to the period May through December. It is anticipated that construction during the peak winter months and during the traditional high flow periods will not be feasible.

The major activity during the first calendar year is the sediment removal upstream of the dam. Other construction during the first calendar year will be limited to mobilization; replacing the existing outlet pipes; cleaning and stabilizing the river downstream of the dam; and replacing the foundation of the existing building. These later activities are performed in preparation of the removal of the spillway. Filling the existing inlet pipes to the power facility can commence in the first calendar year and be completed during the winter months.

During the second calendar year, work on the demolition of the spillway will be performed. Other activities will include site restoration.

APPENDIX C

COST ESTIMATES

APPENDIX C

APPENDIX C - PLANNING LEVEL CONSTRUCTION COST ESTIMATES

CDM developed planning level construction cost estimates for each dam removal and sediment removal. Construction activities are detailed in Appendix B and cost developed by line item and presented in the following tables.

Construction Cost Estimates include Contractor overhead (16%), profit (10%), bond and insurance cost (5%) and a contingency of 25%.

Sediment Disposal Costs were estimated based on the quantity of material to be dredged and unit disposal costs. For each of the impoundments studied, a ball park estimate of the percent of total volume of sediment that would be suitable for either upland disposal, landfill reuse or out of state disposal was made based on results of the 2003 USGS in situ sediment program discussed in the CDM report entitled "Assabet River Sediment Management Plan", dated December 2008.

Actual sediment disposal cost will depend on the physical and chemical quality of the dredged sediment. It was determined that additional data will be needed to determine sediment suitability for disposal and a detailed sediment sampling and analysis plan is included in the CDM report entitled "Assabet River Sediment Management Plan", dated December 2008.

Assabet River. Planning Level Dredge Material Dispsoal Costs

	Volume of Sediment to be Dredged	Volume of Sediment to be Disposed [1]	Upland Disposal[2]		Landfill Re-use [3]		Out-of-State Landfill [4]		Subtotal - Hauling and Disposal [5]
	yd^3	yd^3	tons	Cost	tons	Cost	tons	Cost	Cost
Aluminum City	1,304	1,434	918	$ 15,606	1,377	$ 70,228	-	$ -	$ 85,834
Allen Street	2,237	2,500	2,000	$ 34,000	2,000	$ 102,000	-	$ -	$ 136,000
Hudson	71,558	79,000	50,560	$ 859,520	75,840	$ 3,867,840	-	$ -	$ 4,727,360
Gleasondale	27,856	31,000	19,840	$ 337,280	29,760	$ 1,517,760	-	$ -	$ 1,855,040
Ben Smith	67,601	75,000	33,600	$ 571,200	84,000	$ 4,284,000	2,400	$ 225,600	$ 5,080,800
Powdermill	65,833	73,000	-	$ -	93,440	$ 4,765,440	23,360	$ 2,195,840	$ 6,961,280

1) Estimated a 10% increase in volume based on solidification with additive.

2) Transportation and handling only, assumes no disposal cost, unit cost of $17 per ton for transp, handling and hauling

3) Unit cost of $51 per ton for landfill re-use (based on recent data)

4) Unit cost of $94 per ton for out of state landfill (based on recent data)

5) For each of the impoundments, % of total volume was estimated for the disposal options based on results of the 2003 USGS in situ sediment program. Estimated cost includes handling, transportation and disposal only. Actual disposal will depend on the physical and chemical quality of the dredged sediment and approval by the appropriate regulatory agencies.

Aluminum City Dam, Construction Cost for Dam Removal	
Cost Estimate developed by CDM for Assabet Study, 2008, Cost Estimate provided for Planning purposes only.	($)
General Work Items	
Mobilization/De-Mobilization	24,000
Site Access and Clearing	2,000
Landscaping - Live Staking & Rip-Rap	29,250
General Work Items - Subtotal	55,250
Dam Demolitition	
Cofferdam Equipment Mobilization - Rig Only	25,000
Install Cofferdam - 1st Area	35,700
Remove Dam - 1st area	2,520
Install Bypass Culvert	8,100
Install Bypass Culvert Fill	7,600
Install Cofferdam - Final Area	31,350
Remove Dam - Final area	5,040
Create Buttress to Support Building Foundation	13,500
Cofferdam Dewatering	10,000
Dam Demolitition - Subtotal	138,810
Channel/Foundation Improvements	
Install Temporary Shoreline (Cofferdam - 1st area)	33,750
Foundation/Wall Repairs - 1st area	24,500
Scour Protection - West Side	2,000
Install Temporary Shoreline (Cofferdam - final area)	49,500
Foundation/Wall Repairs - final area	32,000
Scour Protection	2,000
Cofferdam Dewatering	5,000
Channel/Foundation Improvements - Subtotal	148,750
Culvert and Channel Finishing	
Fill Conduit	36,850
Culvert and Channel Finishing - Subtotal	36,850
Sediment Removal	
Mechanical Dredging	64,800
Dewatering	104,080
Sediment Removal	168,880
Subtotal - Direct Costs	548,540
Indirect Costs (Contractor OH, Profit, Bond, Insurance)	191,000
Subtotal - Direct + Indirect Costs	739,540
Contingency	184,790
TOTAL Construction Costs	924,330
Estimated Sediment Disposal Cost (1,304 cy)	86,000
TOTAL with Sediment Disposal Cost	1,010,330

Allen Street Dam, Construction Cost for Dam Removal	
Cost Estimate developed by CDM for Assabet Study, 2008, Cost Estimate provided for Planning purposes only.	($)
Mobilization/De-Mobilization	38,000
Site Access and Clearing	2,500
Landscaping - Seed Mix Planting	2,900
Landscaping - Live Staking & Rip-Rap	8,500
General Work Items - Subtotal	51,900
Dam Demolitition	
Cofferdam Equipment Mobilization - Rig Only	25,000
Bridge Abutment Shoring - Concrete	42,000
Foundation Wall Repair - 1st Area	30,000
Install Cofferdam - 1st Area	117,000
Remove Dam - 1st area	6,300
Install Cofferdam - Final Area	117,000
Foundation Wall Repair - Final Area	30,000
Remove Dam - Final area	6,300
Cofferdam Dewatering	15,000
Dam Demolitition - Subtotal	388,600
Channel/Foundation Improvements	
Install Temporary Shoreline (Cofferdam - 1st area)	41,250
Foundation/Wall Repairs - 1st area	33,000
Install Temporary Shoreline (Cofferdam - final area)	22,500
Foundation/Wall Repairs - final area	12,000
Cofferdam Dewatering	5,000
Channel/Foundation Improvements - Subtotal	113,750
Culvert and Channel Finishing	
Clear Work Area	2,810
Fill Channel/Raceway	41,250
Culvert and Channel Finishing - Subtotal	44,060
Sediment Removal	
Hydraulic Dredging	58,000
Dewatering	315,640
Sediment Removal - Subtotal (does not include disposal cost)	373,640
Subtotal - Direct Costs	971,950
Indirect Costs (Contractor OH, Profit, Bond, Insurance)	338,000
Subtotal - Direct + Indirect Costs	1,309,950
Contingency	327,430
TOTAL	1,637,380
Estimated Sediment Disposal Cost (2,237 cy)	136,000
TOTAL with Sediment Disposal Cost	1,773,380

Hudson Dam, Construction Cost for Dam Removal	
Cost Estimate developed by CDM for Assabet Study, 2008, Cost Estimate provided for Planning purposes only.	($)
Mobilization/De-Mobilization	54,000
Landscaping - Live Staking & Rip-Rap	28,000
General Work Items - Subtotal	82,000
Dam Demolitition	
Cofferdam Equipment Mobilization - Rig and Barge	75,000
Install Cofferdam - 1st Area	128,250
Remove Dam - 1st area	23,100
Remove Sediment and Vegetation - 1st area	290
Install Cofferdam - Final Area	68,400
Remove Dam - Final area	23,100
Remove Sediment - Final area	79,650
Cofferdam Dewatering	20,000
Dam Demolitition - Subtotal	417,790
Channel/Foundation Improvements	
Repair Sluice Gate	4,000
Cofferdam to Divert Flow through Sluice Gate	199,500
Foundation/Wall Repairs - 1st area	68,000
Foundation/Wall Repairs - final area	24,000
Cofferdam Dewatering	5,000
Channel/Foundation Improvements - Subtotal	300,500
Sediment Removal	
Hydraulic Dredging	1,041,880
Dewatering	879,450
Sediment Removal - Subtotal (does not include disposal cost)	1,921,330
Bridge/Stone Arch Repair	
Repair Stone Arch Bridge	18,000
Bridge/Stone Arch Repair - Subtotal	18,000
Downstream Bridge Repairs	
Repairs and Stabilization of the walls	12,000
Downstream Bridge Repairs - Subtotal	12,000
Replace Fire Protection	
Replace Fire Protection Inlet	25,000
Replace Fire Protection - Subtotal	25,000
Subtotal - Direct Costs	2,776,620
Indirect Costs (Contractor OH, Profit, Bond, Insurance)	965,000
Subtotal - Direct + Indirect Costs	3,741,620
Contingency	935,380
TOTAL	4,677,000
Estimated Sediment Disposal Cost (71,558 cy)	4,727,000
TOTAL with Sediment Disposal Cost	9,404,000

Gleasondale Dam, Construction Cost for Dam Removal	
Cost Estimate developed by CDM for Assabet Study, 2008, Cost Estimate provided for Planning purposes only.	($)
General Work Items	
Mobilization/De-Mobilization	91,000
Site Access and Clearing	6,750
Landscaping - Seed Mix Planting	18,300
Landscaping - Live Staking & Rip-Rap	21,500
General Work Items - Subtotal	137,550
Dam Demolitition	
Cofferdam Equipment Mobilization - Rig and Barge	75,000
Install Cofferdam - 1st Area	48,750
Remove Dam - 1st area	16,800
Remove Abutment - 1st area	29,250
Remove Sediment and Vegetation - 1st area	5,900
Install Cofferdam - Final Area	78,000
Remove Dam - Final area	33,600
Remove Sediment - Final area	11,800
Stabilize Abutment and Dam	30,000
Cofferdam Dewatering	20,000
Dam Demolitition - Subtotal	349,100
Channel/Foundation Improvements	
Stabilize Bypass and Block Open Channel	12,500
Repair Abandoned Bridge Abutment	12,000
Foundation/Wall Repairs - 1st area	7,500
Remove Sediment and Vegetation	50,300
Add Stone Riprap	49,000
Channel/Foundation Improvements - Subtotal	131,300
Sediment Removal	
Hydraulic Dredging	393,050
Dewatering	556,560
Sediment Removal - Subtotal (does not include disposal cost)	949,610
Outlet Channel Removal	
Demolish Outlet Structure	25,000
Fill Bypass Channel and Outlet Channel	120,000
Concrete Fill - Chase under Building and Driveway	550,000
Outlet Channel Removal - Subtotal	695,000
Replace Fire Protection	
Precast Wet well - 8' diameter	40,000
Trash Rack - 20' x 4'	20,000
Submersible Pump - 200 gpm	40,000
Force Main - 6"	28,800
Replace Fire Protection - Subtotal	128,800
Subtotal - Direct Costs	2,391,360
Indirect Costs (Contractor OH, Profit, Bond, Insurance)	831,000
Subtotal - Direct + Indirect Costs	3,222,360
Contingency	805,590
TOTAL	4,027,950
Estimated Sediment Disposal Cost (27,860 cy)	1,855,000
TOTAL with Sediment Disposal Cost	5,882,950

Ben Smith Dam, Construction Cost for Dam Removal	
Cost Estimate developed by CDM for Assabet Study, 2008, Cost Estimate provided for Planning purposes only.	($)
General Work Items	
Mobilization/De-Mobilization	171,000
Site Access and Clearing	2,500
Site Access and Clearing - Paved Parking Area	30,000
Replace Parking Area	75,000
Landscaping - Seed Mix Planting	22,250
Landscaping - Live Staking & Rip-Rap	100,750
General Work Items - Subtotal	401,500
Dam Demolitition	
Cofferdam Equipment Mobilization - Rig and Barge	75,000
Install Cofferdam - 1st Area	27,000
Remove Dam - 1st area	5,040
Remove Sediment and Vegetation - 1st area	9,440
Install Temporary Culvert and Embankment	100,000
Install Cofferdam - Final Area	54,000
Remove Dam - Final area	11,760
Remove Sediment - Final area	20,060
Remove Cofferdam, Temporary Culvert and Embankment	13,500
Cofferdam Dewatering	20,000
Dam Demolitition - Subtotal	335,800
Channel/Foundation Improvements	
Install Temporary Shoreline (Cofferdam - 1st area)	75,000
Relocate Temporary Shoreline (Cofferdam)	37,500
Remove Sediment and Vegetation	47,200
Remove Large Blocks	12,600
Add Stone Riprap	60,000
Scour Protection	4,000
Cofferdam Dewatering	5,000
Channel/Foundation Improvements - Subtotal	241,300
Sediment Removal	
Hydraulic Dredging	1,042,410
Dewatering	857,180
Sediment Removal - Subtotal (does not include disposal cost)	1,899,590
Pump Station and Force Main	
Pump Staion - 4 mgd	400,000
Suction Line - 18"	86,400
Force Main - 12"	374,400
Pump Station and Force Main - Subtotal	860,800
Remove Gatehouse and Channel	
Regrade @ Former Dam and Upstream	25,000
Riprap	17,500
Fill Channel	800,000
Demolish Gatehouse and Sluice Gates	25,000
Remove Gatehouse and Channel - Subtotal	867,500
Subtotal - Direct Costs	4,606,490
Indirect Costs (Contractor OH, Profit, Bond, Insurance)	1,601,000
Subtotal - Direct + Indirect Costs	6,207,490
Contingency	1,551,810
TOTAL	7,759,300
Estimated Sediment Disposal Cost (67,600 cy)	5,081,000
TOTAL with Sediment Disposal Cost	12,840,300

Powdermill Dam, Construction Cost for Dam Removal	
Cost Estimate developed by CDM for Assabet Study, 2008, Cost Estimate provided for Planning purposes only.	($)
General Work Items	
Mobilization/De-Mobilization	66,000
Site Access and Clearing	5,000
Landscaping - Seed Mix Planting	10,000
Landscaping - Live Staking & Rip-Rap	90,000
General Work Items - Subtotal	171,000
Dam Demolitition	
Cofferdam Equipment Mobilization - Rig and Barge	75,000
Foundation Wall Repair - 1st Area	11,000
Install Cofferdam - 1st Area	90,000
Remove Sediment and Vegetation - 1st area	64,900
Install Cofferdam - Final Area	90,000
Demolish Spillway	136,000
Remove H-piles - 40'/each	18,000
Cofferdam Dewatering	20,000
Dam Demolitition - Subtotal	504,900
Channel/Foundation Improvements	
Install Temporary Bypass (Cofferdam)	45,000
Install Temporary Bypass Culvert - 72" CMP	67,500
Install Temporary Shoreline (Cofferdam - final area)	90,000
Remove Sediment and Vegetation	64,900
Remove Bypass Culvert	20,000
Cofferdam Dewatering	7,500
Channel/Foundation Improvements - Subtotal	294,900
Sediment Removal	
Hydraulic Dredging	979,590
Dewatering	846,610
Sediment Removal - Subtotal (does not include disposal cost)	1,826,200
Power Facility Intake	
Remove Stop Logs	7,000
Fill Intake Pipes	70,000
Power Facility Intake - Subtotal	77,000
Subtotal - Direct Costs	2,874,000
Indirect Costs (Contractor OH, Profit, Bond, Insurance)	999,000
Subtotal - Direct + Indirect Costs	3,873,000
Contingency	968,180
TOTAL	4,841,180
Estimated Sediment Disposal Cost (65,830 cy)	6,961,000
TOTAL with Sediment Disposal Cost	11,802,180

APPENDIX D

WETLANDS DESCRIPTION AND IMPACT IDENTIFICATION

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INTRODUCTION

The purpose of this Appendix is to describe the changes to wetland resource areas as a result of dam removal along the Assabet River. The intent is to inform agencies, stakeholders, and decision makers on what might be expected with dam removal. Six dams and their impoundments were studied. Information contained in this report is for planning purposes only and more detailed investigations will be needed as part of dam removal design.

The Powdermill Dam impoundment located in Acton was breached in 2004 due to outlet failure and therefore, a description of with and without dam wetland impacts is not provided for this site. However, specific observations at the site are included.

A general description of wetlands occurring along the Assabet River is provided first, followed by a discussion of the impacts to wetland resources resulting from the dam removals on the Assabet River and specific observations for each dam. Maps comparing wetland before and after dam removal are included as Attachment A. A list of plant species observed in the study area is included as Attachment B.

Wetlands and Riparian Vegetation

Hundreds of acres of vegetated wetlands occur along the Assabet River. The extent of wetlands along the river varies greatly. In areas where the river is affected by development there may be only a narrow fringe of vegetated wetland or none at all. In some impoundments, expansive mosaics of floodplain wetlands extend hundreds of feet from the river. Many of the wetlands along the Assabet River exist because of impoundments or are hydrological influenced by impoundments to varying degrees. Shoreline along most impoundments is largely undeveloped. There are typically long reaches where broad areas of emergent and scrub-shrub wetland lie between open water and upland habitat. Most impoundments also contain areas with well defined banks where open water transitions abruptly to forested wetland or upland**.**

Wetlands within the Assabet River watershed have been mapped and classified by the MA Wetlands Conservancy Program. The mapping is based on interpretation of 2001-color aerial photography. Fieldwork conducted by the Corps in 2005 indicated that these maps were accurate enough for this study, except for Powdermill Dam where the dam was partially breached in April 2004 and the wetland plant community is adjusting to new hydrologic conditions and the Ben Smith Dam where the upstream impoundment is shown as deep marsh, when it is more accurately described as open water. Other sources of information include maps of aquatic vegetation at impoundments prepared by ENSR (2001) and OAR (2006).

The Ben Smith impoundment supports the most wetland and open water aquatic habitat, followed by Gleasondale, Hudson, Powdermill, Allen Street, and Aluminum City Dams.

Open water is the dominant community type, followed by emergent, scrub-shrub, and forested wetlands. A brief description of wetland communities is provided below. A list of plant species reported at each impoundment is provided in Attachment 1 at the end of this Appendix.

Open Water: The shallow and nutrient rich Assabet River impoundments support productive communities of submerged and floating aquatic plants. Common species include filamentous green algae, floating plants (duckweed and water meal), coontail, elodea, pondweeds, and fanwort. Water chestnut is present at Ben Smith and the Clock Tower millponds. Distribution of vegetation probably depends mostly on water depth, current, and substrate. Shallow areas with slow current and soft substrate are generally most heavily vegetated with submerged aquatics. Scoured channels with hard bottom are typically sparsely vegetated. Floating plants are susceptible to currents and tend to accumulate in backwater areas, channel margins, or areas where the impoundment widens and current velocity slows. Studies by ENSR (2001) do show that plant community composition can vary considerably from year to year. There are also seasonal changes, with growth of duckweed and filamentous algae typically peaking in late summer. Under low flow conditions duckweed accumulations can be extremely heavy.

Emergent Wetland: Emergent wetlands are dominated by reed canary grass, and to a lesser extent, purple loosestrife and cattail. In the Assabet River impoundments, reed canary grass often forms semi-floating mats that are loosely attached to the bottom and float up and down with changing water levels. The mats are dense enough to be colonized by other emergent species, shrubs, and small trees. Associated species include bur-reed, pickerelweed, smartweeds, water willow, yellow flag, soft stem bulrush, smartweed, buttonbush, black willow, and red maple. Although reed canary grass dominated wetland is the most common emergent community, stands dominated by smartweeds, bur-reed cattail, and mixed emergent communities are also found.

Scrub-shrub Wetland: Common shrub and tree species in Assabet River scrub-shrub wetlands include alder, black willow, high bush blueberry, sweet gale, red maple, winterberry, northern arrow-wood, European buckthorn, and dogwoods. Herbaceous species occurring in scrub-shrub wetlands include purple loosestrife, tussock sedge, wool grass, sensitive fern, and royal fern.

Forested Wetland: Forested wetlands along impoundment shorelines are dominated by red maple. Associated species include silver maple; swamp white oak, blueberry, northern arrow-wood, and winterberry are common understory shrubs.

Forested Upland (Bank): Banks along the impoundment shorelines where open water abruptly transitions to forested upland were typically vegetated with red maples, red or white oak, and white pine. Less common tree species on the banks include hemlock, weeping willow, silver maple, tree of heaven, and common catalpa.

Methodology for Evaluating Changes to Wetlands and Riparian Habitat

The Assabet River riparian corridor is characterized by a diverse landscape; including light and heavy development as well as areas of undeveloped broad floodplain and protected open space. There are hundreds of acres of vegetated wetlands ranging from narrow fringes of vegetated wetland (or none at all) in developed areas to expansive mosaics of floodplain wetlands which extend hundreds of feet from the river. The amount (acres) and types of wetland associated with each impoundment under existing conditions are depicted on Table 1 - Estimated Change in Wetland Areas Following Dam Removal.

It is important to note that wetland acreage calculated for the existing conditions, as listed in the first column of Table 1, are wetland areas hydrologically influenced by the dams. This "area of influence" was determined using the elevation of the dam in conjunction with field observations by Army Corps of Engineers wetland specialists and includes wetland areas directly influenced by the dam and hydrologically connected contiguous wetland areas. To provide a consistent depiction of wetland changes, the same "area of influence" was used to calculate the wetland areas after dam removal.

Some wetland areas associated with the impoundments include long reaches where broad areas of emergent and scrub-shrub wetland lie between open water and upland habitat. There are also areas with well defined banks where open water transitions abruptly to forested wetland or upland**.** In order to evaluate the after dam removal conditions, predictions needed to be made as where new wetland areas will develop and where existing wetlands will transition to upland or other types of wetlands following the expected change in hydrology from an impoundment to a riverine system (over the short and long term). The development of wetlands is dependent on many physical and chemical parameters with the dominant successional force being soil

moisture. Small changes in water level and elevation can greatly alter wetland structure and species composition.

No site-specific data or biological benchmarks were available that links specific elevations to the growth of different types of wetlands (shallow marsh meadow or fen, shrub swamp and wooded swamp) in the study area. As well, the available topographic maps of the area have a nine foot contour interval; a range too broad to capture topographic features associated with the development of individual categories of wetlands. To provide a prediction of future conditions (and changes to wetland areas) due to dam removal, some broad-based assumptions were developed using general observations of the existing wetlands and topography in conjunction with the professional judgment of Army Corps of Engineers wetland specialists. It was noted that when comparing the existing wetland maps relative to the available topography (9 foot contour interval), all types of vegetated wetlands (from meadow to wooded swamp) have developed (for the most part) within the first topographic contour (9 feet or less) above open water (with the exception of those areas associated with an incoming tributary, seeps or other features). This is consistent with a general expectation (professional judgment of Corps wetland biologists), that the entire range of wetland types will develop within a narrow elevation range above the newly created river's open water.

Bathymetric Data and Water Level Data used for Wetland Predictions

United States Geologic Survey (USGS) collected impoundment water depth information for each impoundment within the study area during summer and fall of 2004. These depths were measured by prope and were not tied into a specific elevation datum. The depth measurement was used by USGS to develop one-foot depth contours of the impoundments. Although these depth contours are not static (e.g. water depth varies with flow), they can be used to provide a sense of the incremental elevation change along the river cross-section and are useful in identifying areas of wetland development after dam removal in the impoundments.

For the wetlands analysis, an estimate of the future river channel foot print in the impoundment was prepared by CDM using the HEC-RAS output for the without dam conditions and the USGS bathymetry discussed above. This would be the area of future open water. Between the summer water level and spring high water level it is assumed that this area would be a river bank area with limited wetland vegetation. [The spring high water elevation was calculated to be 0.9 feet above the summer average flow level by Army Corps of Engineers water management specialist (i.e. the river will fluctuate approximately one foot or less between the average summer low and spring high flow)].

Adjacent to the impoundments and upstream of the impoundments decreases in water levels with dam removal were calculated based on the HEC-RAS river modeling performed by CDM for the Assabet Study. Predicated decreases in water levels are several feet and magnitude varies depending on the river location.

Biological Assumptions Used for Wetlands Predictions

Broad-based biological benchmarks provide the basis for calculating the acreage of each type of wetland within the impoundments after dam removal. The wetland acreage figures are based on the future wetland conditions approximately several decades after dam removal. In general, after removal of the dam, it is expected that shallow marsh meadow will initially colonize exposed sediments due to the pioneering and rapid growth capabilities of emergent vegetation. However, over the long-term, water velocities and shade (as more woody vegetation becomes established) should limit herbaceous emergent vegetation to a narrow fringe landward of the spring high water level elevation along the river channel. Backwater areas located adjacent to the river channel are also expected to develop into shallow marsh meadow areas due to the repositioning of sediments into deep holes and protected (slower velocity) areas. Therefore, the shallow marsh meadow was calculated to be the area approximately one foot above the spring high flow elevation. Vegetation will then transition to scrub-shrub vegetation over the next 1-foot of elevation, then transition to wooded swamp over the next 1-foot of elevation prior to transitioning to upland.

Maps were prepared for each dam and wetland acreage figures were calculated for the future without dam condition. The prediction of the after dam removal condition was based on numerous physical landscape features and existing hydrological data in conjunction with the applied broad-based biological benchmarks as discussed in the previous paragraph. Predictions of wetland areas upstream and adjacent to the impoundments, were made based on estimated water level decreases, existing wetland vegetation type, predicted river channel development (thalwag), the movement and repositioning of sediment (based on the predicted channel configuration), the location of incoming tributaries. A detailed discussion of the predictions for individual impoundments and specific noteworthy wetlands is provided later in this section. Table 1 Estimated Change in Wetland Areas Following Dam Removal lists the predicted acreage for each wetland type after dam removal, the change in the amount of each wetland type when compared to existing conditions and the amount of wetland expected to transition to upland.

One of the recommendations of the Assabet River Sediment and Dam Removal Study, Modeling Report (CDM, 2008), is to remove sediment behind the dam prior to dam removal. The removal of sediments will minimize the transport of fine materials and potential contaminated sediments downstream subsequent to dam removal. A planning level sediment management plan (SMP) has been developed by CDM for the Corps which includes a discussion of site-specific conditions; depth of sediment, and the physical and chemical analysis of impounded sediments based on existing data. Varying scenarios for dredged material management are possible depending upon the findings of additional recommended testing detailed in the SMP; some of the dredged sediment may be removed from the site to an upland landfill (lowering the bottom profile of the river), some dredged sediment may be reused on site to create contours and terraces (potentially increasing the area available for the development of wetland floodplain species). It is expected that sediment transport processes will fill irregularities in the river channel (backwater areas and holes) over time.

It is recognized that sediment dredging will change the bathymetry of the impoundment and may alter areas predicted to support different types of wetland vegetation however, a detailed dredging plan is not available to consider at this time. Even with detailed dredging plans, the repositioning of sediments will be subject to geomorphological riverine processes over a long period of time and through a range of events (i.e. daily flows, spring high flows, and flooding events) which can not be predicted with accuracy. It is expected that the majority of wetland changes will be captured in this evaluation since the major hydrologic factor affecting wetland development, the change in water level after removal of the dam, is considered at this reconnaissance level of study. As well, the dredging of sediments from the bottom of the impoundment (located within the boundaries of the newly created river channel area) will not effect wetland development predictions because wetland vegetation is expected to develop from the spring high water level and above (not within the river channel). Reconfiguration of the river banks above the spring high water level, to create terraces for example, will change contours (and affect the development of wetlands after dam removal) but detailed information about re-contouring the river banks is not available at this time. A more detailed evaluation of wetland impacts can be accomplished during the next stage of study once a more detailed design and sediment/ bank contour plan is developed for each impoundment.

Previously, open water was the dominant community type, followed by emergent, scrub-shrub, and forested wetlands. Under the after dam removal condition, it is predicted that scrub-shrub and forested vegetation will dominate, followed by open water and emergent vegetation. These communities will not be monotypic but, mixed, overlapping and transitional. Emergent communities are likely to have a percentage of scrub-shrub inclusions; scrub-shrub communities

are likely to have an herbaceous ground cover or trees in the overstory depending of the successional stage of growth, and forested wetlands are likely to have a scrub-shrub understory. A brief description of each wetland community type after dam removal is provided below.

Open Water: Currently, the shallow and nutrient rich Assabet River impoundments support productive communities of submerged and floating aquatic plants. These shallow areas with slow currents and soft substrates are dominated by filamentous green algae, floating plants, coontail, elodea, pondweeds, and fanwort. Following the removal of the dam, the impounded open water will be replaced by a smaller amount of open water associated with the river channel. Although it is likely that some sediment will be dredged at each dam to minimize downstream impacts, there will also be a transport of sediment downstream for a period of time through natural geomorphological processes. The river channel will undergo scouring and deposition until a stable and functional channel profile is reached. Riverine open water habitat will eventually be characterized by a complex of riffles and pools along the reach, the distribution of which is dependent on the gradient (more riffles with a steeper gradient) and length of restored river channel. The riffles will have a substrate of cobbles while the pools, with more quiescent waters, will have a substrate of medium sized cobble, gravel and sand.

Emergent Wetland: Semi-floating mats of reed canary grass are a dominant and unique feature of the Assabet River emergent wetland community. It is expected that initially after removal of the dam; these mats will settle down onto the exposed substrate and continue to grow. However, these mats will gradually become less dominant as more woody vegetation becomes established and increased water velocity in the river prevents the mats from expanding or forming in the river channel. Herbaceous vegetation will rapidly colonize exposed areas as seed and root stock will be readily available.

However, as was mentioned previously, it is expected over the long term that herbaceous emergent vegetation will be replaced by more woody vegetation over time, eventually limiting emergent vegetation to a narrow fringe along more quiescent waters (pools) in the river in the 1-foot elevation range above the spring high water. Purple loosestrife, bur-reed, pickerelweed, smartweeds, water willow, soft stem bulrush, and cattail currently grow on site and will likely be found in future emergent plant communities.

Table 1. Estimated Change in Wetland Areas Following Dam Removal

Impoundment	Description	Acres Wetlands - Existing Conditions	After Dam Removal	Change in Wetland Area
Aluminum City	OPEN WATER	0.3	0.2	-0.1
	SHALLOW MARSH MEADOW OR FEN	0	0.0	0.0
	SHRUB SWAMP	0	0.0	0.0
	WOODED SWAMP DECIDUOUS	0	0.1	0.1
Allen Street	OPEN WATER	6.9	2.4	-4.5
	SHALLOW MARSH MEADOW OR FEN	2.0	1.7	-0.3
	SHRUB SWAMP	0	1.7	1.7
	TRANSITION TO UPLAND	0	0.2	-0.2
	WOODED SWAMP DECIDUOUS	0	2.9	2.9
Hudson	OPEN WATER	27.0	16.8	-10.2
	SHALLOW MARSH MEADOW OR FEN	6.9	7.6	0.7
	SHRUB SWAMP	7.4	7.3	-0.1
	TRANSITION TO UPLAND	0	6.4	-6.4
	WOODED SWAMP DECIDUOUS	4.7	7.9	3.2
Gleasondale	DEEP MARSH	3.3	0	-3.3
	OPEN WATER	14.5	10.8	-3.7
	SHALLOW MARSH MEADOW OR FEN	35.7	14.8	-20.9
	SHRUB SWAMP	18.1	13.4	-4.8
	TRANSITION TO UPLAND	0	60.1	-60.1
	WOODED SWAMP CONIFEROUS	10.4	0	-10.4
	WOODED SWAMP DECIDUOUS	56.0	39.0	-17.0
	WOODED SWAMP MIXED TREES	2.6	2.6	0.0
Ben Smith	DEEP MARSH *	126.6 (26.6)	12.8	-113.8 (-13.8)
	OPEN WATER *	20.8 (120.8)	70.2	49.4 (-50.6)
	SHALLOW MARSH MEADOW OR FEN	87.3	75.6	-11.7
	SHRUB SWAMP	76.5	81.3	4.8
	TRANSITION TO UPLAND	0	43.5	-43.5
	WOODED SWAMP DECIDUOUS	107.2	134.9	27.7
	WOODED SWAMP MIXED TREES	19.2	19.2	0.0

* MADEP classified a significant portion of the Ben Smith Impoundment area as Deep Marsh ~100 acres. However if this classification were changed to open water then the change in wetlands would be as shown in parentheses in the above Table.

Scrub-shrub Wetland: It is expected that scrub-shrub wetlands will develop within a 1-foot elevation range above the emergent wetland area. As scrub-shrub wetlands become established, emergent wetland areas will become less common over the long term. Species currently found in the study area, such as alder, black willow, high bush blueberry, sweet gale, winterberry, northern arrow-wood, European buckthorn, and dogwoods would likely be found in future scrub-shrub wetlands due to the availability of seed and root stock. Herbaceous species, such as tussock sedge, wool grass, sensitive fern, and royal fern may persist as ground cover as long as light and supporting hydrology are available.

Forested Wetland: Over the long term, it is expected that forested wetlands will develop within the 1-foot elevation range above the upper limit of the scrub-shrub area. Red maple will most likely remain the dominant species however, silver maple and swamp white oak may also be present with blueberry, northern arrow-wood, and winterberry as associated understory shrubs.

The existing forested wetlands will experience a major change in hydrology when the impoundment is drained. This may result in some degree of mortality initially however, red maple is categorized as a "facultative" species in the U.S. Fish and Wildlife Service National List of Plant Species That Occur In Wetlands (USFWS 1988). A "facultative" species is equally likely to occur in wetland as in nonwetlands and therefore, red maple may survive under the new dryer hydrological regime. In the case of a facultative-dominated forested wetland area (such as a red maple swamp), species composition may stay relatively the same with some infusion of more upland species over the long term. However, these areas would no longer be considered forested wetlands due to lack of hydrology (and hydric soils).

Invasive Species

Invasive species are non-native plants that threaten native habitats by spreading so prolifically that they crowd out native species in sensitive forest, wetland and aquatic habitats. Common invasive emergent plants within the Assabet River study area include reed canary grass, which often forms semi-floating mats that are loosely anchored to the bottom and float up and down with changing water levels. Purple loosestrife, a ubiquitous invader, is also found in emergent wetlands and scrub-shrub wetlands along the Assabet River. Purple loosestrife would likely rapidly colonize exposed areas with saturated soils following a draw down for dam removal. Oriental knotweed could colonize exposed areas at higher elevations. Norway maple, Tree of heaven, Japanese barberry, European buckthorn, Japanese honeysuckle, and multiflora rose are also found in tree and shrub communities. Phragmites and yellow iris do not seem to be widespread in Assabet River wetlands. However, non-native invasive species are opportunistic

invaders in disturbed habitats, have prolific reproductive capabilities and the ability to out-complete native vegetation. Therefore, it is prudent to develop a vegetation management plan in conjunction with dam removal to avoid the spread of these species to newly exposed areas. A post dam removal monitoring and control program could prevent initial invasion and long-term establishment of these noxious species.

Invasive aquatic plants occurring in the study area include water chestnut, fanwort, and curly pondweed. Generally, these species are associated with the lacustrine environment (sluggish flows and soft substrate) and will not survive in a riverine system due to increase water velocities and inadequate substrates.

Mitigation for Loss of Wetlands

There is a history of dam building in the eastern United States to provide water-based power for various industrial purposes, most commonly mills, as well as flood control and hydroelectric power. The Assabet River has nine dams on the river, starting in Westborough at the George H. Nichols Dam constructed by the National Resource Conservation Service (NRCS) (formerly the Soil Conservation Service) in 1968 for flood prevention and fish and wildlife habitat. Downstream from this are seven old mill dams and one additional flood control dam the Tyler Dam, a "dry bed" flood control facility constructed in1965 by NRCS. Increasingly, dam removal is being considered a viable alternative to costly repairs or rehabilitation to deal with the problem of aging or unsafe dams or to address environmental degradation.

The benefits to stream or river restoration are widely recognize by the environmental community. Water movement through impounded areas is slow, allowing the retention of sediments, chemical and nutrient contamination which can lead to degraded water quality, eutrophication and warming. As well, fish passage and movement of other aquatic species up and down the river are restricted. Many opportunities exist in the Assabet River study area for aquatic ecosystem restoration and improvement through the removal of obsolete dams. These benefits include improved water quality, fisheries and wildlife habitat and the restoration of a self-maintained and sustainable riverine system.

The Massachusetts Department of Environmental Protection recently published guidance designed to encourage environmental improvements through dam removal projects (MA DEP 2007). Under the Wetland Protection Act (310 CMR 10.53(4)), dam removal may be considered a limited project and as such, the assignment of traditional mitigation requirements is discretional for the local conservation commission (the responsible permitting board). The benefits of dam removal, such as long term water quality and wildlife habitat benefits may be recognized as

mitigation as long as the net benefits of dam removal are clearly demonstrated. These inherent benefits are likely to outweigh the short term impacts to water quality (turbidity) and loss of wetland resources. The U. S. Army Corps of Engineers, the agency responsible for the administration of Section 404 of the Clean Water Act, also has some flexibility in accounting for the benefits of river restoration project and applying mitigation requirements. The evaluation of a "proactive project", as referred to in the Massachusetts General Programmatic Permit (GPP), requires consultation with the Corps, State and Federal agencies "to determine that net adverse effects are not more than minimal."

Dam Removal Considerations for All Project Areas (Natural Resources)

Newly exposed riparian areas and transitional upland areas should be protected to preserve the open space, wildlife, water quality and flood storage benefits of the land. Development of transitional upland areas would be considered cumulative impacts under The Council on Environmental Quality (CEQ) which defines cumulative impact as found in 40 Code of Federal Regulation (CFR) section 1508.7 as "the impact on the environment which results from the incremental impact of the action when added to other past, present and reasonably foreseeable future actions regardless of what agency (Federal or nonfederal) or persons undertakes such other acts." Real estate ownership should be clearly addressed prior to dam removal and a protection plan for transitional upland areas should be implemented prior to dam removal to avoid the potential cumulative impacts associated with urban/suburban development.

Increased water velocities within the river channel after removal of the dam will likely limit invasive species infestations, such as reed canary grass, fanwort, water chestnut, yellow flag, etc. by preventing rooting or by flushing unanchored vegetation downstream. However, the presence of purple loosestrife in many areas is of particular concern because of its ability for prolific growth and rapid reproductive capabilities in exposed wet soils and shallow aquatic sites. Following dam removal, newly exposed banks will be highly susceptible to purple loosestrife infestation. The focus of management after dam removal should be to prevent the further spread of purple loosestrife by encouraging the growth of a healthy zone of native vegetation. A vegetation seeding plan should be implemented to provide an initially quick vegetative cover for exposed soils to prevent purple loosestrife seeds from making contact with exposed soils and the maintenance of a dense and durable vegetative cover over the long-term. This may require multiple seeding with different seed mixes depending on the time of year seeding is conducted.

ALUMINUM CITY DAM

Existing Wetland and Riparian Habitat and Vegetation

The Aluminum City impoundment is approximately 300 feet long and 30 feet wide. About 70 percent of the impoundment shoreline is forested. The remainder is bordered by developed areas (retaining wall, parking lot, or lawn). Habitat maintained by the impoundment is primarily open water, vegetated with scattered submerged aquatic plants (wild celery and a narrow leaved pondweed). There is a small area of emergent and scrub-shrub vegetation on the north side of the impoundment near the dam. Reed canary grass, impatiens, Virginia creeper, and dogwood are the dominant species. Red maple, box elder, and American elm are the dominant tree species. There are several large, apparently healthy, elms growing just downstream of the dam. Some duckweed was observed growing along the margin of the impoundment. Flow through the impoundment and a short retention time likely preclude development of dense growth of duckweed, except under very low flow conditions.

Upstream of the impoundment to the railroad bridge crossing (ca. 1500 feet), the river passes through an extensive forested wetland. River flow through this reach is sluggish, with little riffle habitat. The riparian zone is largely forested with little development except for a sewer line right-of-way within 500 feet of the river.

Downstream of the dam (between route 20 and Hudson Road) the riparian corridor is moderately developed, with a narrow (<100 feet wide forested riparian zone) along most of the reach.

General Description of Impacts

Currently, the Aluminum City Dam impoundment is approximately 300 feet long by 30 feet wide with a surface area of about 0.3 acres. In general, the environmental effects of the removal of the dam will be surface water level reductions in the impoundment and along the Assabet River to an upstream riffle complex (where a sewer-line crosses the river). As stated in the introduction, decreases in water levels due to dam removal were calculated based on the HEC-RAS river modeling performed by CDM for the Assabet Study. There were only two cross-sections in the Aluminum City Dam impoundment which limits the information available to predict the effects of dam removal and distance of hydrological influence upstream by the dam. However, based on this limited data, it appears that surface water levels will decrease approximately 8 feet at the dam and 5 feet approximately 100 feet upstream of the dam. This is indicative of a steep gradient within the impoundment reach.

To determine the surface water level after dam removal, the HEC-RAS river modeling was evaluated in conjunction with the United States Geologic Survey (USGS) water depth information (bathymetric contours). Although the water level decrease at the dam and in the impoundment is sizeable, the overall appearance of open water and change in wetlands is predicted to be minimal. The amount of open water is similar in the before and post-dam condition (0.3 acres before and 0.2 acres after dam removal) due to steep bathymetric contours and a possible constriction or natural fall at the dam site, although the open water area will be more representative of a riverine pool after dam removal. Some fringing wetlands are expected to develop on the exposed river banks.

Figure 1 in Attachment A displays a map of wetlands areas predicted to develop, change or transition following dam removal. The amount of each wetland category is provided on Table 1 to provide a comparison of the existing condition versus after dam removal condition for each wetland category and a new category was added to accommodate the amount of wetland area expected to transition to upland.

Riparian Habitat and Vegetation After Dam Removal

It appears that the Assabet River will encompass more of a pool and riffle complex after the Aluminum City Dam is removed as the impoundment area will be replaced by open water more characteristic of a riverine pool. Upstream of the dam, a sluggish section of the river flows into a short section of riffle (where a sewer pipeline crosses the river), which will then flow into a riverine pool at the location of the previous impoundment which will then flows to the steep-sided rock strewn channel downstream of the former dam. Currently, there are few wetlands associated with the Aluminum City Dam impoundment; about 70 percent of the Aluminum City Dam impoundment riparian zone is upland forested and the remainder is bordered by developed areas (retaining wall, parking lot, or lawn). After dam removal, some development of fringing emergent, shrub and forested wetlands is expected on exposed banks which may be composed of impatiens, Virginia creeper, dogwood, red maple, box elder, and American elm due to the availability of seed and root stock. Open water habitat will be riverine (versus the slower flows associated with impounded water) and therefore, submerged aquatic plants (reed canary grass, wild celery, narrow leaved pondweed) will probably be limited by the higher velocity flows. Duckweed, observed growing along the margin of the impoundment, will be flushed downstream.

Invasive Species

Increased water velocities within the river channel after removal of the dam will likely limit the growth of yellow flag (noted growing along the impoundment shoreline) however, an invasive species management plan should be implemented in the project area to control the growth and spread of purple loosestrife.

ALLEN STREET DAM

Existing Wetland and Riparian Habitat and Vegetation

The Allen Street impoundment is approximately 3000 feet long, with a maximum width of about 300 feet. About one-half of the impoundment shoreline is forested and undeveloped. A narrow riparian buffer along Hudson Street borders the remainder. The most extensive wetland areas are just upstream of the Wachusett Aqueduct. Wetlands are restricted by the steep upland habitat, highway access and urban development.

Habitat maintained by the impoundment is primarily open water or emergent wetland. In August of 2005, emergent wetlands were dominated by reed canary grass, and to a lesser extent cattail, impatiens, and purple loosestrife. Other species noted included *Sparganium*, smartweed, pickerelweed, and bulrush. Scattered shrubs, mostly buttonbush, occur in the emergent wetland. Most of the emergent wetland appears to be semi floating, rising and falling with river flows. Backwater areas were heavily vegetated with duckweed (100 % cover in some locations). Open water areas were generally shallow (2 – 6 ft.) and soft bottomed, with scattered beds of Elodea and pondweeds. ENSR (2001) reported moderately productive growth of filamentous green algae.

Upstream of the impoundment to River Street Bridge, the river passes through a largely undeveloped riparian corridor. The riverbank is mostly forested, with some areas of scrub-shrub or emergent-scrub-shrub habitat fringing the river. River flow through this reach is sluggish (run or pool), with no riffle habitat. Depth ranges from 2-4 feet, with some deeper (6 – 8 ft.) pools. Beds of narrow leaf pondweed were present in some areas. The reach is generally hard bottomed sand and gravel, with cover provided by scattered boulders and large woody debris (snags). The riparian zone is largely forested with little development within 100 ft. feet of the river. Steep banks seem to have limited encroachment along the south side of the river.

Immediately downstream of the dam the riparian corridor is largely developed, with only a narrow (< 50 ft wide) vegetated riparian zone along most of the reach. An old mill building converted to apartments spans the river about 200 feet downstream of the Allen Street Bridge. Much of this reach is riffle. Approximately 1000 ft. downstream of the dam, the river enters a broad emergent and scrub-shrub wetland and flows approximately one mile to Boundary Street. A tributary brook joins the Assabet within this reach. Downstream of Boundary Street the Assabet River receives discharge from the Marlboro WWTP and flows for approximately ¾ mile through a largely undeveloped riparian corridor before it passes under Route 290 and by the Solomon Pond Mall.

General Description of Impacts

Currently, the Allen Street Dam impoundment is approximately 3000 feet long, has a maximum width of 300 feet and a surface area of about 7 acres. In general, the environmental effects of the removal of the Allen Street Dam will be surface water level reductions in the impoundment and along the Assabet River to River Street in Northborough. This will create a narrower riverine channel with a maximum width of approximately 55 feet and provide substrate for the impoundment open water to transition to a mixture of wetland community types. It is expected that a small portion of wetlands located at higher elevations will transition to upland. The change in surface water lessens along the impoundment (and river channel) further upstream; a range of approximately 3 feet at the dam to less that 1 foot above River Street in Northborough. (Based on field observation, it was thought that the dam influence was to River Street however, the area of influence may go to East Main Street. During detailed studies these areas will also need to be considered.)

Figure 1 in Attachment A displays a map of wetlands areas predicted to develop, change or transition following dam removal. The amount of each wetland category is provided on Table 1 to provide a comparison of the existing condition versus after dam removal condition for each wetland category and a new category was added to accommodate the amount of wetland area expected to transition to upland.

Riparian Habitat and Vegetation After Dam Removal

Following removal of the Allen Street dam, the width of the impoundment will decrease to approximately 30 to 55 feet with a diversity of wetland habitats developing east and west of the river (previously open water). It is expected that the existing 6.9 acres of open water will be reduced to 2.4 acres (for a difference of 4.5 acres) and shallow marsh will be reduced from 2.0

acres to 1.7 acres (for a difference of 0.3 acres). Open water and shallow marsh areas are expected to be replaced by shrub swamp (1.7 acres), wooded swamp (2.9 acres) with some transition to uplands (0.2 acres). Immediately upstream of the dam, on the east side of the river, a backwater area composed of shallow emergent vegetation is predicted to develop based on the USGS impoundment bathymetry. This area may have a small pool of open water (which may function as a vernal pool) surrounded by fringing emergent vegetation, shrubs and trees. Further upstream, another backwater area is expected to develop along the west side of the river composed of a mixture of shallow emergent vegetation, fringing shrubs and trees.

Floating beds of reed canary grass found in the existing open and shallow wetland areas are expected to float down with the water level decrease, settle and continue to grow on exposed substrates until shrubs or trees become established. Reed canary grass may also expand to newly created backwater areas but will be more susceptible in the river channel to detachment and being flushed downstream during high flows. Ribbon-leaf pondweed, duckweed, cattail, impatiens, purple loosestrife, Sparganium, smartweed, pickerelweed, and bulrush will likely populate newly created emergent wetlands due to the availability of seed and rootstock in the area with buttonbush as a volunteer shrub species. Rooted aquatic vegetation, such as Elodea, pondweeds and filamentous green algae will likely be limited due to the increase flow velocity (riverine characteristics) in open water areas.

The existing emergent vegetation in the impoundment area is expected to transition to forested wetlands over time with a small portion transitioning to upland along Hudson Street. Red maple is found in this area and as a facultative species (adapted to wetlands and upland equally) may transition to upland without notable visible mortality.

A small amount of wetlands in the upper elevation area on the west side of the impoundment is also expected to transition to upland. The river channel and backwater areas, with the diversity of wetland vegetation composition and structure, will likely provide excellent wildlife habitat value and an aesthetically pleasing viewshed.

Much of the upstream reach of the impoundment to River Street, which passes through a largely undeveloped riparian corridor, will maintain its riverine characteristics except for a narrowing of the river channel and potential development of some fringing emergent, shrub and trees on exposed sediments (at a lower elevation). River flows may increase slightly through this reach with some riffle habitat development (currently, it is primarily run or pool habitat).

No vernal pools or potential vernal pools, as mapped by the MA DFW (February 2008), are located within the area of influence of the Allen Street Dam. As stated previously, one small open water area may develop in a backwater area to the east of the river after dam removal which may function as a vernal pool. As valuable and protected resources in Massachusetts, this potential vernal pool area should be evaluated after dam removal to determine its capability for providing breeding habitat to amphibian and reptile vernal pool species.

Invasive Species

Purple loosestrife and yellow flag, noted growing along the impoundment shoreline, may still be problematic in the backwater areas expected to develop east and west of the river channel. Increased water velocities within the river channel after removal of the dam will likely limit the growth of unanchored vegetation however, an invasive species management plan should be implemented in the project area to control the growth and spread of purple loosestrife.

HUDSON DAM

Existing Wetland and Riparian Habitat and Vegetation

The lower 1200 feet of the Hudson Dam impoundment ranges in width from about 300 to 600 feet. The shoreline along this reach is moderately developed, with several businesses and about 15 homes having physical access or a view of the impoundment. Further upstream the impoundment ranges in width from about 30 to 100 feet and has riverine characteristics, which make the influence of the dam difficult to discern. Development along the upper reaches of the impoundment is sparse, with the undeveloped riparian corridor typically at least 600 ft. wide. The riparian corridor between the dam and Chapin Road includes town parkland, O'Donnell field (recreation area), and Hudson High School.

Wetland habitat maintained by the impoundment is primarily open water, emergent wetland, and scrub-shrub. In 2000, open water areas near the dam were heavily vegetated with coontail and elodea (ENSR, 2001). In September of 2005, elodea, milfoil, coontail, and filamentous green algae, including a Rhizoclonium were abundant. In riverine sections, open water was largely free of vegetation, except for scattered beds of narrow leaved Potamogeton. Backwater areas of were heavily vegetated with duckweed (100 % cover in some locations), but open water areas exposed to current were largely free of floating aquatic plants.

Emergent wetlands are strongly dominated by reed canary grass, and to a lesser extent, purple loosestrife. Associated species include cattail, Sparganium, impatiens, rice cut grass, pickerelweed, Sagitaria, soft stem bulrush, and yellow flag. Shrubs occurring in emergent wetland include buttonbush and black willow. As at the Allen Street dam, most of the emergent wetland appears to be semi floating, rising and falling with river elevation.

Species present in the scrub-shrub and scrub-shrub/forested wetlands include red maple, alder, elm, dogwoods, northern arrow-wood, sweet pepperbush, wild grape, grey birch, and white oak.

Immediately downstream of the dam the riparian corridor is heavily developed, with only a narrow vegetated riparian zone along most of the reach from Route 85 to Maning Street. Downstream of Broad Street to the Stow-Hudson town-line the riparian corridor is moderately developed.

General Description of Impacts

The Hudson Dam has an open water surface area of 22 acres and an impoundment length of about 4,000 ft.. The base of the dam is constructed on bedrock at the site of natural waterfalls. Based on field observations the main influence of the dam appears to extend about 1.3 miles upstream. (Note: wetland impacts likely extend beyond Chapin Road to approximately Rt. 290, another 2.6 miles (linear) or 3.4 river miles. During detailed studies, these additional wetland areas will also need to be considered)**.** Water level reductions will range from approximately 7.0 feet at the dam to approximately 2.6 feet Chaplin Road. It is expected that fringe wetlands in the area of the impoundment will transition to a narrow area of shallow marsh, shrubs and trees and the extensive wetlands at the inflow from Tripp Pond (Hog Brook) from the west will change in composition with some transition to upland. Further upstream, the river is bounded by emergent wetlands that are expected to change in composition with some transition to upland along the periphery.

Figure 2 in Attachment A displays a map of wetland areas predicted to develop, change or transition following dam removal. The amount of each wetland category is provided in Table 1 to provide a comparison of the existing condition versus after dam removal condition for each wetland category and a new category was added to accommodate the amount of wetland area expected to transition to upland.

Riparian Habitat and Vegetation after Dam Removal

Currently, the lower 1200 feet of the impoundment ranges in width from about 300 to 600 feet which will narrow to a range of about 100 to 250 feet following dam removal. It is expected that open water in the impoundment will change from the current 27 acres to 16.8 acres after dam removal (for a change of 10.2 acres). Since the dam is located at a natural waterfall, the pool remaining after dam removal will still maintain depths of about 5 to 6 feet and the impoundment will remain open water, however some changes to the viewshed will be observed by the businesses and homes along this shoreline. Aside from the narrowing of the impoundment, the large area of emergent and submergent vegetation associated with the inflow from Tripp Pond (Hog Brook) is expected to transition to emergent vegetation (with one small area of open water which has characteristics of a potential vernal pool), shrubs, and trees with some area transitioning to upland. The loss of open water is expected to be replaced by additional shallow marsh (an increase of 0.7 acres), an increase in wooded swamp by 3.2 acres and the transition of 6.4 acres of wetland to upland.

The narrowed impoundment will probably continue to be vegetated, although to a lesser degree, with coontail, elodea, milfoil, and filamentous green algae although some of this biomass may periodically be flushed downstream during high water events (higher velocity flows). In riverine sections, open water will remain largely free of vegetation, except for scattered beds of narrow leaved Potamogeton and duckweed in backwater areas.

There are large areas of emergent wetlands located northeast of Chapin Road on either side of the river. These areas are strongly dominated by semi-floating mats of reed canary grass, and to a lesser extent, purple loosestrife. The river is estimated to be approximately 2.5 to 3 feet lower in this area and the mats of reed canary grass are expected to float down with the water level, settle and continue to grow in quiescent backwater areas and along the shore (until higher velocity river waters scour the channel of unanchored plant materials). Seed and root stock availability from plants that currently grow in the area will promote revegetation of the riverbanks by emergent and shrub species such as impatiens, rice cut grass, soft stem bulrush, buttonbush and black willow. A large portion of these emergent wetlands will transition to shrub and forested wetlands composed of species found in the area such as red maple, alder, elm, dogwoods, northern arrow-wood, sweet pepperbush, wild grape, grey birch, and white oak with some wetland area transitioning to upland along the periphery. It is expected that the wetlands associated with an unnamed tributary on the south side of the river will remain the same as hydrological support is assumed to be derived from the tributary.

One potential vernal pool has been identified by the MA DFW (February 2008) in the project area (from the dam to Chapin Road) that may be hydrologically influenced by the Hudson Dam. This pool is located northeast of Chapin Road in an area currently delineated as emergent wetlands. Since river water levels are estimated to drop approximately 2.5 feet in this area, the vegetated wetlands in this area are expected to transition to a forested wetland community with some upland areas along the periphery. Therefore, water levels necessary for the completion of the amphibian aquatic development may not be adequate after dam removal to support vernal pool functioning in this pool. On-sight inspection is needed to fully evaluate the impact of the removal of Hudson Dam on this potential vernal pool. (In addition there are three other vernal pools between Chapin Road and Rt. 290 which will need to be considered in future detailed studies if dam removal is pursued.)

Modifications (deepening of the pool) may be considered to avoid impacts to existing resource areas. As stated previously, an area that will be isolated from the river (but may maintain a groundwater connection) after dam removal which is associated with the inflow from Tripp Pond (Hog Brook) may function as a vernal pool after dam removal and should be evaluated after dam removal to determine its function.

Invasive Species

After dam removal, the impoundment maintains a width of approximately 250 feet which may allow infestations of reed canary grass currently found in the Hudson Dam impoundment to continue to grow due to more quiescent waters in the pool. Upstream of the pool, increased water velocities within the river channel will likely reduce the infestations by flushing unanchored vegetation downstream however, an invasive species management plan should be implemented in the project area to control the growth and spread of purple loosestrife.

GLEASONDALE DAM

Existing Wetland and Riparian Habitat and Vegetation

The Gleasondale impoundment has a length of about 3200 feet and a surface area of 13.6 acres. ENSR (2001, Figure 3-2) indicates the influence to the impoundment extends about 3 miles upstream of the dam. The impoundment (as delineated by the USGS) is generally linear, with open water ranging in width from about 75 to 150 feet. Most of the shoreline is fringed with emergent wetland. Just upstream of the dam the impoundment is constrained between Orchard Hill to the south and Lambert Hill to the north. The river broadens about 0.4 miles upstream of

the dam and receives an unnamed tributary stream from the north. A second unnamed tributary joins the Assabet River from the north about 0.8 miles upstream of the dam. The impoundment is bordered to the south by pasture and to the north by an extensive forested and scrub-shrub wetland and the Stow Acres Country Club. Upstream of the USGS delineated impoundment, the river narrows. No riffle is present and any hydrological influence of the dam is difficult to discern. Development along the river is sparse until the Hudson WWTF, upstream of the dam.

Wetland habitat maintained by the impoundment is primarily open water, emergent wetland, and scrub-shrub. In the summer of 1999 and 2000, open water areas within the impoundment were heavily vegetated with coontail, elodea and floating plants (Lemma and Wolfia). (ENSR, 2001). In November of 2005, the open water areas were largely free of vegetation, except for scattered senescent beds of elodea and coontail. Open water areas were largely free of duckweed or other floating aquatic plants.

Emergent wetlands are strongly dominated by reed canary grass, and to a lesser extent, purple loosestrife and cattail. Associated emergent species include bur-reed, pickerelweed, yellow flag, and false nettle. Shrubs and small trees that occur in emergent wetland include buttonbush, black willow, and red maple. As at other Assabet River impoundments, most of the emergent wetland appears to be semi floating, rising and falling with river flows. A local resident reported grassy islands floating downstream during high flows in the fall of 2005.

Open water areas of the northern embayment contained scattered patches of coontail, elodea, and sporangium, and a few shoots of wild rice. The sediments were extremely soft and were producing gas bubbles. Sedge hummocks adjacent to the open water were vegetated with tussock sedge, purple loosestrife, sweet gale, and other species. Scrub-shrub wetland adjacent to the embayment was vegetated with sweet gale, swamp rose, red maple, alder, winterberry, blueberry, and herbaceous species. Forested wetlands near the impoundment were dominated by red maple.

There are several potential vernal pools mapped by the MA DFW that may be hydrologically influenced by the Gleasondale Dam.

Downstream of the dam, the river flows for 600 hundred feet past the Gleasondale Mill complex to Glendale Road (Route 62). The reach between the Dam and Route 62 is riffle. Downstream of Glendale Road, river velocity slows and it meanders through a broad, largely undeveloped, floodplain until it reaches Sudbury Road, the upper reaches of the Ben Smith impoundment.

Flow from Lake Boon enters the Assabet about 2 miles downstream of the Gleasondale Dam, and 0.5 miles upstream of Sudbury Road.

General Description of Impacts

The Gleasondale Dam currently has an open water/deep marsh area of 17.8 acres and generally ranges in width from about 75 to 100 feet. In general, the environmental effects of the removal of the Geasondale Dam will be surface water level reduction in the impoundment and along the Assabet River to approximately Cox Street. Water level reductions will range from approximately 4.8 feet at the dam to 0.8 feet at Cox Street. The 6 feet square stone lined open box culvert on the west bank about 50 feet upstream from the dam will no longer function as a sluiceway/canal after dam removal (river surface water level will be below the box culvert invert). It is expected that fringe wetlands in the area of the impoundment will transition to a narrow area of shallow marsh, shrubs and trees. Further upstream, the river is bounded by extensive shrub and forested wetlands; a large portion of which will transition to upland due to the change in hydrology after dam removal. Fewer changes will occur to wetlands further upstream towards Cox Road as the range of water level change is reduced to about 1 to 2 feet and existing wetlands are limited to a narrow area adjacent to the river. Figure 3 in Attachment A displays a map of wetland areas predicted to develop, change or transition following dam removal. The amount of each wetland category is provided on Table 1 to provide a comparison of the existing condition versus after dam removal condition for each wetland category and a new category was added to accommodate the amount of wetland area expected to transition to upland.

Riparian Habitat and Vegetation After Dam Removal

Following the removal of the Geasondale Dam, surface water levels in the impoundment will be lowered approximately 4 to 5 feet. As a result, the width of the impoundment will be reduced to a range of about 40 to 90 feet and the reduction of 7.0 acres of open water/deep marsh. The existing fringing emergent wetlands should transition to a narrow, linear area vegetated with emergent vegetation, shrubs and trees due to the steep impoundment bathymetry (based on the 1-foot bathymetric contours) (See Figure 3.) It is expected that shallow marsh, shrub swamp, wooded coniferous swamp, and wooded deciduous swamp will all have reductions in acreages after dam removal (20.9 acres, 4.8 acres, 10.4 acres and 17.0 acres, respectively) with 60.1 acres of wetlands transitioning to upland. The aquatic vegetation, such as coontail, elodea and floating plants observed in the impoundment will be flushed downstream with increased water velocity in the river.

About 0.4 miles upstream of the dam, the river broadens and an unnamed tributary stream joins the Assabet River from the north and a second unnamed tributary joins the river from the north about 0.8 miles upstream of the dam. In this location, the river is bordered to the south by pasture and to the north by an extensive forested and scrub-shrub wetland. The river surface water levels will be reduced by approximately 3 to 4 feet in this area which is expected to result in the transition of large areas of deciduous and coniferous wooded swamp to upland. Some tree species found in these wetlands, such as red maple, are facultative species (adapted to wetland and uplands equally) and so may adapt to this hydrological change. However, some visible mortality would be expected in this area considering the large amount of area affected. It appears that the unnamed streams in this area will provide some degree of supporting hydrology to the adjacent wetland communities and therefore, the unnamed tributary riparian areas will not be altered as much (with less change the further distance upstream and away from the hydrological influence of the river).

The emergent wetlands in this area are strongly dominated by semi-floating mats of reed canary grass which are expected to float down with the water level, settle and continue to grow in quiescent backwater areas and along the shore (until higher velocity river waters scour the channel of unanchored plant materials). Seed and root stock availability from plants that currently grow in the area will promote revegetation by volunteer emergent and shrub species such a tussock sedge, purple loosestrife, bur-reed, pickerelweed, yellow flag, false nettle, buttonbush, swamp rose, alder, winterberry, blueberry, sweet gale, black willow, and red maple. It does not appear that there will be open water areas remaining in the northern embayment due to the level of surface water reduction in this area.

Water level changes resulting from dam removal become less with more distance further upstream toward Cox Road. Surface water levels are predicted to be reduced by 1 to 3 feet in this area resulting in the narrowing of the river to some degree. Existing emergent wetlands adjacent to the river will probably transition to shrubs, trees and upland and new areas of fringe emergent will develop adjacent to the river.

There are a total of 7 potential vernal pools mapped by the MA DFW (February 2008) that may be hydrologically influenced by the Gleasondale Dam; one of which is located within the impoundment area and the remaining 6 are located within the extensive wetland area located about a half mile upstream from the dam. The potential vernal pool located closest to the dam is in a backwater along the south side of the impoundment. Although water level changes are most extreme in this area, it appears that this area will still receive water to support vernal pool

functions based on aerial photo interpretation. Five (5) out of the remaining 6 potential vernal pools are currently located in shrub or tree communities which are expected to transition to upland and therefore, water levels necessary for the completion of the amphibian aquatic development may not be adequate after dam removal in these pools. The remaining potential vernal pool is currently located in an area delineated as an emergent wetland and it appears based on aerial photo interpretation that this area may still receive adequate hydrology after dam removal. However, on-sight inspection is needed to fully evaluate the impact of the removal of Gleasondale Dam on these potential vernal pools and modifications (deepening of the pool) may be considered to avoid impacts.

Removal of the impoundment would not dramatically change the viewshed from Orchard Hill or Lambert Hill. For the most part the existing impoundment has riverine characteristics, and after dam removal the river would just appear narrower. Some residents along Route 62 might object to replacement of the "waterfall" created by the dam spillway with a natural river channel, most likely a section of riffle. Most of the vegetation changes would occur in the east of Hudson Road, where large tracts of forested wetland may transition to upland with some visible mortality expected.

Invasive Species

Increased water velocities within the river channel after removal of the dam will likely reduce the infestations of reed canary grass and yellow flag that are currently found in the Gleasondale Dam impoundment. However, an invasive species management plan should be implemented in the project area to control the growth and spread of purple loosestrife.

BEN SMITH IMPOUNDMENT (INCLUDING CLOCK TOWER POND)

Existing Wetland and Riparian Habitat and Vegetation

The Ben Smith Dam in located in Maynard. According to the USGS (2005) the impoundment has a surface area of 146 acres. This makes it the largest impoundment on the Assabet River, with a surface area exceeding that of all other impoundments combined. The Ben Smith dam diverts water through a 1500 feet long canal and two small ponds to Clock Tower Pond in downtown Maynard. Offices in a redeveloped mill building overlook the pond. The pond has a maximum depth of about 15 - 20 feet. Flow from the pond passes under the mill building and flows into the Assabet River at two locations, with the main flow rejoining the Assabet near Walnut Street in Maynard.

ENSR (2001, Figure 3-2) stream profile indicates the influence of the impoundment extends nearly to the Gleasondale Dam. The impoundment (as delineated by the USGS) is generally linear, with open water ranging in width from about 200 to 400 feet from the dam upstream to Crow Island. Water depth throughout this reach is typically about 6 feet, with some areas reaching 8 – 10 feet. Most of the shoreline downstream of Crow Island is fringed with a narrow band of emergent or scrub-shrub wetland vegetation.

North of Crow Island the impoundment broadens into a shallow (2 – 4 ft deep), 600 feet wide pool. The 35-acre pool is heavily vegetated. An old channel of the Assabet, now largely vegetated with scrub-shrub wetland, lies south of Crow Island. The 30-acre island is connected to land by a long wetland crossing. The island is flat and largely vegetated with grasses, with a fringe of hemlock and oak trees along the Assabet River. The privately owned island is used as an airstrip for ultra light aircraft and has an aircraft metal hangar. The island contains a 2.5 acre excavated pond that is probably hydrologically influenced by the Assabet River. Upstream of Crow Island to Sudbury Road, open water ranges from 200 to 300 feet wide. Near Sudbury Road there are broad areas of fringing emergent wetland. From Sudbury Road upstream to Route 62 the river slowly meanders for about 2 miles through a broad, largely undeveloped, floodplain. Riffles downstream of Route 62 mark the definitive end of the impoundment.

The impoundment receives inflow from several tributary streams. Flow from Lake Boon enters the Assabet River about 0.5 miles upstream of Sudbury Road. Other major tributaries to the impoundment include Taylor Brook, which enters from the south about 1000 feet upstream of the dam and Elizabeth Brook, which enters from the north upstream of White Pond Road.

The Ben Smith impoundment shoreline is largely undeveloped. There are about 15 homes on the north shore of the impoundment between the dam and White Pond Road. Upstream of White Pond Road the shoreline is almost entirely undeveloped except for a golf course east of Elizabeth Brook and Crow Island. Much of the shoreline between White Pond Road and Sudbury Road is protected open space. The Assabet River National Wildlife Refuge borders the river for 1.5 miles along this reach. To the north is Stow's Gardner Hill Conservation Area.

Of all the Assabet River dams being studied, the Ben Smith impoundment supports the most extensive wetland and aquatic habitat. Wetland habitat maintained by the impoundment is primarily open water, emergent wetland, and scrub-shrub. In the summer of 1999 and 2000, ENSR mapped aquatic vegetation from the dam to the Elizabeth Brook confluence. Plant growth was excessive and dominated by filamentous green algae, floating plants (lemna and wolfia), and

coontail. Observation by OAR in 2005 found variable and occasionally heavy growth of aquatic vegetation in the impoundment from the dam to White Pond Road. Filamentous green alga and coontail were the dominant taxa (Flint, 2006).

During the summer the shallow embayment north of Crow Island is heavily vegetated with aquatic weeds, including yellow water lily, filamentous algae, coontail, elodea, duckweed, and wollfia. (Flint, pers., comm.). In November of 2005, the open water areas were largely free of vegetation, except for senescent beds filamentous algae, and scattered colonies of coontail, elodea, and water chestnut.

Downstream of Sudbury Road, emergent wetlands are dominated by reed canary grass, and to a lesser extent, purple loosestrife and cattail. Associated species include bur-reed, pickerelweed, smartweeds, water willow, yellow flag, soft stem bulrush, and smartweed. As in other Assabet River impoundments the grass-dominated wetlands are semi-floating. Even in mid November, duckweed was abundant in areas protected from the current. Scrub-shrub wetland adjacent to the river was vegetated with sweet gale, swamp rose, red maple, winterberry, blueberry, and northern arrow-wood. Herbaceous species noted in scrub-shrub wetlands included purple loosestrife, tussock sedge, and wool grass. In many areas the shoreline rises steeply to uplands, allowing only a narrow wetland fringe. Oak, white, pine and red maple were the most common trees species. Blueberry, northern arrow-wood, alder, and dogwood were common understory shrubs along the shoreline.

There are several potential vernal pools mapped by the MA DFW that may be hydrologically influence by the Ben Smith Dam.

Downstream of the Ben Smith Dam the river flows for about 1.5 through a moderately to highly developed riparian corridor before reaching the headwaters of the Powdermill Dam impoundment. The river drops in elevation about 30 feet through this high gradient reach.

The Ben Smith Dam diverts water to Clock Tower Pond through a 1600 feet long canal to two mill Ponds (known as the Upper and Lower Mill Ponds). The shoreline of the 40 feet wide canal is heavily vegetated. The canal ends at a manually operated gatehouse that controls flow into the mill ponds.

The Upper Mill Pond extends from the gatehouse downstream to Sudbury Road and has a surface area of approximately 6.5 acres. The upper pool was heavily vegetated with emergent and floating plants (duckweed and water meal) in September of 2005.

The lower millpond begins at the Sudbury Road Bridge and has a surface area of approximately 12 acres. This lower pond can be divided into a forebay pool and a main pool. The forebay pool (ca. 1 acre) is divided from the main pool by the remains of an old berm (or log boom?). The forebay consists mostly of open water habitat, with a maximum depth of 15 feet. Patches of emergent vegetation grow along the shoreline and on the log boom berm. The forebay pool was heavily vegetated with fanwort and floating leaved plants (woolfia and duckweed).

The main pool has a maximum depth of about 20 feet. The shoreline is almost entirely developed with a parking lot, old mill building, lawn, and several private homes. The southern shoreline is landscaped with weeping willow, silver maple, and other trees and shrubs. Water depth increases rapidly from shore and the pond has only a narrow, scattered, fringe of emergent vegetation. In September of 2005, percent cover of duckweed and wolfia in the pond was about 5% and the water was noticeably turbid from an algal bloom. Flow from the pond passes under the mill building and flows into the Assabet River immediately upstream of the Walnut Street Bridge approximately 7,000 feet downstream of the Ben Smith Dam.

General Description of Impacts

The Ben Smith Dam currently has a surface area of about 146 acres and generally ranges in width from about 200 to 400 feet, but broadens to 600 feet wide north of "Crow Island". In general, the environmental effects of the removal of the Ben Smith dam will be surface water level reductions in the impoundment and along the Assabet River to Route 62 in Gleasondale. This will create a narrower riverine channel approximately half the present width of the impoundment and provide substrate for the development of fringe wetland vegetation along the banks of the river. It is expected that some wetlands located at higher elevations will transition to upland. The change in surface water lessens along the impoundment (and river channel) further upstream; a range of approximately 7 feet at the dam to less that 1 foot at Route 64 in Gleasondale. Figure 4 in Attachment A displays a map of wetland areas predicted to develop, change or transition following dam removal. The amount of each wetland category is provided in Table 1 to provide a comparison of the existing condition versus after dam removal condition for each wetland category and a new category was added to accommodate the amount of wetland area expected to transition to upland.

Riparian and Habitat and Vegetation After Dam Removal

Following the removal of the Ben Smith dam, the width of the impoundment will be approximately 60 to 150 feet (downstream of Crow Island to the dam) and the steep impoundment bathymetry (predicted using the 1 foot bathymetric contours) will support the development of narrow zones of vegetated wetland areas (shallow marsh, shrubs and trees), similar to existing conditions except at a lower elevation (see Figure 4.). The amount of open water increases after dam removal; from 20.8 acres to 70.2 acres due to the transition of deep marsh to open water (deep marsh wetlands are reduced from 126.6 acres to 12.8 acres). Shallow marsh is reduced by 11.7 acres, shrub swamp gains 4.8 acres, wooded deciduous swamp gains 27.7 acres and 43.5 acres of wetland is expected to transition to upland. Since surface water level reduction is greatest in the impoundment area (approximately 7 feet at the dam), the amount of wetland expected to transition to upland is greater around the impoundment.

However, it should be noted that many wetland shrub and tree species found in the impoundment area, such as red maple, blueberry, northern arrow-wood, alder, and dogwood also grow in uplands some of the time and therefore, the transition to an upland vegetation community may be very gradual as these species may adapt to the new hydrology. Emergent wetlands will be more susceptible to the water level change and will be more likely to display abrupt and noticeable mortality with the exception perhaps of floating rafts of reed canary grass located upstream of Crow Island. It is expected that reed canary grass will float down with the water level reduction, settle and continue to grow on the newly exposed banks.

There will also be notable changes to the area north of Crow Island with water level reductions estimated to be in the range of 3 to 4 feet. A river channel (approximately 100 to 200 feet in width) will replace the broadened impoundment. The river will be flanked by large expanses of shallow marsh meadow and shrub swamps due to gradual impoundment bathymetry and repositioning of sediments in backwater areas. There will also be wetland areas transitioning to uplands along the higher elevations and in the remnant channel of the Assabet River (south of Crow Island). This area is now largely vegetated with scrub-shrub wetland and although it is fed by a perennial stream, it appears the Assabet River is the primary source of hydrology supporting this area. The 30-acre island may experience a reduction in the water level in the excavated pond (as it may be hydrologically influenced by the Assabet River) but minor changes are expected along the riverbank.

Upstream of Crow Island to Sudbury Road, the surface water level reduction becomes increasingly less, approximately 2 feet at Sudbury Road to almost no change at Route 62 (riffles

downstream of Route 62 mark the definitive end of the impoundment). The width of the river should narrow to about 100 feet (from approximately 200 to 300 feet) and in general, fringing wetlands are expected to transition from shallow marsh to shrub swamp or from shrub swamp to forested wetland or change very little depending on the site-specific conditions such as species composition, other hydrological contributions, etc. Downstream of Sudbury Road, there are wide expanses of emergent wetlands which are dominated by reed canary grass. This area will be subjected to minimal water level reduction (approximately 1 foot) and therefore, it is expected that the semi-floating grass-dominated wetlands will move with water level changes. Scrub-shrub wetlands containing species that are also adapted to dried conditions, such as sweet gale, red maple, blueberry, and northern arrow-wood, may tolerate the hydrological change. A small amount of peripheral fringe wetlands in the higher elevations are expected to transition to uplands. The expansive wetlands between the Assabet River and Main Street will be generally unaffected due to the small change in water level and hydrological contributions from Fort Meadow Brook.

There are a total of 10 vernal pools (9 potential vernal pools and 1 certified vernal pool) mapped by the MA DFW (February 2008) that are located within the area of influence of the Ben Smith Dam. In the area from the dam to Crow Island, there are two potential vernal pools located in what appears to be a remnant channel of the Assabet River. Since the water level reduction in the impoundment area is the greatest, a portion of the forested wetlands are expected to transition to upland in this area and therefore, water levels necessary for the completion of the amphibian aquatic development may not be adequate after dam removal in these pools. There are 2 potential vernal pools and one certified vernal pool located in the Crow Island to Sudbury Road area. These pools are located in contiguous forested wetlands that are associated with contributing drainage and therefore, do not appear to be dependent on hydrology from the Assabet River. From Sudbury Road to Route 62, there are 5 potential vernal pools which are located in the extensive wetlands adjacent to the Assabet River. Water level reduction in this area is minimal and therefore, these vernal pools will most likely be unaffected by the dam removal project. However, vernal pools are a valuable and protected resource in Massachusetts providing breeding habitat to a variety of amphibian species, some of which are rare. Therefore, the vernal pool and potential vernal pools in this area should be evaluated prior to dam removal and modifications (deepening of the pools) may be considered should the impact of reduced hydrology associated with dam removal be determined to have a detrimental affect. An isolated pool on an exposed floodplain on the northern bank of the river upstream of Crow Island is one noteworthy potential vernal pool created as a result of the dam removal. This area is a shallow open water area surrounded by emergent and shrub wetland and appears to have characteristics of a potential vernal pool.

The impoundment and shallow embayment north of Crow Island have been heavily vegetated with aquatic weeds, including yellow water lily, filamentous algae, coontail, elodea, and duckweed. After dam removal, water velocities will exceed the tolerance range of aquatic rooted vegetation in the channel and transport floating vegetation downstream however, backwater areas will probably still support smaller populations of these aquatic weeds.

The Ben Smith Dam diverts water to Clock Tower Pond downstream through a 1600 feet long canal to two mill Ponds (known as the Upper and Lower Mill Ponds). These pools are heavily vegetated with emergent, floating plants and algae. If water is still diverted into the canal during the average summer low flow then surface water levels may not be dramatically affected in these ponds compared to the upstream impoundment. However, reduced flows may exacerbate the nuisance vegetation problem. In addition, through scouring of the river channel, some sediment may move from the former impoundment downstream to be retained in these ponds. One of the recommendations of the Assabet River Modeling Study (CDM, 2008), is to remove some sediments to minimize the transport of fine materials and potentially contaminated sediments downstream subsequent to dam removal. A sediment management plan is being developed which will include a dredging plan based on site-specific conditions; depth of sediment, and the physical and chemical analysis of impounded sediments. However, it is expected that poor water quality will be a continued problem in these ponds and will affect the Assabet River at the discharge site immediately upstream of the Walnut Street Bridge (7,000 feet downstream of the dam).

Invasive Species

Water velocities within the river channel after removal of the dam will likely reduce the infestations of yellow flag, fanwort, and water chestnut that are currently found in the Ben Smith dam impoundment and limit the growth of unanchored vegetation however, an invasive species management plan should be implemented in the project area to control the growth and spread of purple loosestrife.

Restoration Considerations (Natural Resources)

Much of the Ben Smith impoundment shoreline is undeveloped or protected open space (the Assabet River National Wildlife Refuge and Stow's Gardner Hill Conservation Area). The protection of newly exposed riparian areas and transitional upland areas is especially important in the Ben Smith area to maintain the integrity of existing open space and conservation areas.

POWDERMILL DAM

Existing Wetland and Riparian Habitat and Vegetation

The Powdermill Dam is a stone and timber-crib dam built in the early 1920's. The dam is located in Acton. The impoundment, sometimes known as Ripple Pond, stretches into Maynard.

According to the USGS (2005) the impoundment has a surface area of 27 acres. A stream profile provided by ENSR (2001) indicates the end of the impoundment extends upstream to about the USGS gauge in Maynard (a length of about 1.3 miles or about 6,800 feet), the impoundment length measured from as aerial is about 3,900 feet. The dam and spillway are in disrepair and the impoundment is currently drawn-down to a channel. A bridge open to only foot traffic spans the dam.

The dam's purpose is to create sufficient head to run a small hydroelectric facility at the site. The flow of water to two 40 feet long 6 feet diameter steel penstocks is controlled by three timber head gates. Water passing through the generator is discharged into a sluiceway which rejoins the Assabet a few hundred feet downstream of the powerhouse.

In April of 2004, during high flows, a sink hole developed at the outlet work compromising the dam. As a result the impoundment is drawn-down. Currently, under high flow conditions some water is retained in the impoundment. Under low flow conditions most of the flow passes through the open outlet works.

Based on the growth of emergent vegetation and other field indicators the present influence of the impoundment is typically about 0.2 miles. Discharge from the Maynard Wastewater Treatment Plant and an unnamed tributary flow into the existing impoundment from the north. Numerous groundwater seeps on the north side of Powdermill impoundment also discharge into the Assabet River.

According to ENSR (2001) the normal (pre-drawdown) Powdermill impoundment extended about 1.3 miles upstream of the dam. The 1 mile reach below Crane Avenue/Warren Street was most influenced by the impoundment. The width of the impoundment ranged from about 40 feet near Crane Avenue/Warren Street to about 500 feet near the dam. Route 62 parallels the south side of the impoundment and there is moderate to heavy development between Crane Avenue and the dam.

The north side of the impoundment is largely undeveloped, with about 2/3 thirds of the shoreline between the dam and Warren Street in public ownership. Upstream of Crane Avenue/Warren Street the impoundment is about 40 feet wide, and has riverine characteristics which make the influence of the dam difficult to discern. Currently the impoundment normally extends no more than about 600 feet upstream of the dam.

Upstream of this point the Assabet River is now usually about 30 – 50 feet wide, shallow, and free flowing. During high flows, however, the impoundment can be reestablished and flood the riverine habitat. The riparian corridor downstream of the dam is largely undeveloped and there is generally at least a 50 foot wooded buffer along the sides of the river to the Assabet River-Sudbury River confluence.

Prior to its lowering, the impoundment was primarily open water, with a minor amount of scrub-shrub wetland and fringing emergent vegetation. In 1999 and 2000, before the impoundment was lowered, open water areas were densely vegetated with submerged aquatic vegetation and floating vegetation (ENSR, 2001). Predominant species included coontail, elodea, fanwort, floating plants, and filamentous green algae.

By 2005 vegetation within the former impoundment had changed markedly in response to the new hydrologic regime. Areas that are open water or riverine habitat are primarily un-vegetated except for some elodea growing in open water areas near the dam.

The very soft, flocculent like, sediments in the residual open water area likely inhibits growth of other submerged aquatic plants. Areas that are more frequently flooded by the residual impoundment are mudflat with only scattered growth of emergents. The remaining area (approximately 1/3 thirds of the former impoundment) is vegetated primarily by herbaceous vegetation, with scattered pioneer shrubs (mostly black willow with some European buckthorn at higher elevations) and tree seedlings or saplings (mostly red maple, with some aspen and silver maple). Red maple saplings were up to three feet tall at higher elevations. Dominant species in the emergent community were purple loosestrife, smartweed, and common forget-me-not at lower elevations. Other species present include sedges, spike rush, treefoil, softrush, pickerel weed, yellowflag, reed canary grass, pale impatiens, and duckweed.

Riparian and Habitat and Vegetation After Dam Removal

The existing wetlands have changed in response to the breach of the dam, so it was not possible to provide the with and without dam analysis for this site comparable to the other dam sites.

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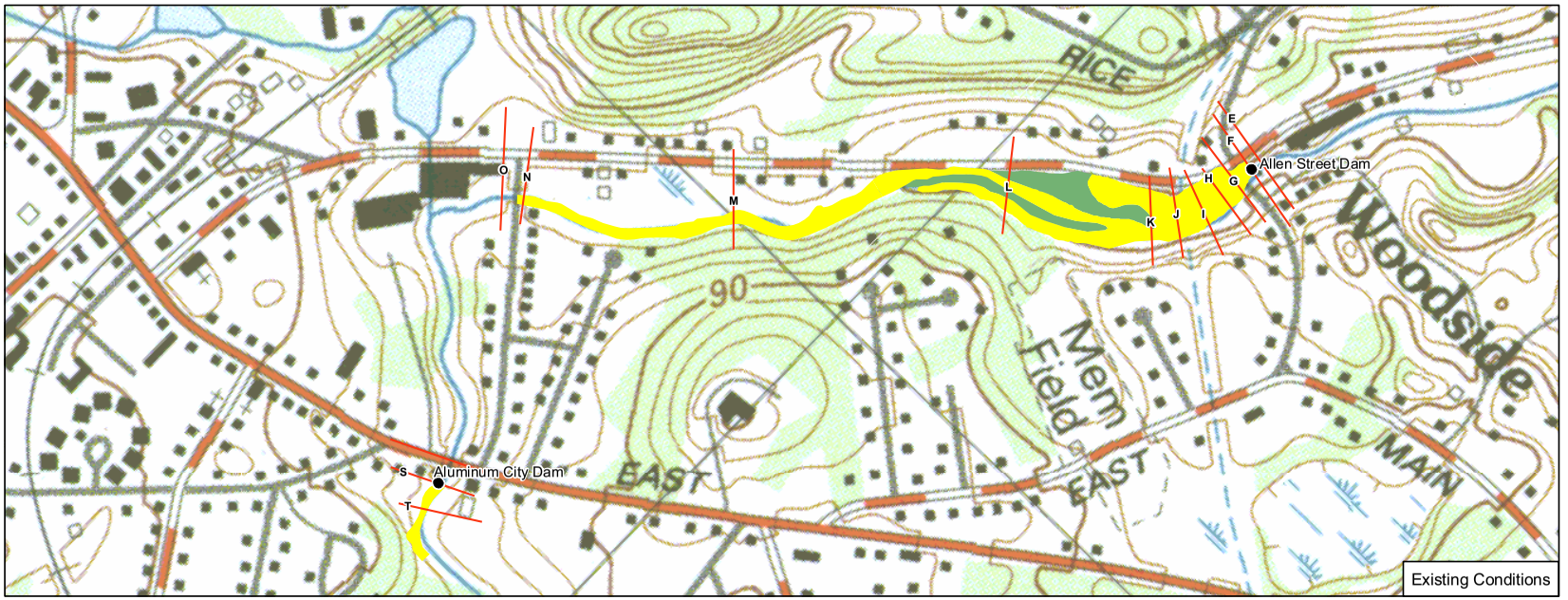
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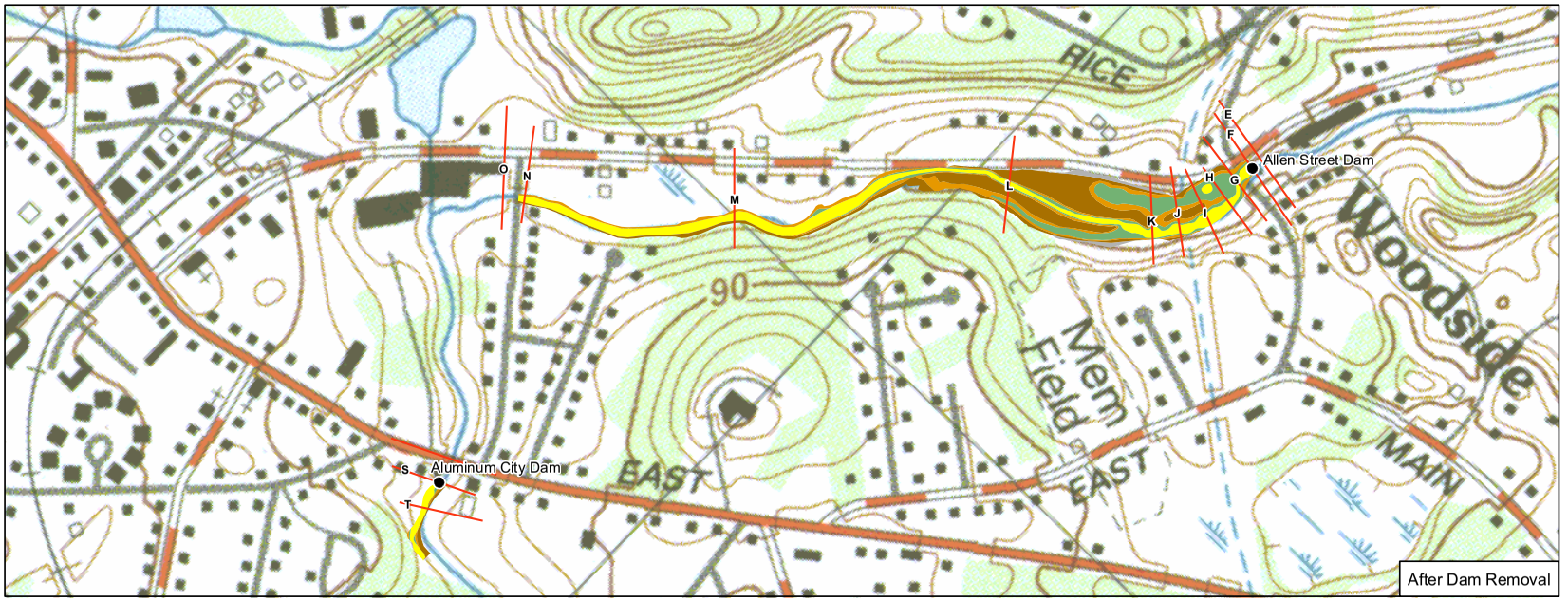
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ATTACHMENT A

WETLANDS MAPS





LEGEND

Wetland Types

Description

- TRANSITION TO UPLAND
- OPEN WATER
- SHALLOW MARSH MEADOW OR FEN
- DEEP MARSH
- SHRUB SWAMP
- WOODED SWAMP DECIDUOUS
- WOODED SWAMP MIXED TREES
- RIVER CROSS SECTION (from modeling)

LOCATION MAP



NOTES & SOURCES

Basemap data from US Geological Survey 7 1/2 minute Topographic Maps. Source: MassGIS
Aerial Photos: Color Digital Orthophotos:
Date Flown: 2002 Source: EarthData International

TITLE

Assabet River
Sediment and Dam Removal
Feasibility Study
Comparison of Wetlands
Before and After Dam Removal
Aluminum City and Allen Street Dams

0 500 Feet

US Army Corps of Engineers - New England District

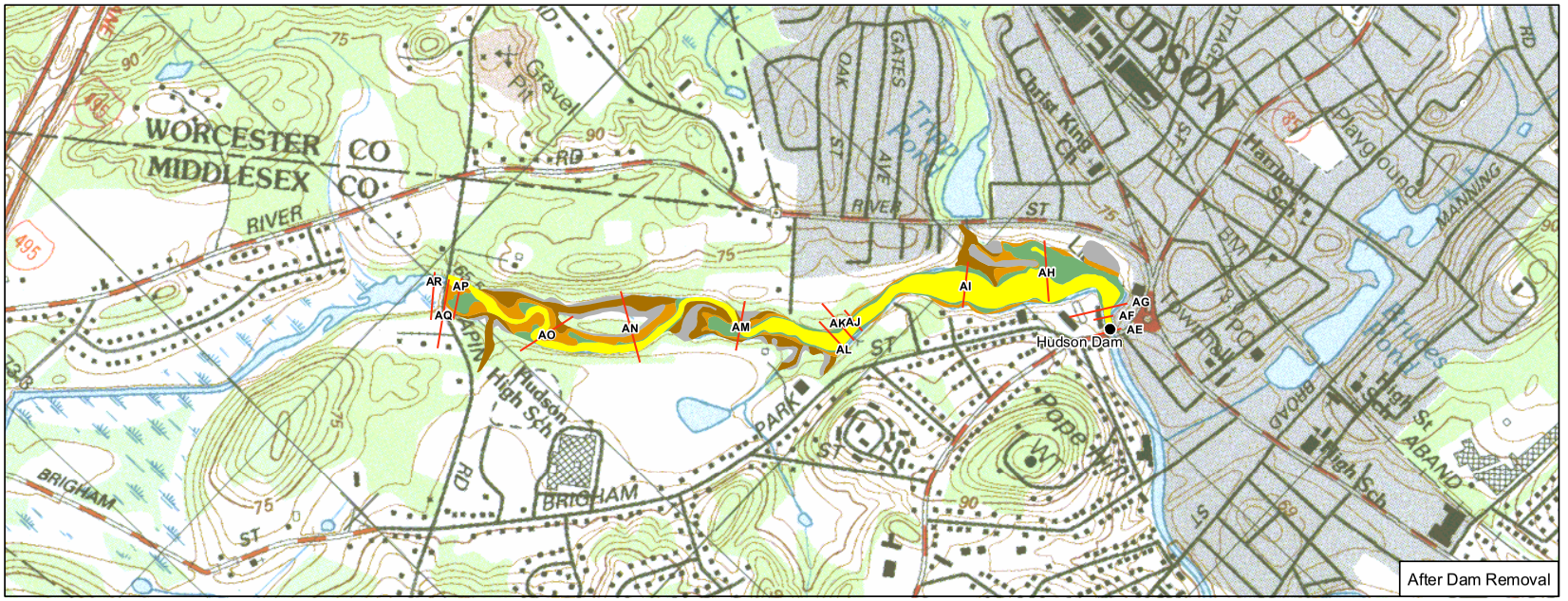
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FIGURE 1

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LEGEND

Wetland Types

Description

- TRANSITION TO UPLAND
- OPEN WATER
- SHALLOW MARSH MEADOW OR FEN
- DEEP MARSH
- SHRUB SWAMP
- WOODED SWAMP DECIDUOUS
- WOODED SWAMP MIXED TREES
- RIVER CROSS SECTION (from modeling)

LOCATION MAP



NOTES & SOURCES

Basemap data from US Geological Survey 7 1/2 minute
Topographic Maps. Source: MassGIS
Aerial Photos: Color Digital Orthophotos:
Date Flown: 2002 Source: EarthData International

TITLE

Assabet River
Sediment and Dam Removal
Feasibility Study
Comparison of Wetlands
Before and After Dam Removal
Hudson Dam

0 1,000 Feet

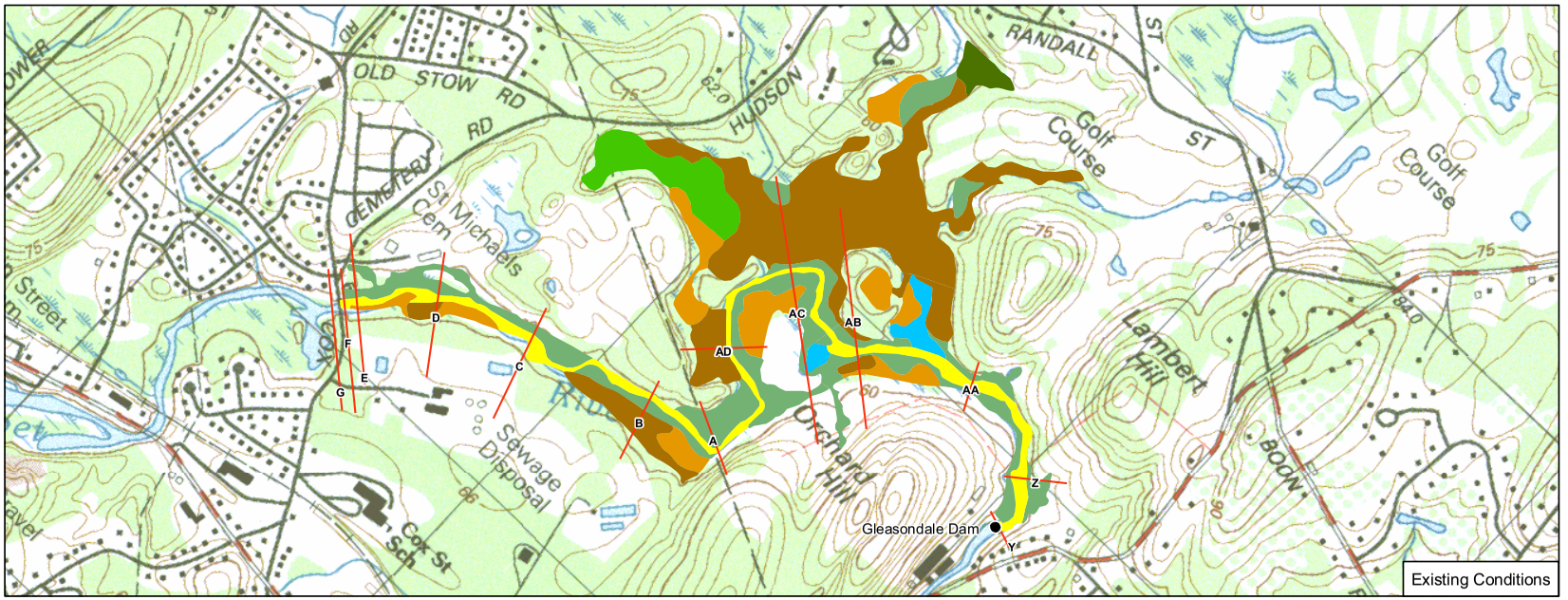
US Army Corps of Engineers
New England District

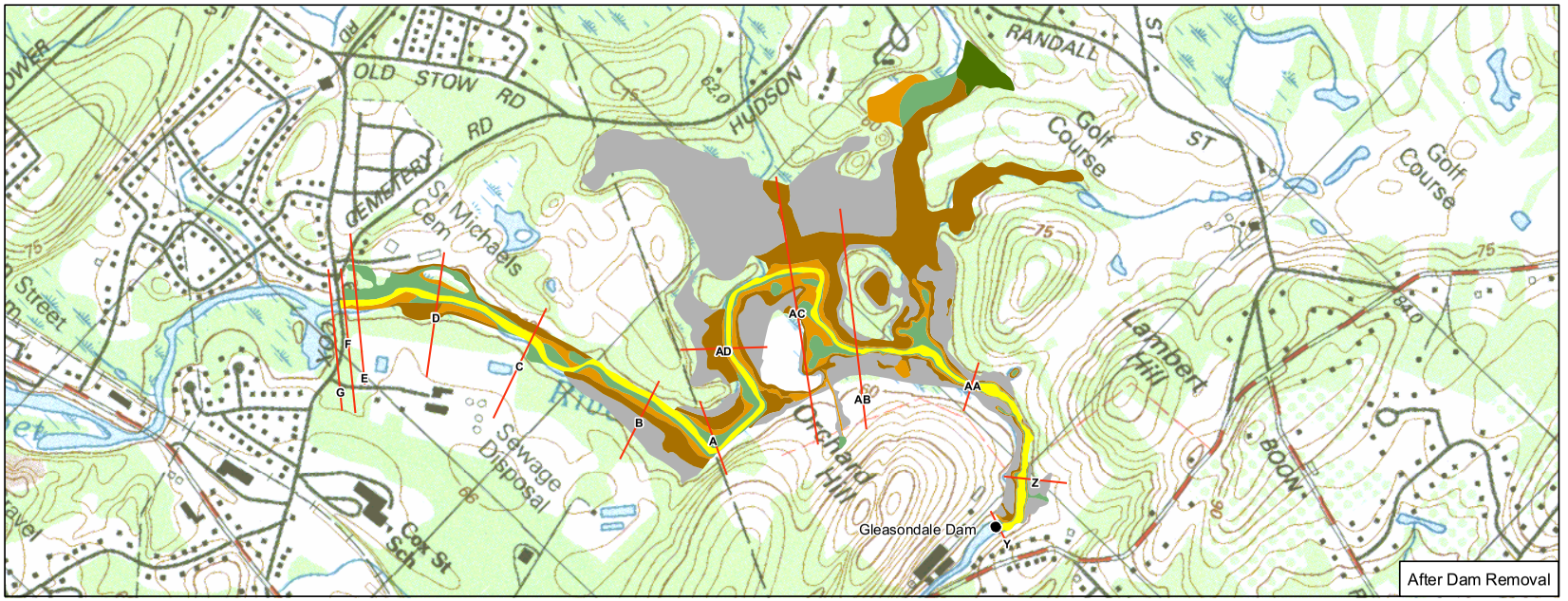
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FIGURE 2

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LEGEND

Wetland Types

Description

- TRANSITION TO UPLAND
- OPEN WATER
- SHALLOW MARSH MEADOW OR FEN
- DEEP MARSH
- SHRUB SWAMP
- WOODED SWAMP CONIFEROUS
- WOODED SWAMP DECIDUOUS
- WOODED SWAMP MIXED TREES

RIVER CROSS SECTION (from modeling)

LOCATION MAP



NOTES & SOURCES

Basemap data from US Geological Survey 7 1/2 minute
Topographic Maps. Source: MassGIS
Aerial Photos: Color Digital Orthophotos:
Date Flown: 2002 Source: EarthData International

TITLE

Assabet River
Sediment and Dam Removal
Feasibility Study
Comparison of Wetlands
Before and After Dam Removal
Gleasondale Dam

0 1,000 Feet

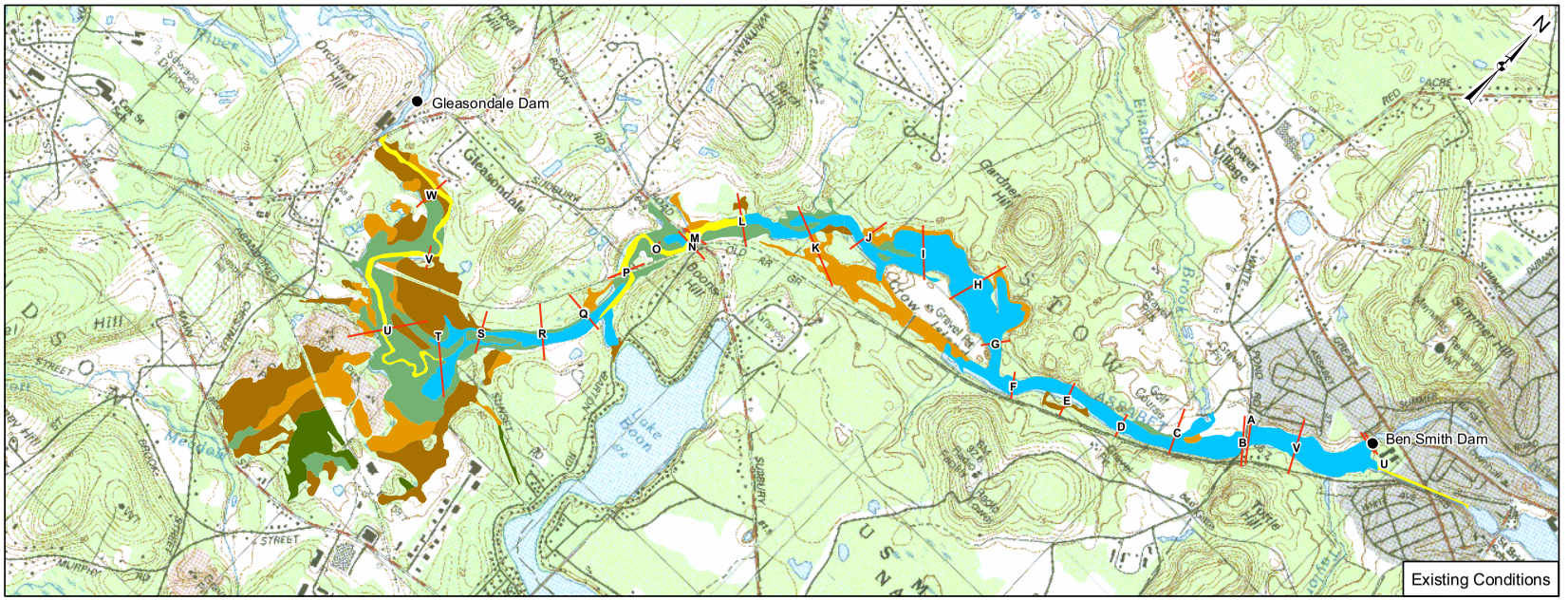
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New England District

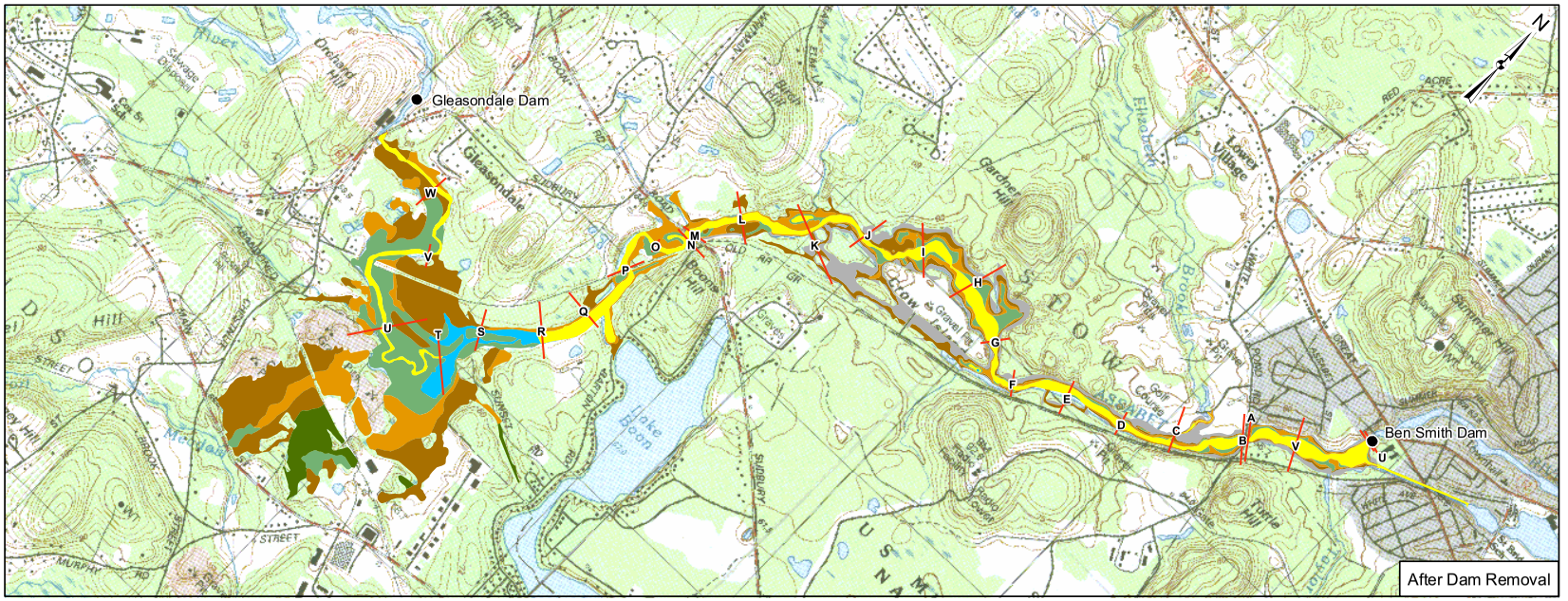
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FIGURE
3

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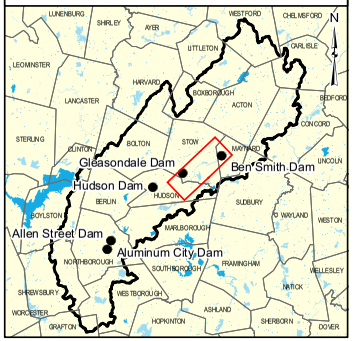
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Wetland Types

Description

- TRANSITION TO UPLAND
- OPEN WATER
- SHALLOW MARSH MEADOW OR FEN
- DEEP MARSH
- SHRUB SWAMP
- WOODED SWAMP DECIDUOUS
- WOODED SWAMP MIXED TREES
- RIVER CROSS SECTION (from modeling)

LOCATION MAP



NOTES & SOURCES

Basemap data from US Geological Survey 7 1/2 minute
Topographic Maps. Source: MassGIS
Aerial Photos: Color Digital Orthophotos:
Date Flown: 2002 Source: EarthData International

TITLE

Assabet River
Sediment and Dam Removal
Feasibility Study
Comparison of Wetlands
Before and After Dam Removal
Ben Smith Dam

0 2,000 Feet

US Army Corps of Engineers
New England District

DRAFT

FIGURE 4

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ATTACHMENT B

PLANT LISTS (with maps)

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ATTACHMENT B

Assabet River Impoundments - Plant Community Site Observations

Impoundment	Site Location # (See maps for Site Location and Tables for Plants observed at Sites)	Classification
Aluminum City	1	Riparian
	2	SS/EM
	3	FO
Allen St	1	Riparian
	2	Riparian
	3	Riparian
	4	EM
	5	EM
Hudson	1	EM
	2	FO/SS
	3	EM
	4	FO/SS
	5	EM
	6	FO/SS
Gleasondale	1	EM/SS
	2	EM
	3	EM
	4	EM
	5	EM
	6	Riparian
Ben Smith	1	EM
	2	EM
	3	SS
	4	SS/EM

Riparian – wooded (upland)
EM – Emergent wetland
FO – Forested wetland

TABLE VALUES

Cover Code	Cover Estimate
1	< 5 %
2	5 - 25 %
3	26 - 50 %
4	51 - 75 %
5	> 75 %
◆	Observed at site

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Scientific Name	Common Name	Aluminum City			Allen St.					Hudson					
		1	2	3	1	2	3	4	5	1	2	3	4	5	6
TREES, SHRUBS AND VINES															
Acer negundo	Box elder	2		5											
Acer pensylvanicum	Striped-maple	1													
Acer platanoides	Norway maple				5										
Acer rubrum	Red maple	2				4	4				5	1	5		5
Acer saccharinum	Silver maple														
Ailanthus altissima	Tree of heavan				1										
Alnus incana rugosa	Speckled alder	2				3					2		3		3
Betula papyrifera	White birch	1													
Betula populifolia	Gray birch					1					1				1
Celastrus orbiculata	Asiatic bittersweet	2													
Cephalanthus occidentalis	Buttonbush	2			1			1		1					
Clethera alnifolia	Sweet pepperbush	2									1				
Cornus sp.	Dogwood		2		1								2		1
Fraxinus americana	White ash			1	2										
Ilex glabra	Inkberry			1			1								
Illex verticillata	Winterberry														
Juniperus virginiana	Red cedar														
Lonicera sp.	Honeysuckle			2									1		
Myrica gale	Sweet gale														
Pachysandra terminalis	Pachysandra						1								
Parthenocissus quinquefolia	Virginia creeper	2	3		1										
Picea abies	Norway spruce				1										
Pinus resinosa	Red pine				2										
Pinus strobus	Eastern white pine				2	2							1		
Populus deltoides	Cottonwood														
Populus tremuloides	Aspen														
Prunus sp.	Cherry														
Prunus virginiana	Black cherry						1								
Quercus alba	White oak						4								
Quercus bicolor	Swamp white oak					2					1				
Quercus rubra	Northern red oak	1				1					1				
Rhus radicans	Poison ivy				1										

Scientific Name	Common Name	Aluminum City			Allen St.					Hudson					
		1	2	3	1	2	3	4	5	1	2	3	4	5	6
TREES, SHRUBS AND VINES															
Rosa multiflora	Multifloa rose			3											
Rosa palustris	Swamp Rose														
Rosa rugosa	Rugosa rose				1										
Salix babylonica	Weeping willow														
Salix nigra	Black willow									1		1			
Salix sp.	Willow sp.				1										
Sambucus canadensis	Common elderberry	2													
Ulmus rubra	Slippery elm	3													1
Vaccinium corymbosum	Highbush blueberry			1		3	1								
Virburnum recognetum	Northern arrowwood			1		1	1				1				
Vitis labrusca	Fox grape			1											
Vitis sp.	Wild grape				1						2				1
HERBACEOUS															
Arisaema triphyllum	Jack in the pulpit			1											
Asclepias incarnata	Swamp milkweed														
Aster sp.	Aster sp.														
Bidens sp.	Bidens sp.														
Boehmeria cylindrica	False nettle								1						
Carex sp	Sedge														
Carex stricta	Tussock sedge														
Cuscuta sp.	Dodder								1						
Cyperus eragrostis	Umbrella sedge														
Cyperus sp.	Flatsedge														
Daucus carota	Wild carrot	1													
Dennstaedtia punctilobula	Hay-scented fern	1		3			1								
Dichanthelium clandestinum	Deer tongue grass	1													
Eleocharis sp.	Spike rush														
Equisetum sp.	Horsetail	1													
Eupatorium perfoliatum	Bonset														
Epilobium glandulosum	Purple-leaved willow herb														
Graminae	Unidentifeid grass														
Hypericum mutilium	Dwarf St. John's-wort														
Hypericum virginicum	Marsh St. John's-wort														

Scientific Name	Common Name	Aluminum City			Allen St.					Hudson					
		1	2	3	1	2	3	4	5	1	2	3	4	5	6
HERBACEOUS															
Impatiens capensis	Jewelweed	1	3	1	1		1	2	2	1					
Impatiens pallida	Jewelweed														
Iris pseudocarus	Yellow flag	1								1					
Iris versicolor	Blue flag														
Isoetes sp.	Quillwort														
Juncus effusus	Soft rush														
Lactuca canadensis	Wild lettuce														
Leersia oryzoides	Rice cut grass											1		1	
Lobelia cardinalis	Cardinal flower														
Lythrum salicaria	Purple loosestrife	1	1					1	1	2		2		2	
Onoclea sensibilis	Sensitve fern	1													
Osmunda cinnamomea	Cinnamon fern	1				1	2								
Osmunda regalis	Royal fern	1				1									
Peltandra virginica	Arrow arum								1						
Phalaris arundinacea	Reed canary grass	2	3					5	5	4		5		5	
Polygonum sp.	Smartweed							1							
Polygonum hydropiperoides	Mild water-pepper														
Polygonum persicaria	Lady's thumb														
Polygonum pensylvanicum	Pinkweed														
Pontederia cordata	Pickerelweed						1	1		1					
Sagittaria cuneata	Northern arrowhead											1		1	
Sagittaria graminea	Grass-like arrowhead							1							
Sagittaria latifolia	Broadleaf arrowhead	2	1					1	1	1					
Scirpus cyperinus	Woolgrass														
Scirpus sp.	Bullrush							1						1	
Scirpus validus	Softstem bullrush														
Scuttelaria epilobifolia	Marsh scullcap														
Solanum dulcamara	Deadly nightshade	1	2												
Sparganium sp.	Burreed							1	1	1		1		1	
Sparganium androcladum	Branching burreed														
Typha angustifolia	Narrowleaf cattail														
Typha latifolia	Broadleaf cattail							2	2						
Typha sp.	Cattail sp.									1				1	
Zinzania aquatica	Wild rice														

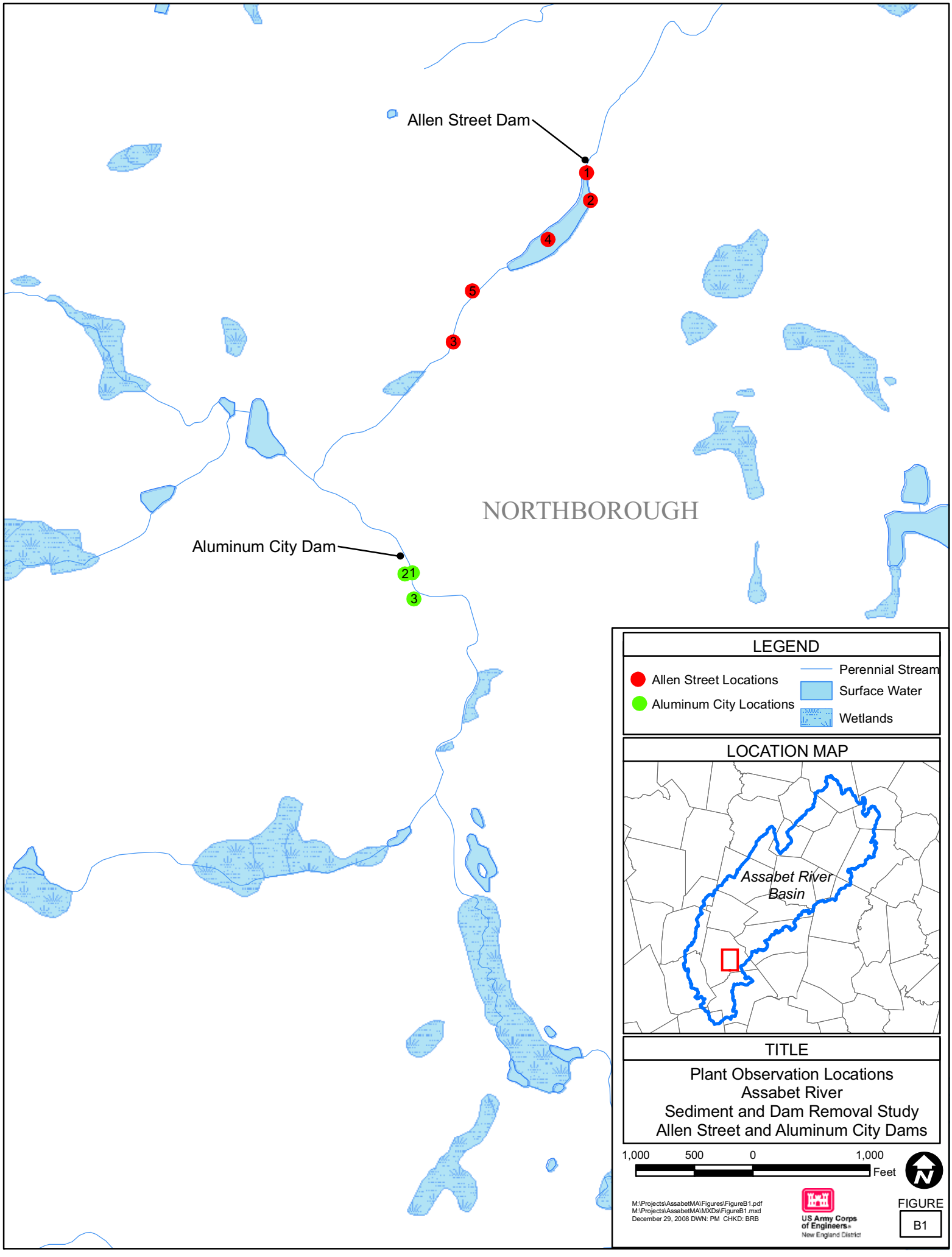
Scientific Name	Common Name	Gleasondale						Ben Smith				Clock Tower Site List	Powder Mill Site List
		1	2	3	4	5	6	1	2	3	4		
TREES, SHRUBS AND VINES													
Acer negundo	Box elder											◆	
Acer pensylvanicum	Striped-maple												
Acer platanoides	Norway maple												
Acer rubrum	Red maple	2		1	1		4				1	◆	◆
Acer saccharinum	Silver maple											◆	◆
Ailanthus altissima	Tree of heavan											◆	
Alnus incana rugosa	Speckled alder	1	1	1			1			1	2	◆	
Betula papyrifera	White birch											◆	
Betula populifolia	Gray birch												
Celastrus orbiculata	Asiatic bittersweet												
Cephalanthus occidentalis	Buttonbush				1	1						◆	
Clethera alnifolia	Sweet pepperbush											◆	◆
Cornus sp.	Dogwood						1					◆	
Fraxinus americana	White ash												
Ilex glabra	Inkberry												
Illex verticillata	Winterberry	1								2			
Juniperus virginiana	Red cedar												
Lonicera sp.	Honeysuckle												
Myrica gale	Sweet gale	2	3								2		
Pachysandra terminalis	Pachysandra												
Parthenocissus quinquefolia	Virginia creeper											◆	
Picea abies	Norway spruce												
Pinus resinosa	Red pine												
Pinus strobus	Eastern white pine												
Populus deltoides	Cottonwood												
Populus tremuloides	Aspen												◆
Prunus sp.	Cherry												
Prunus virginiana	Black cherry												
Quercus alba	White oak												
Quercus bicolor	Swamp white oak						1			1			
Quercus rubra	Northern red oak						4						
Rhus radicans	Poison Ivy												

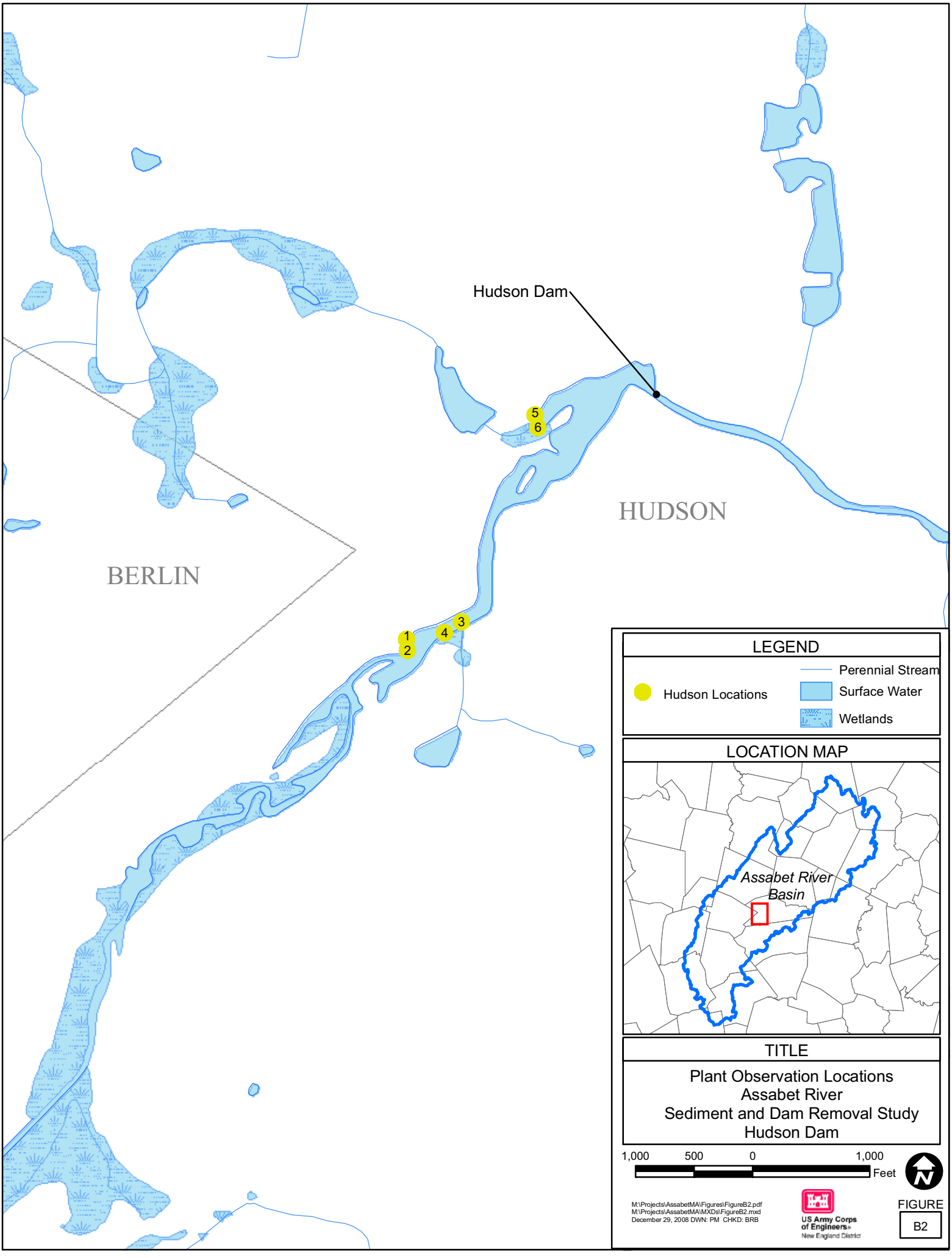
Scientific Name	Common Name	Gleasondale						Ben Smith				Clock Tower Site List	Powder Mill Site List
		1	2	3	4	5	6	1	2	3	4		
TREES, SHRUBS AND VINES													
Rosa multiflora	Multifloa rose												
Rosa palustris	Swamp Rose	2	1	1							1		
Rosa rugosa	Rugosa rose												
Salix babylonica	Weeping willow											◆	
Salix nigra	Black willow					1							◆
Salix sp.	Willow sp.											◆	
Sambucus canadensis	Common elderberry												◆
Ulmus rubra	Slippery elm												
Vaccinium corymbosum	Highbush blueberry	1					1			2	2	◆	
Virburnum recognetum	Northern arrowwood						1					◆	
Vitis labrusca	Fox grape												
Vitis sp.	Wild grape											◆	◆
HERBACEOUS													
Arisaema triphyllum	Jack in the pulpit												
Asclepias incarnata	Swamp milkweed		1										
Aster sp.	Aster sp.		1										
Bidens sp.	Bidens sp.												◆
Boehmeria cylindrica	False nettle				1								◆
Carex sp	Sedge												◆
Carex stricta	Tussock sedge	2	3								1		
Cuscuta sp.	Dodder												
Cyperus eragrostis	Umbrella sedge												
Cyperus sp.	Flatsedge												◆
Daucus carota	Wild carrot												
Dennstaedtia punctilobula	Hay-scented fern												
Dichanthelium clandestinum	Deer tongue grass												
Eleocharis sp.	Spike rush												◆
Equisetum sp.	Horsetail												
Eupatorium perfoliatum	Bonset												
Epilobium glandulosum	Purple-leaved willow herb												◆
Graminae	Unidentified grass												
Hypericum mutilium	Dwarf St. John's-wort												◆
Hypericum virginicum	Marsh St. John's-wort												

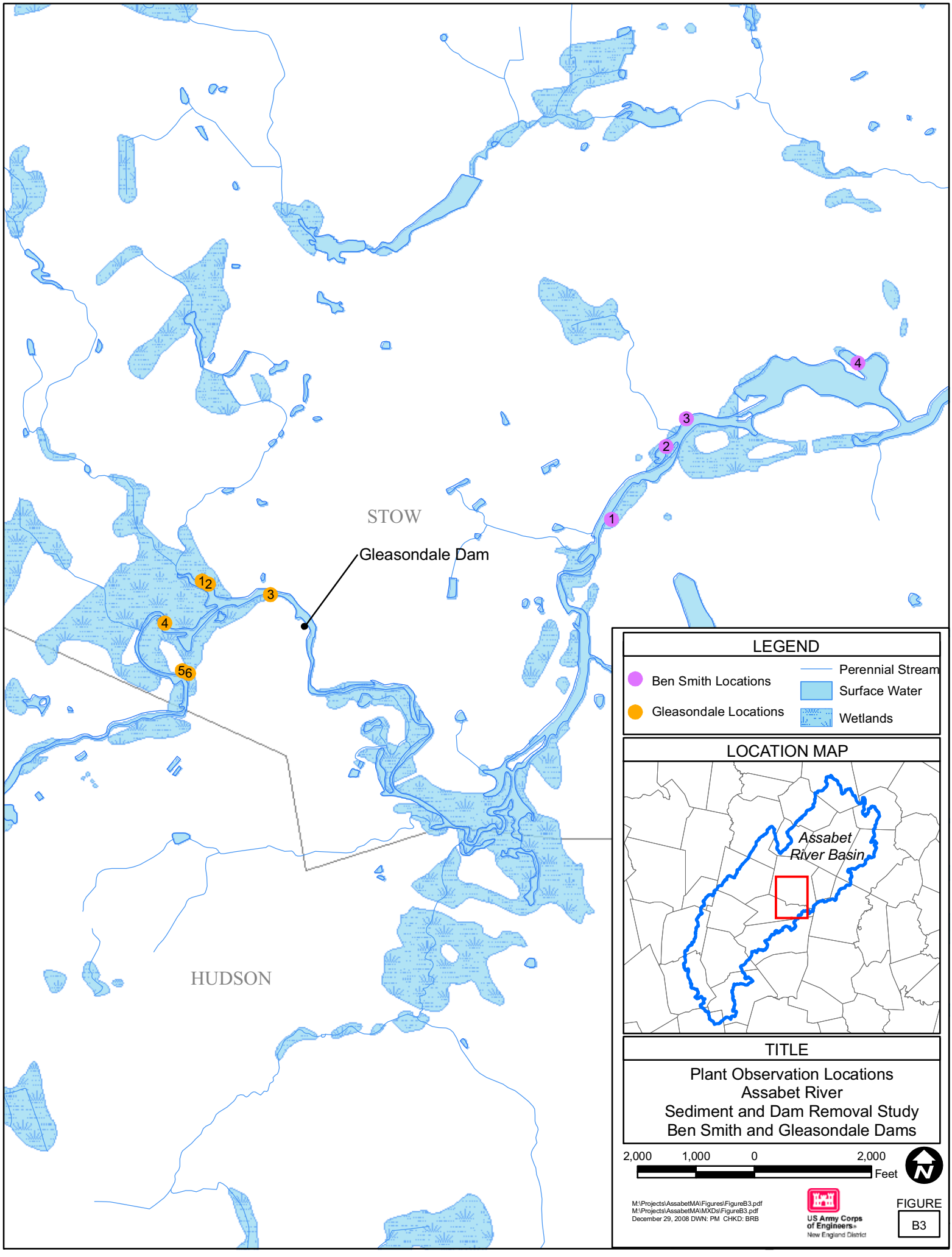
Scientific Name	Common Name	Gleasondale						Ben Smith				Clock Tower Site List	Powder Mill Site List
		1	2	3	4	5	6	1	2	3	4		
HERBACEOUS													
Impatiens capensis	Jewelweed												
Impatiens pallida	Jewelweed												◆
Iris pseudocarus	Yellow flag	1	1		1	1					1	◆	
Iris versicolor	Blue flag							1					
Isoetes sp.	Quillwort												
Juncus effusus	Soft rush												◆
Lactuca canadensis	Wild lettuce												
Leersia oryzoides	Rice cut grass												
Lobelia cardinalis	Cardinal flower												◆
Lythrum salicaria	Purple loosestrife	1	3	3	2	2		4	2		1		◆
Onoclea sensibilis	Sensitve fern										1		◆
Osmunda cinnamomea	Cinnamon fern												
Osmunda regalis	Royal fern	1								1			
Peltandra virginica	Arrow arum											◆	
Phalaris arundinacea	Reed canary grass	1	1	4	4	4		2	3			◆	◆
Polygonum sp.	Smartweed		1					1					◆
Polygonum hydropiperoides	Mild water-pepper												
Polygonum persicaria	Lady's thumb												◆
Polygonum pensylvanicum	Pinkweed												◆
Pontederia cordata	Pickerelweed	3			1				1		1	◆	◆
Sagittaria cuneata	Northern arrowhead												
Sagittaria graminea	Grass-like arrowhead												◆
Sagittaria latifolia	Broadleaf arrowhead												
Scirpus cyperinus	Woolgrass		3										
Scirpus sp.	Bullrush												
Scirpus validus	Softstem bullrush	1							1				
Scuttelaria epilobifolia	Marsh scullcap												◆
Solanum dulcamara	Deadly nightshade												
Sparganium sp.	Burreed	1											
Sparganium androcladum	Branching burreed							2	1				
Typha angustifolia	Narrowleaf cattail												
Typha latifolia	Broadleaf cattail											◆	
Typha sp.	Cattail sp.				2	1		1	2				◆
Zinzania aquatica	Wild rice	1	1	1									

Scientific Name	Common Name	Impoundment						
		Aluminum City	Allen St.	Hudson	Gleasondale	Ben Smith	Clock Tower	Powdermill
Cabomba carolians	Fanwort				✟	✟	✟	✟
Ceratophyllum demersum	Coontail			✟	✟	✟		✟
Callitriche stagnalis	Water starwort		✟					
Elodea canadensis	Waterweed		✟	✟	✟	✟		✟
Lemna minor	Duckweed	✟	✟	✟	✟	✟	✟	✟
Myriophyllum sp.	Water millfoil			✟				
Nitella flexilis	Stonewort			✟				
Nuphar variegata	Yellow water lily				✟			
Nymphaea odorata	Water lily				✟			
Potamogeton amplifolius	Large-leaved pondweed				✟			
Potamogeton conferoides	Alga-like pondweed		✟					
Potamogeton crispus	Curly muck-weed		✟			✟		✟
Potamoogeton epihydrus	Nuttall's pondweed		✟	✟				✟
Potamageton pusillus var. tenuissimus	Small pondweed		✟		✟	✟		✟
Potamogeton robbinsii	Robbin's pondweed					✟		
Potamogeton spirillus	Spiral pondweed							✟
Potamogeton zosteriformis	Flat-stem pondweed				✟	✟		✟
Potamogeton sp.	Pondweed sp.	✟						
Trapa natans	Water chestnut					✟	✟	✟
Wolfia comubiana	Water meal	✟	✟	✟	✟	✟	✟	✟

Sources: ENSR (2001), Sue Flint (2006); USGS(2005); ACOE 2005 Fieldwork


Allen Street Dam
1
2
4
5
3
NORTHBOROUGH
Aluminum City Dam
21
3
LEGEND
Allen Street Locations
Aluminum City Locations
Perennial Stream
Surface Water
Wetlands
LOCATION MAP
Assabet River Basin
TITLE
Plant Observation Locations
Assabet River
Sediment and Dam Removal Study
Allen Street and Aluminum City Dams
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December 29, 2008 DWN: PM CHKD: BRB
US Army Corps of Engineers
New England District
FIGURE
B1


Hudson Dam
HUDSON
BERLIN
1
2
3
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5
6
LEGEND
Hudson Locations
Perennial Stream
Surface Water
Wetlands
LOCATION MAP
Assabet River Basin
TITLE
Plant Observation Locations
Assabet River
Sediment and Dam Removal Study
Hudson Dam
1,000 500 0 1,000
Feet
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December 29, 2008 DWN: PM CHKD: BRB
US Army Corps of Engineers
New England District
FIGURE
B2


STOW
Gleasondale Dam
HUDSON
1
2
3
4
1
2
3
4
5
6
LEGEND
Ben Smith Locations
Gleasondale Locations
Perennial Stream
Surface Water
Wetlands
LOCATION MAP
Assabet
River Basin
TITLE
Plant Observation Locations
Assabet River
Sediment and Dam Removal Study
Ben Smith and Gleasondale Dams
2,000
1,000
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Feet
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US Army Corps
of Engineers
New England District
FIGURE
B3

APPENDIX E

TARGET FISH COMMUNITY ANALYSIS (TFC)
ASSABET RIVER

APPENDIX TFC

Assabet River, Massachusetts Sediment and Dam Removal Study
Assabet River Target Fish Community (TFC) Evaluation
January 2009 Final Draft

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FIGURE 5. COMPARISON OF THE TARGET FISH COMMUNITY (TFC) AND EXISTING FISH COMMUNITIES (EFC) BASED ON HABITAT-USE CLASSIFICATION GUILDS 21

1. INTRODUCTION/STUDY PURPOSE

The purpose of the Assabet River Sediment and Dam Removal study is to achieve water quality compliance and a sustainable and restored aquatic ecosystem.

Aquatic ecosystem objectives include restoration of a combination of habitats in different portions of the Assabet River that currently support typical warm-water species (as found in the impoundment or "pond" behind each dam) or fluvial specialist species (as found in the riverine or free-flowing sections); and improvements in the migratory corridor by improving river continuity for diadromous species such as the American eel and river herring.

Results of computer modeling studies determined that the most beneficial water quality improvements to the Assabet River can be achieved through planned wastewater treatment plant (WWTP) improvements, dam removal, and consideration of lower winter effluent limits than currently planned for WWTP. Dam removal findings identified removal of Ben Smith Dam as the first priority followed by the removal of the Gleasondale Dam and then the Hudson Dam. The removal of Allen Street Dam and Aluminum City Dam should also be considered for habitat benefits only since removal of these dams has minimal affect on overall river water quality.

The TFC approach was recommended by the Massachusetts Division of Fisheries and Wildlife (MADFW) as the methodology to be used on the Assabet River to evaluate the existing fisheries community and habitat and potential fisheries community and habitat that is expected to occur as the result of dam removal. This is accomplished by comparing the existing fish communities based on all sample collections, the impounded segments versus the free flowing or riverine segments with the TFC Model for the Concord River Watershed that includes the Sudbury, Assabet and Concord Rivers (SuAsCo) as developed by Todd Richards, MADFW Fisheries Biologist.

2. TARGET FISH COMMUNITY CONCEPT

Target Fish Community (TFC) models have been utilized within instream flow related studies on multiple rivers in Southern New England since Bain and Meixler's initial development and application of the methodology on the Quinebaug River in 2000. Successful applications of the approach to assess the status of native fish communities on the Quinebaug, Ipswich, Assabet, Charles, Housatonic, Pomperaug, Souhegan, Eightmile and Lamprey Rivers (Bain and Meixler 2000; Lang et al. 2001; Armstrong et al. 2001; Parker et al. 2004; Meixler 2005; Kearns et al. 2005; Legros 2007a & b; Parasiewicz et al. 2007a & b; Legros and Paraweicz 2007) have proven the effectiveness of TFC models as fish community assessment tools. These practical

applications illustrate the ability of TFC models to assess the biological integrity of streams using an inference approach based on the biological requirements of fish species (or species groups) and a comparison of their compositions within a TFC and the existing fish community of a study stream (or stream segment). The increasing use and acceptance of this methodology, and similar methods, are indicative of the significance of using fish communities to assess the biological integrity of aquatic systems (Karr 1981, Fausch et al. 1990, Hughes 1995, Halliwell et al. 1999). The past success and recognized importance of the TFC approach has led to its adoption by the Commonwealth of Massachusetts and State of New Hampshire as a component of their water resources policy development processes regarding Protected Instream Flows (PISF) (Legros and Parasiewicz 2007).

The Target Fish Community (TFC) approach developed by Bain & Meixler (2000) evaluates the status of a river based on a comparison between the current or Existing Fish Community (EFC) and the desired TFC or Reference Fish Community. Its computational framework, accounts for spatial and temporal variations of the native community and creates a robust, interannual representation of the expected native fauna composition at the watershed scale. The Bain and Meixler paper (2000) provides the guidelines and calculations required to create a representation of what the desired species assemblage in a river should resemble. The concept is based on identifying the types of fish species and their expected proportions within the community that is as close as possible to what may have been in the ecosystem with limited human alteration and therefore a goal of natural resources management. Bain and Meixler (2000) acknowledge that finding or restoring a river community to pristine, untouched status would be impossible, especially due to widespread introduction of non-native and desired game species and the highly developed condition of some watersheds. Instead, they state that the use of the TFC or reference rivers in a mostly natural or desired state will provide a baseline community that can be used to determine where the actual community deviates from management targets (Bain and Meixler 2000).

The TFC provides a list of species as well as expected proportions that can be compared to what is actually surveyed (existing fish community) by using a similarity measurement method such as a percent affinity model (Novak and Bode 1992). The community can also be analyzed using pollution tolerance indices (i.e. intolerant, moderately tolerant and tolerant) and classifications of the habitats required by the species (i.e. fluvial dependent, fluvial specialists, or macrohabitat generalists) (Bain and Meixler 2000).

It is useful to look at the target and existing fish species in terms of these macrohabitat guilds. Fluvial specialists are species that rely entirely on rivers and flowing water throughout their life cycle. Fluvial dependents are species that require stream habitat for at least one portion of their life cycle such as spawning, migration etc. Generalists are species that can utilize multiple types

of habitat and are often associated with ponded areas (Parker et al 2004). Generalists are becoming more common in rivers as dams or low flows create higher number of ponded areas. In terms of target fish communities, the general objective for rivers is to have of the fish population comprised in a large part of native, fluvial specialists and fluvial dependent species (Parker et al 2004).

The goal of developing a TFC for the main-stem Assabet River is to define the fish community that is appropriate for a natural river of this size in southern New England. Accordingly TFC assessments are used to identify the current status of a main-stem river such as the Assabet River in that the fish tell the story as they are long-lived, reflect stresses over time, and are easily recognized and identified.

The premise for the TFC is quite simple in that Rivers should have fluvial or "river" fish communities. The TFC for the SuAsCo serves as our target for river rehabilitation in the Assabet River and as an endpoint of evaluating environmental improvements such as the removal of dams. The sampled existing fish community (EFC) is compared to the target fish community (TFC) to evaluate the potential fish community resulting from the river rehabilitation objective (i.e. removal of a dam). Use of the target fish community approach can guide and evaluate environmental rehabilitation where restoration objectives cannot simply be to copy pristine, natural ecosystem properties.

3. FISHERIES HABITAT EVALUATIONS USING THE TFC APPROACH

3.1 TFC DEVELOPMENT AND METHODS

The existing fisheries data for the main-stem Assabet River used in this TFC evaluation was provided by MADFW to the USACE for subsequent data reduction and analysis in direct coordination with Todd Richards, Fisheries Biologist, MADFW. Similarly the TFC model for the Concord River Watershed used in this evaluation for the Assabet River was also provided to the USACE by Todd Richards (Richards 2008).

Sampling Protocol

Since 1998 the MADFW has sampled over 1,000 sites with over 140,000 fish records as part of their statewide fish survey using a variety of collection gear depending on the water body sampled. For each fisheries sample collected, all of the fish are identified to species and total length is measured to the nearest millimeter (mm) up to a maximum of 100 of each species if large numbers are collected, and all live fish are released except those specimens that are taken and preserved for the voucher collection.

Habitat-Use and Pollution Tolerance Classifications

The data is loaded into excel spreadsheets and each fish record is completed by entering its respective Massachusetts Habitat Use Classification (MA HUC) and Pollution Tolerance (PT) classifications, the two most important metrics in a TFC evaluation. As described in Bain and Meixler (2000) species habitat requirements and pollution tolerances were classified using regional and state ichthyology books (Scott and Crossman 1973, Pflieger 1975, Lee et al. 1980, Trautman 1981, Becker 1983, Burr and Warren 1986, Scarola 1997, Robison and Buchanan 1988, Hartel et al. 2002, Jenkins and Burkhead 1994).

As a group, these reference books describe the North American life history of fish. Habitat requirements were summarized into three macrohabitat (water body type) classes: macrohabitat generalists (MG), fluvial dependents (FD), and fluvial specialists (FS). These groupings have been found effective in relating fish community change to river habitat alteration (Bain et al. 1988; Kinsolving and Bain 1993; Quinn and Kwak 2003).

Some adjustment was made to the classifications to accommodate regional differences in habitat requirements: three of the habitat classifications (fallfish, longnose dace, and brook trout) were changed from generalists to fluvial specialists by agreement of the project Management Committee. American eel is a catadromous fish (migrates to sea for spawning) that requires access to stream habitats to complete its life cycle. This fish was classified by MADFW as a macrohabitat generalist because the species occupies a wide range of habitats throughout its life albeit others have classified it as a fluvial dependent due to this species dependency upon fluvial conditions for migration to and from the sea.

For pollution tolerance (PT) classifications, we used the classification of Halliwell et al. (1999) for Northeast US fishes: intolerant (I), moderately tolerant (M), or tolerant (T). Finally, species were designated as native or exotic (introduced) from Schmidt (1986), Whitworth (1996) and Hartel et al. (2002) albeit this metric was not specifically analyzed in our quantitative TFC evaluation since it was not entered onto the excel fish data sheets received from the MADFW. However, this metric is discussed from a qualitative perspective as warranted.

3.2 RESULTS

Assabet River Target Fish Community (Based on Concord Watershed TFC)

The Target Fish Community (TFC) model for the Assabet River based on the Concord River Watershed is provided in Table 1. The TFC was based on a number of riverine main-stem

sampling sites in the Sudbury, Assabet and Concord Rivers (SuAsCo). The TFC for the Assabet River consist of a diverse assemblage of fifteen (15) native species representing eight (8) families.

The TFC also includes as expected the following native anadromous fish species: American shad, alewife, and blueback herring; and the sea lamprey. These species are expected providing that fish passage facilities are constructed and/or obstructions are removed in the Concord River watershed so that they can reach their historical spawning grounds. The US Fish and Wildlife Service (USFWS) and other stakeholders collaboratively began an active anadromous fish restoration program in the Concord River watershed in 2000 that continues to the present. An update of their program and results are discussed in the section on Restoration of Anadromous Fish in the Concord River Watershed after the TFC Discussion.

The top seven most abundantly expected species, comprising approximately 83% of the total, include fallfish (37.3%), common shiner (18.7%), white sucker (9.3%), redbreast sunfish (6.2%), American eel (4.1%), tessellated darter (3.7%), and brook trout (3.4%). The remaining species have expected proportions between 1.4% and 2.9% and represent almost 17% of the fauna. The species includes fluvial specialists such as fallfish, tessellated darter, brook trout and the creek chubsucker as well as fluvial dependents such as common shiner and white sucker, and macrohabitat generalists such as redbreast sunfish, American eel, bridle shiner, yellow perch, pumpkinseed, chain pickerel, brown bullhead, redfin pickerel and golden shiner.

The TFC based on habitat use classifications is composed of 45.8% fluvial specialist, 28.0% fluvial dependent, and 26.4% macrohabitat generalist species. Relative to pollution tolerances, the TFC is composed of 7.7% intolerant, 75.4% moderate, and 17.1% tolerant fish species.

The TFC based on habitat use classification guilds and pollution tolerance is graphically shown in Figures 2 and 3 in the TFC Discussion Section 3.3 and the TFC results for these two metrics are compared to the total existing fish community (EFC), and the existing fish communities in the impoundment (EFC-I) and riverine (EFC-R) habitat reaches, respectively.

Assabet River Existing Fish Community

Assabet River Sampling Locations and Collection Method

The existing fish community was surveyed primarily in 2001. Fifteen (15) locations were sampled in the Assabet River main-stem using a backpack shocker, barge shocker, boat shocker or gill net as dictated by prevailing conditions at each of the sites (Table 2). The fish sample locations ranged from approximately River-mile 31 near the headwaters in Westboro to River-

mile 4 above confluence with the Sudbury River as shown in Figure 1. Nine of the locations sampled represented riverine habitats while six locations sampled represented impoundment (pond) habitats as a result of existing dams. Four of the six impoundments (Aluminum City Dam, Hudson Dam, Gleasondale Dam, and Ben Smith Dam) were sampled once while the Powdermill Dam Impoundment was sampled in two areas. No fish sample was collected in the Allen Street Impoundment. Since an assessment of water quality relative to the various wastewater treatment plants (WWTP) was also part of the overall study objectives several of the fish locations were selected to bracket the discharges of the various WWTPs (i.e. above and below the respective discharge).

Table 1. Target Fish Community (TFC) Model for the Assabet River Based on the Concord River Watershed.

Common Name	Scientific Name	Species Designation	Thermal Regime	Habitat Use	Pollution Tolerance	TFC %
Fallfish	Semotilus corporalis	Native	Eurythermal	FS	M	37.3
Common shiner	Notropis cornutus	Native	Eurythermal	FD	M	18.7
White sucker	Catostomus commersoni	Native	Eurythermal	FD	T	9.3
Redbreast sunfish	Lepomis auritis	Native	Warm	MG	M	6.2
American eel	Anguilla rostrata	Native	Eurythermal	MG(*)	T	4.1
Tesselated darter	Etheostoma olmstedi	Native	Eurythermal	FS	M	3.7
Brook trout	Savelinus fontinalis	Native	Cold	FS	I	3.4
Bridle shiner	Notropis bifrenatus	Native	Warm	MG	I	2.9
Yellow perch	Perca flavescens	Native	Eurythermal	MG	M	2.7
Pumpkinseed	Lepomis gibbosus	Native	Warm	MG	M	2.5
Chain pickerel	Esox niger	Native	Warm	MG	M	2.3
Brown bullhead	Ameiurus nebulosus	Native	Warm	MG	T	2.1
Redfin pickerel	Esox americanus	Native	Warm	MG	M	2
Golden shiner	Notemigonus crysoleucas	Native	Eurythermal	MG	T	1.6
Creek chubsucker	Erimyzon oblongus	Native	Eurythermal	FS	I	1.4
Alewife	Alosa pseudoherangus	Native	Eurythermal	FD	M	Expected
American Shad	Alosa sapidissima	Native	Warm	FD	M	Expected
Blueback Herring	Alosa aestivalis	Native	Warm	FD	M	Expected
Sea Lamprey	Petromyzon marinus	Native	Eurythermal	FD	M	Expected
Total						100.2

Native or Introduced status and Cold, Eurythermal, or Warm water thermal regime tolerances are given for each species; and following MA Habitat Use Classification Guilds: fluvial specialist (FS), fluvial dependent (FD), or macrohabitat generalist (MG); and Pollution Tolerances: intolerant (I), moderately tolerant (M), or tolerant (T).

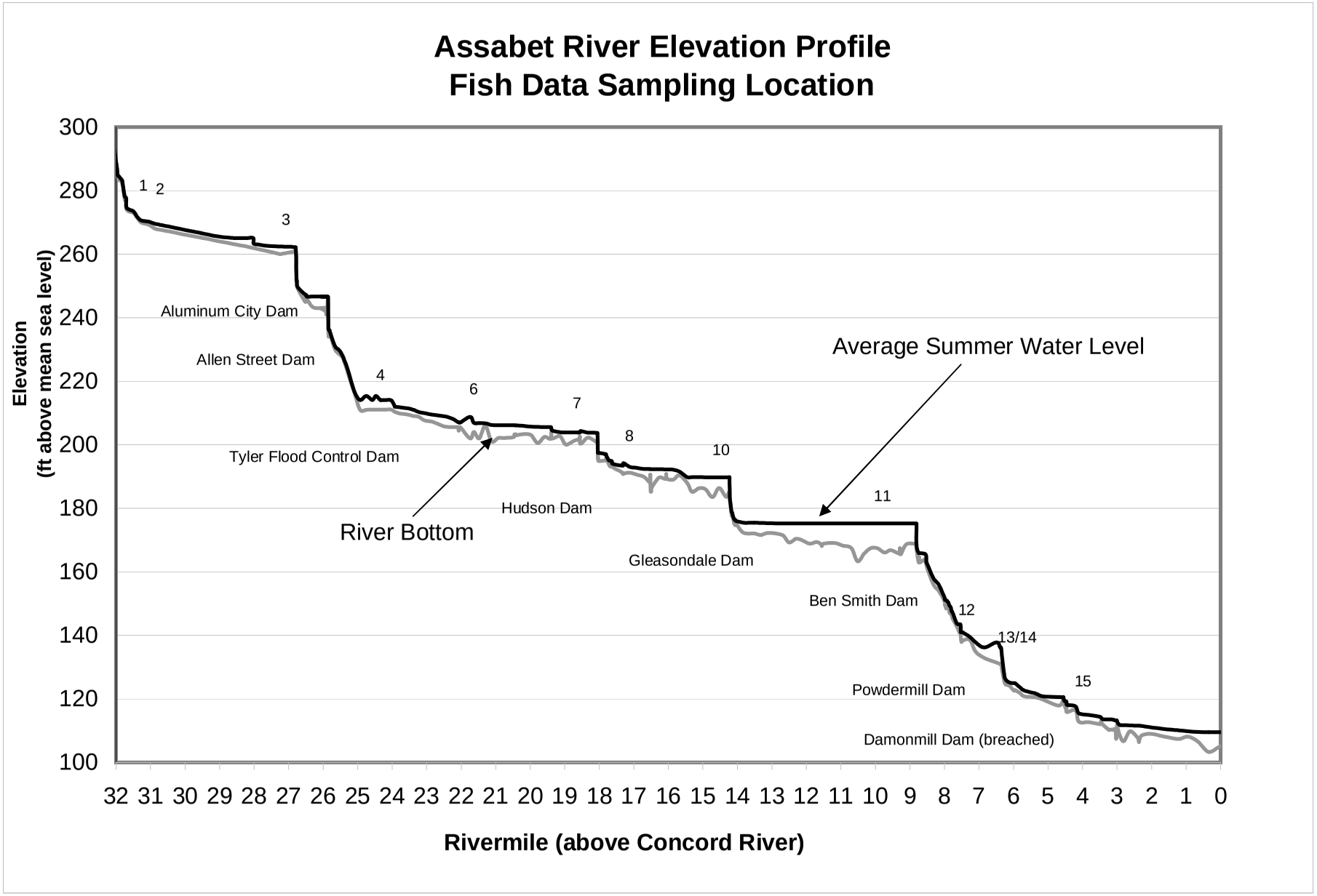
*American eel have been classified as fluvial dependent (FD) in other TFC due to this species dependency upon fluvial conditions for migration to and from the sea to complete their catadromous life-cycle.

Table 2. Assabet River Fish Data Sampling Locations, Methods and Habitat Types.

Station Number	Sample ID	Date	Town	Method	Habitat Type	Notes
1	502	7/25/2001	Westborough	Backpack Shocking	Riverine	Above Aluminum City Dam Impoundment
2	433	8/24/2001	Westboro	Barge Shocking	Riverine	Above Aluminum City Dam Impoundment
3	501	8/24/2001	Northboro	Barge Shocking	Impoundment	Within Aluminum City Dam Impoundment
4	373	6/7/2001	Northborough	Barge Shocking	Riverine	Above Hudson Dam Impoundment
5	308	6/7/2001	Northboro/Marlboro	Barge Shocking	Riverine	Above Hudson Dam Impoundment
6	91	8/31/1999	Berlin	Barge Shocking	Riverine	Above Hudson Dam Impoundment
7	498	5/18/2001	Hudson	Gillnet	Impoundment	Within Hudson Dam Impoundment
8	306	6/7/2001	Hudson	Barge Shocking	Riverine	Above Gleasondale Dam Impoundment
9	500	8/24/2001	Hudson	Barge Shocking	Riverine	Above GleasondaleDam Impoundment
10	427	5/30/2001	Hudson	Gillnet	Impoundment	Within Gleasondale Dam Impoundment
11	307	5/8/2001	Maynard	Boat Shocking	Impoundment	Within Ben Smith Dam Impoundment
12	497	7/11/2001	Maynard	Barge Shocking	Riverine	Above Powdermill Dam Impoundment
13	499	5/16/2001	Maynard	Boat Shocking	Impoundment	Within Powdermill Dam Impoundment
14	527	5/16/2001	Maynard	Boat Shocking	Impoundment	Within Powdermill Dam Impoundment
15	496	7/11/2001	Concord	Barge Shocking	Riverine	Below Breached Damonmill Dam

See Figure 1 for Assabet River sample locations and Attachment A (Tables 1-15) for individual fish sample collection data.

Figure 1


Assabet River Elevation Profile
Fish Data Sampling Location
Elevation
(ft above mean sea level)
300
280
260
240
220
200
180
160
140
120
100
1
2
3
4
6
7
8
10
11
12
13/14
15
Aluminum City Dam
Allen Street Dam
Tyler Flood Control Dam
Hudson Dam
Gleasondale Dam
Ben Smith Dam
Powdermill Dam
Damonmill Dam (breached)
Average Summer Water Level
River Bottom
32 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
Rivermile (above Concord River)

Assabet River Existing Fish Community (EFC) - Total Catch All Habitats

The Existing Fish Community (EFC) for the Assabet River based on the total catch by sampling the main-stem river in both impoundment and riverine habitats is provided in Table 3. A total of 1,881 fish representing 23 species were identified in the Assabet River during the fish surveys. The individual fish collection data for each of the 15 locations is provided in Attachment A.

The top ten (10) most abundantly collected species, comprising approximately 85.5% of the total, include white sucker (20.3%), bluegill (17.3%), pumpkinseed (11.7%), largemouth bass (8.1%), American eel (6.3%), yellow bullhead (4.7%), redbreast sunfish (4.7%), fallfish (4.4%), golden shiner (4.1%), and blacknose dace (3.9%). The remaining thirteen (13) species (redfin pickerel, chain pickerel, black crappie, common carp, yellow perch, brown bullhead, rainbow trout, creek chubsucker, spottail shiner, banded sunfish, brook trout, and tiger trout) comprise between 3.2% and 0.1% of the total catch and represent 14.5% of the fauna.

The EFC based on habitat use classification consisted of 11.2% fluvial specialist, 20.3% fluvial dependent, and 68.5% macrohabitat generalist fish species. Relative to pollution tolerances, the EFC consisted of 2.9% intolerant, 35.6% moderate, and 61.5% tolerant fish species. A total of 23 different fish species were sampled from the Assabet River, 14 of which were native, comprising 64% of the total catch. Eight non-native fish species, bluegill, black crappie, brown trout, largemouth bass, rainbow trout, rock bass, smallmouth bass, and yellow bullhead and one hybrid species (tiger trout) were collected and accounted for a combined 36% of the total catch.

The EFC based on habitat use classification guilds and pollution tolerances is graphically shown in Figures 2 and 3.

Assabet River Existing Fish Community for Impoundment Habitats (EFC-I)

The Existing Fish Community for the impoundments (EFC-I) in the Assabet River based on six sampling stations is provided in Table 4. A total of 698 fish representing 15 species were identified in the Assabet River during the fish surveys in the impoundments.

The top ten (7) most abundantly collected species, comprising approximately 88.3% of the total, include bluegill (34.2%), pumpkinseed (22.1%), white sucker (10.3%), largemouth bass (9.2), American eel (4.6%), common carp (4.2%), and black crappie (3.7%). The remaining eight (8) species (chain pickerel, redbreast sunfish, yellow bullhead, brown bullhead, yellow perch, redfin pickerel, golden shiner, and banded sunfish) comprise between 3.0% and 0.1% of the total catch and represent 11.7% of the fauna.

The EFC for impoundment habitats (EFC-I) consisted of 0% fluvial specialist, 10.3% fluvial dependent, and 89.7% macrohabitat generalist fish species. Relative to Pollution Tolerance, the EFC-I consisted of 0% intolerant, 39.4% moderate, and 60.6% tolerant fish species. A total of 15 different fish species were sampled from the Assabet River impoundments, ten (10) of which were native, comprising 47% of the total catch. Five non-native fish species, bluegill, largemouth bass, common carp, black crappie and yellow bullhead were collected and accounted for 53% of the total catch.

The EFC-I for impoundment habitats based on habitat use classification guilds and pollution tolerance is graphically shown in Figures 2 and 3. (See TFC Discussion Section 3.3.)

Assabet River Existing Fish Community for Riverine Habitats (EFC-R)

The Existing Fish Community for riverine habitat (EFC-R) in the Assabet River based on nine sampling stations is provided in Table 5. A total of 1183 fish representing 22 species were identified in the Assabet River during the fish surveys of riverine habitat.

The top eleven (11) most abundantly collected species, comprising approximately 91.0% of the total, include white sucker (26.2%), largemouth bass (7.5), American eel (7.4%), bluegill (7.3%), fallfish (7.0%), yellow bullhead (6.3%), golden shiner (6.3%), blacknose dace (6.3%), redbreast sunfish (6.1%), pumpkinseed (5.7%), and redfin pickerel (4.9%).

The remaining eleven (11) species (chain pickerel, rainbow trout, creek chubsucker, brown trout, spottail shiner, brook trout, yellow perch, brown bullhead, black crappie, banded sunfish, and tiger trout) comprise between 1.5% and 0.1% of the total catch and represent 9.0% of the fauna.

The EFC for riverine habitats (EFC-R) consisted of 17.8% fluvial specialist, 26.2% fluvial dependent, and 56.0% macrohabitat generalist fish species. Relative to pollution tolerances, the EFC consisted of 4.6% intolerant, 33.4% moderate, and 62.0% tolerant fish species. A total of 22 different fish species were sampled from the Assabet River impoundments, fourteen (14) of which were native, comprising 75% of the total catch. Eight non-native fish species, largemouth bass, bluegill, yellow bullhead, rainbow trout, brown trout, spottail shiner, black crappies, and tiger trout accounted for 25% of the total catch.

The EFC-R for riverine habitats based on habitat use classification guilds and pollution tolerance are graphically shown in Figures 2 and 3. (See TFC Discussion Section 3.3.)

Figure 2. Assabet River Habitat-Use
EFC -Total Count

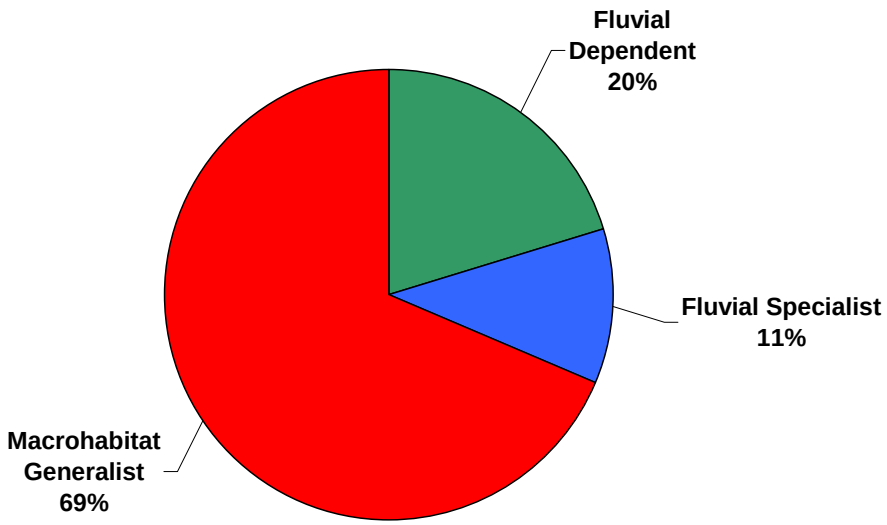


Figure 3. Assabet River Pollution Tolerance
EFC - Total Count

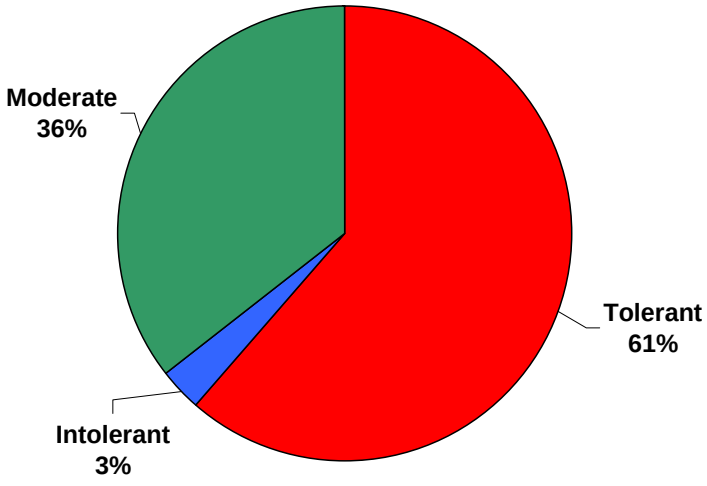


Table 3. Assabet River Existing Fish Community (EFC) - Total Catch All Habitats Relative Abundance and Species Composition of Fishes Collected.

Common Name	Scientific Name	Total	Percent Comp	Designation	Thermal Regime	MA HUC	Pollution Tolerance
White sucker	Catostomus commersoni	382	20.3	Native	Eurythermal	FD	T
Bluegill	Lepomis macrochirus	325	17.3	Introduced	Warm	MG	T
Pumpkinseed	Lepomis gibbosus	221	11.7	Native	Warm	MG	M
Largemouth bass	Micropterus salmoides	153	8.1	Introduced	Warm	MG	M
American eel	Anguilla rostrata	119	6.3	Native	Eurythermal	MG (*)	T
Yellow bullhead	Ameiurus natalis	89	4.7	Introduced	Warm	MG	T
Redbreast sunfish	Lepomis auritus	88	4.7	Native	Warm	MG	M
Fallfish	Semotilus corporalis	83	4.4	Native	Eurythermal	FS	M
Golden shiner	Notemigonus crysoleucas	78	4.1	Native	Eurythermal	MG	T
Blacknose dace	Rhinichthys atratulus	74	3.9	Native	Eurythermal	FS	T
Redfin pickerel	Esox americanus americanus	61	3.2	Native	Warm	MG	M
Chain pickerel	Esox niger	39	2.1	Native	Warm	MG	T
Black crappie	Pomoxis nigromaculatus	32	1.7	Introduced	Warm	MG	M
Common carp	Cyprinus carpio	29	1.5	Introduced	Warm	MG	T
Yellow perch	Perca flavescens	21	1.1	Native	Eurythermal	MG	M
Brown trout	Salmo trutta	20	1.1	Introduced	Cold	FS	I
Brown bullhead	Ameiurus nebulosus	19	1.0	Native	Warm	MG	T
Rainbow trout	Oncorhynchus mykiss	16	0.9	Introduced	Cold	FS	I
Creek chubsucker	Erimyzon oblongus	15	0.8	Native	Eurythermal	FS	I
Spottail shiner	Notropis hudsonius	11	0.6	Introduced	Eurythermal	MG	M
Banded sunfish	Enneacanthus obesus	3	0.2	Native	Warm	MG	T
Brook trout	Salvelinus fontinalis	2	0.1	Native	Cold	FS	I
Tiger trout	Salvelinus fontinalis X Salmo trutta	1	0.1	Hybrid	Cold	FS	I
Totals:		**1881**	**100.0**				

*American eel have been classified as *fluvial dependent* (FD) in other TFC due to this species dependency upon fluvial conditions for migration to and from the sea to complete their catadromous life-cycle.

Table 4. Assabet River EFC for Impoundments (EFC-I) - Relative Abundance and Composition of Fishes Collected within Assabet River Impoundments.

Sample Site Numbers 307, 427, 498, 499, 501, and 527 (n=6).

Common Name	Number Collected	Percent Composition	Habitat Use Class	Pollution Tolerance
Bluegill	239	34.2	MG	T
Pumpkinseed	154	22.1	MG	M
White sucker	72	10.3	FD	T
Largemouth bass	64	9.2	MG	M
American eel	32	4.6	MG	T
Common carp	29	4.2	MG	T
Black crappie	26	3.7	MG	M
Chain pickerel	21	3.0	MG	T
Redbreast sunfish	16	2.3	MG	M
Yellow bullhead	14	2.0	MG	T
Brown bullhead	12	1.7	MG	T
Yellow perch	12	1.7	MG	M
Redfin pickerel	3	0.4	MG	M
Golden shiner	3	0.4	MG	T
Banded sunfish	1	0.1	MG	T
Totals:	698	100.0		

Table 5. Assabet River EFC for Riverine Habitats (EFC-R) - Relative Abundance and Composition of Fishes Collected in Riverine Habitats.

Sample Site Numbers 91, 306, 308, 373, 433, 496, 497, 500, and 502 (n-9).

Common Name	Number Collected	Percent Composition	Habitat Use Class	Pollution Tolerance
White sucker	310	26.2	FD	T
Largemouth bass	89	7.5	MG	M
American eel	87	7.4	MG	T
Bluegill	86	7.3	MG	T
Fallfish	83	7.0	FS	M
Yellow bullhead	75	6.3	MG	T
Golden shiner	75	6.3	MG	T
Blacknose dace	74	6.3	FS	T
Redbreast sunfish	72	6.1	MG	M
Pumpkinseed	67	5.7	MG	M
Redfin pickerel	58	4.9	MG	M
Chain pickerel	18	1.5	MG	T
Rainbow trout	16	1.4	FS	I
Creek chubsucker	15	1.3	FS	I
Brown trout	12	1.0	FS	I
Spottail shiner	11	0.9	MG	M
Brook trout	10	0.8	FS	I
Yellow perch	9	0.8	MG	M
Brown bullhead	7	0.6	MG	T
Black crappie	6	0.5	MG	M
Banded Sunfish	2	0.2	MG	T
Tiger trout	1	0.1	FS	I
Totals:	**1183**	**100.0**		

3.3 TFC DISCUSSION

Comparison of Concord River (SuAsCo) Watershed Target Fish Community (TFC) Model to Assabet River Existing Fish Community–Total Catch (EFC), EFC-Impoundments (EFC-I), & EFC-Riverine Habitats (EFC-R)

As previously discussed the Target Fish Community (TFC) approach was recommended by MADFW as the methodology to be used on the Assabet River to evaluate the current or existing fisheries community for the main-stem river and those in impounded or riverine habitats and the potential fisheries community and habitat that is expected to occur as the result of dam removal.

The goal of developing a TFC for the main-stem Assabet River is to define the fish community that is appropriate for a natural river of this size in southern New England. Accordingly TFC assessments are used to identify the current status of a main-stem river such as the Assabet River in that the fish tell the story as they are long-lived, reflect stresses over time, and are easily recognized and identified.

The premise for the TFC is quite simple in that Rivers should have fluvial or "river" fish communities. In terms of target fish communities, the general objective for rivers is to have the fish population comprised in a large part of native, fluvial specialists and fluvial dependent species.

The TFC for the SuAsCo serves as our target for river rehabilitation in the Assabet River and as an endpoint of evaluating environmental improvements such as the removal of dams. The sampled existing fish community (EFC) is compared to the target fish community (TFC) to evaluate the potential fish community resulting from the river rehabilitation objective (i.e. removal of a dam). Use of the target fish community approach can guide and evaluate environmental rehabilitation where restoration objectives cannot simply be to copy pristine, natural ecosystem properties. This is accomplished by comparing the TFC Model for the Concord River (SuAsCo) Watershed to the total existing fish communities in the main-stem river (EFC), the existing fish communities in the impounded segments (EFC-I), and the existing fish community in the free flowing or riverine segments (EFC-R).

The strength in this TFC evaluation is in the comparison of the TFC or reference model community to the existing fish community (EFC) that is a composite of all main-stem samples (total catch), the existing fish community in the riverine sites (EFC-R), and to the existing fish community in all pond sites or impoundments (EFC-I) (pers. Comm. Todd Richards 2008).

The comparison of the TFC and the Existing Fish Communities (EFC) based on habitat use classification guilds and pollution tolerance is summarized in Table 6 and graphically shown in Figures 2 and 3, respectively. As per our SuAsCo Model the reference or expected TFC for the Assabet River fish population is comprised of 15 native species and based on Habitat Use-Class represents 45.8% fluvial Specialists, 28.0% fluvial Dependents, and 26.4% microhabitat generalists. Based on Pollution Tolerance Classification Guilds the TF C is comprised on 7.7% intolerant, 75.4% moderate, and 17.1% tolerant fish species.

Table 6. Comparison of the Target Fish Community (TFC) and Existing Fish Communities (EFC) Based on Habitat-Use and Pollution Tolerance Classification Guilds.

Habitat-Use Class	Expected TFC	Total Existing Fish Community	Impoundment Only	Riverine Only
Fluvial Specialist	45.8	11.2	0	17.8
Fluvial Dependent	28	20.3	10.3	26.2
Macrohabitat Generalist	26.4	68.5	89.7	56
Pollution Tolerance	**Expected TFC**	**Total Existing Fish Community**	**Impoundment Only**	**Riverine Only**
Intolerant	7.7	2.9	0	4.6
Moderate	75.4	35.6	39.4	33.4
Tolerant	17.1	61.5	60.6	62

Relative to comparisons using habitat use classes (Figure 2), the existing fish community (EFC) representing both impoundment and riverine habitats is made up of 68.5% microhabitat generalists, 20.3% fluvial dependents and only 11.2% fluvial specialists. The dramatic increase in the EFC proportion of macrohabitat generalist fish species (that are also more pollution tolerant) and subsequent decrease in the proportion of fluvial fish species to the TFC is anticipated since the continuity of the riverine habitat of the main stem Assabet is fragmented by the dams and their respective impoundments (ponds). Consequently the EFC proportion is also dominated by pollution tolerant fish species at 61.5% with decreasing proportions for moderate (35.6%) and intolerant (2.9%).

Looking at the existing fish community in the impoundments only further strengthens the observed trends in the aforementioned data and our premise that rivers should have river fish communities. The EFC-I is completely dominated by macrohabitat generalists at a proportion of 89.7% followed by only 10.3% for fluvial dependents (white sucker only) and no (0%) fluvial specialists. Consequently the EFC-I proportion is also dominated by pollution tolerant fish species at 60.6% followed by 39.4% for moderate and no (0%) intolerant fish species.

In contrast, the existing fish community in the riverine reaches between the various dams and their impoundments shows signs of recovery in comparison to the TFC relative to the presence of fluvial specialists and increasing proportions of riverine fish species and their abundance. The EFC-R, albeit still dominated by macrohabitat generalists at 56.0%, is also comprised of 26.2 fluvial dependents (white sucker only) and 17.8% fluvial specialists. Similarly the pollution tolerance trends for EFC-R in comparison to the TFC follow that for habitat use being dominated by 62.0% tolerant followed by 33.4% moderate and 4.6% intolerant fish species.

Seven (7) fluvial specialist fish species accounting for 17.8% of the EFC-R were collected in the riverine habitats between the dams while not one fluvial specialist was collected in any of the impoundment collections since they require riverine and not pond habitat. The fluvial species collected include fallfish (7.0%), blacknose dace (6.3%), rainbow trout (1.4%), creek chubsucker (1.3%), brown trout (1.0%), brook trout (0.8%), and tiger trout (0.1%). Fallfish, blacknose dace, creek chubsucker and brook trout are native species while rainbow trout, brown trout and tiger trout (brown X brook hybrid) are introduced species probably stocked within the watershed by the MADFW. It is interesting to note that all of the aforementioned trout species are pollution intolerant and are also classified as coldwater relative to their thermal regime (Table 3) and they were only collected in riverine habitats in the Assabet River and not in any of the impoundments.

Comparing the TFC percentage in Table 1of three native FS species (fallfish at 37.3%, brook trout at 3.4%, and creek chubsucker at 1.4%) to their percentage in Table 5 for the EFC-R (fallfish at 7.0%, brook trout at 0.8%, and creek chubsucker at 1.3%) reveals some recovery of the existing river fish community in these reaches on the Assabet River. However, the continuity of the overall river system is fragmented by the existing dams and impoundments that also impact the value and function of these ecosystems as shown by the EFC relative abundance and species composition in Table 3. This TFC comparison indicates that there is potential for further improvement towards achieving the TFC model commensurate upon the removal of dams.

FIGURE 4
Comparison of the Target Fish Community (TFC) and Existing Fish Communities (EFC) Based on Habitat-Use Classification Guilds

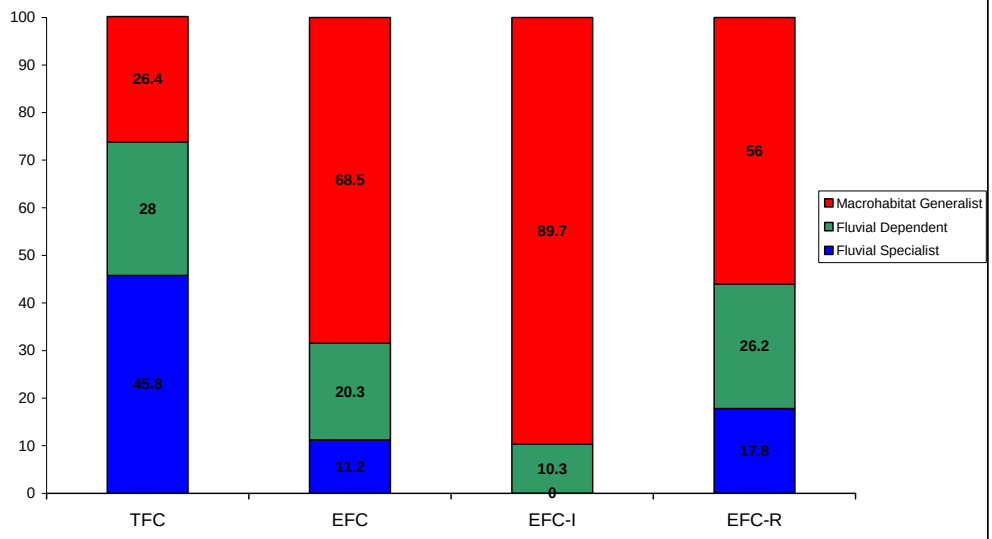
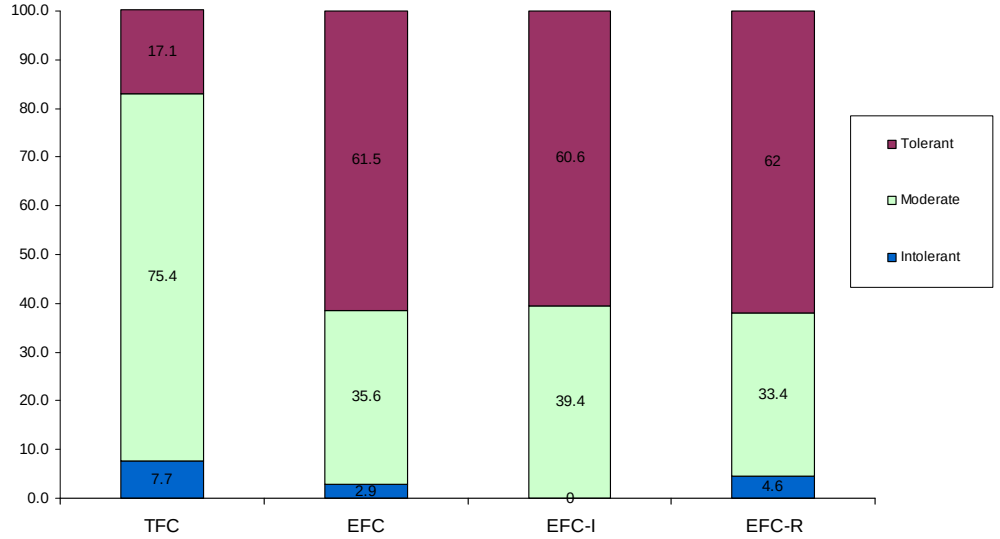


FIGURE 5
Comparison of the Target Fish Community (TFC) and Existing Fish Communities (EFC) Based on Pollution Tolerance Classification Guilds



TFC = Target Fish Community
EFC = Existing Fish Community
EFC-I = Existing Fish Community- Impoundment
EFC-R = Existing Fish Community - Riverine

4. CURRENT STATUS OF RESTORATION OF ANADROMOUS FISH

Over the long term the objective of the U.S. Fish and Wildlife Service (USFWS) is to restore anadromous fish populations in the Sudbury-Assabet-Concord River system (SUASCO). The SUASCO System is connected to the Atlantic Ocean by the Merrimack River. USFWS began the alewife restoration program in the Concord River watershed in 2000 with the transfer of 7,500 alewife from the Nemasket River in southeastern Massachusetts into four sites on the mainstem of the Concord River. Since 2000, USFWS has annually stocked between 5,000 and 7,500 alewife at various locations, progressively moving upriver and recently focused on the Sudbury River.

To access the SUASCO system for breeding the anadromous fish first need to negotiate the Essex Dam in Lawrence, Massachusetts on the Merrimack River. This dam has a fish lift, however the passage conditions here are not optimum. During the high flows that frequently exist during the passage season, competitive flow along the face of the dam (leaky flashboards and flow in excess of the hydraulic capacity) along with predation problems associated with the congregation of the alewife at the fish lift (there is a large stripe bass presences in the tailrace area that greatly impacts alewife during passage) can greatly complicate the successful passage of fish past the dam. Annual fish returns at the Essex Dam in Lawrence are shown in Table 7.

Once past the Essex Dam on the Merrimack River anadromous fish can enter the Concord River in Lowell. On the Concord River mainstem there are a number of impediments to fish passage, In the lower part of the river is the remains of the Middlesex Dam which has been extensively destroyed and is at most only a minor hindrance. Upstream from this is Massuc Falls which is a fairly extensive waterfall. During high flows the falls is mostly flooded out allowing fish passage. Further upstream is the Centennial Island Hydroelectric Facility with a Denil fish ladder.

Lastly, in Billerica is the Billerica Dam (aka Talbot Mills Dam, aka Faulkner Mills Dam). This structure is an absolute impediment to passage. Considerable effort has gone into developing a plan to address this structure with the possibility of complete dam removal.

USFWS is continuing restoration efforts from improving the migratory corridor to developing self sustaining clupeid stocks within the watershed. USFWS have successfully introduced alewife in the Concord-Sudbury system and observed successful breeding of introduced adults. It is expected that the Assabet River would also provide suitable breeding habitat if access were not an issue.

Table 7. Anadromous Fish Returns on the Merrimack River			
Year	River Herring *	American Shad	Atlantic Salmon
1982			23
1983	4,794	5,629	114
1984	1,769	5,497	115
1985	23,112	12,793	213
1986	16265	18,173	103
1987	77209	16,909	139
1988	361012	12,359	65
1989	387973	7,875	84
1990	254242	6,013	248
1991	379588	16,098	332
1992	102166	20,796	199
1993	14027	8,599	61
1994	88913	4,349	21
1995	33425	13,861	34
1996	51	11,322	76
1997	403	22,661	71
1998	1362	27,891	123
1999	7898	56,461	185
2000	24576	72,800	82
2001	1,550	76,717	83
2002	526	54,586	56
2003	10,607	55,620	147
2004	15,051	36,593	129
2005	99	6,382	34
2006	1,257	1,205	91
2007	1,169	17,529	74
2008	108	25,116	119
TOTAL	**1,809,152**	**613,834**	**3,021**

All counts were taken at the Essex Dam Fish Lift in Lawrence, Massachusetts

*River Herring refers collectively to two fish species: blueback herring and alewife

Historically American eel were very abundant in east coast streams. Eel populations appear to be declining in North America. Possible reasons for population decline include barriers to upstream and downstream migration, habitat loss and alternation, ocean conditions, over-fishing,

parasitism, and contaminants. Since 2004 the USFWS and NMFS have been considering extending Federal Endangered Species Act protection to the American eel. The reasons for the sharp decline in American eel stocks across the North Atlantic remain as mysterious as its long migrations. A recent study by a NOAA scientist and colleagues in Japan and the United Kingdom says shifts in ocean-atmosphere conditions may be a primary factor in declining reproduction and survival rates (NOAA 2008).

American eel have been found recently upstream of all Assabet River mainstem dams and slow moving reaches of the Assabet River and tributary streams. Warm-water ponds in the watershed contains considerable potential eel habitat. Upstream migration of juvenile eel likely occurs from April through early summer. Juveniles can survive out of water so long as their skin is moist and they can ascend obstructions such as small dams that block movement of other fish. Installation of specially designed fishways for eel or dam removal would greatly improve eel migration efficiency in the Assabet River.

5. SUMMARY

General Impacts of Dams on Aquatic Habitat

Dams can be detrimental to aquatic habitat as they fragment and block access to habitat. This ecosystem fragmentation has been linked to declines in biodiversity. Dams interrupt the migration of diadromous fish and the movement of resident aquatic species to habitat for spawning, nursery, or refuge. (MADEP, 2007) Many species such as Atlantic salmon, brook trout, river herring, and shad have generally suffered dramatic population declines, in part due to the impact of dams on migratory corridors. The removal of a dam reconnects the upstream and down stream river lengths, significantly expanding the area and quality of land under water for fisheries habitat. While the presence of additional dams upstream or downstream may limit the extent of restoration, dam removal can still provide benefits, even on limited reaches of rivers.

The re-introduction of anadromous fishes to their previous spawning grounds will also have a positive effect on the ecology of those freshwater systems such as the Assabet River (Loesch 1987). In freshwater areas where herring have been restored, studies show that resident fish populations were enhanced. The juvenile herring produced in the spawning run serve as a food supply for bass and other resident species. All life stages of anadromous herrings are important forage for many freshwater and marine fishes; in addition, birds, amphibians, reptiles, and mammals have also been documented as predators. The mortality of anadromous alewives provides an important source of nutrients for headwater ponds.

Dams transform free-flowing rivers to slow-moving water bodies and create impoundments that can become sinks for sediment. Over time impoundments may collect sediments that are contaminated with nutrients and/or urban pollutants and this will further impact the aquatic habitat.

Dams also impact water quality as impoundments increase summer water temperatures significantly by creating larger, slower moving water surface areas exposed to sun. Warmer temperatures decrease the dissolved oxygen content of the water both in the impoundment and for often for some distance downstream of the dam. Dam removal eliminates these artificial impoundments and can significantly improve fisheries habitat and water quality by restoring riverine conditions that support cooler water temperatures and improved dissolved oxygen.

The Assabet TFC versus the EFC

A target fish community (TFC) can be used as a guide to identify the composition of a healthy fish community for large streams and small rivers in the New England region and can guide and evaluate river rehabilitation.

The existing fish community (EFC) in the Assabet is not consistent with the target fish community (TFC) proposed for River. Current fish species composition consists primarily of microhabitat generalists and pollution tolerant species. The overall dominance of macrohabitat generalists and lack of fluvial specialist is directly related to the effect of the dams and the creation of impoundments in what naturally would be free flowing stretches of river. The dominance of the current fish population by more pollution tolerant species (e.g. white sucker and bluegill) indicates that the Assabet River ecosystem is somewhat degraded by a combination water and/or sediment quality as a result of the six dams and their impoundments on the main stem of the Assabet River.

In conclusion, it is expected that removing dams on the Assabet River and improving water quality will provide habitat that will support the increase in fluvial dependent and fluvial specialist species consistent with the proposed target fish community (TFC) for this river. Removal of the priority Ben Smith Dam due to the length of the impoundment (about 2 miles) is expected to result in a significant improvement of the existing fish community (EFC) in this river reach towards achieving the target fish community (TFC) reference model. Over the long term, removing dams on the Assabet would also provide for the future restoration of the migratory corridor on the Assabet and provide access to spawning grounds and nursery habitat for anadromous species when passage is provided at the Talbot Dam in Billerica. In the short term, American eel would likely benefit from removal of obstructions such as dams that impede upstream and downstream passage and make their migration more difficult.

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ATTACHEMENT A

ASSABET RIVER DATA

See FIGURE 1 in page E-11 for site locations.

Site 1. Relative abundance and composition of fishes collected by backpack shocking from the Assabet River (Sample Site Number 502)

Common Name	Number Collected	Percent Composition	Habitat Use Class	Pollution Tolerance
White sucker	23	33.8	FD	T
Largemouth bass	22	32.4	MG	M
Yellow bullhead	15	22.1	MG	T
Chain pickerel	5	7.4	MG	T
Bluegill	2	2.9	MG	T
Golden shiner	1	1.5	MG	T
Totals:	**68**	**100.0**		

Site 2. Relative abundance and composition of fishes collected by barge shocking from the Assabet River (Sample Site Number 433).

Common Name	Number Collected	Percent Composition	Habitat Use Class	Pollution Tolerance
White sucker	97	44.9	FD	T
Golden shiner	53	24.5	MG	T
Redfin pickerel	30	13.9	MG	M
Pumpkinseed	14	6.5	MG	M
Chain pickerel	7	3.2	MG	T
Fallfish	4	1.9	FS	M
Brown bullhead	4	1.9	MG	T
Bluegill	3	1.4	MG	T
Largemouth bass	2	0.9	MG	M
Yellow bullhead	2	0.9	MG	T
Totals:	**216**	**100.0**		

Site 3. Relative abundance and composition of fishes collected by barge shocking from the Assabet River (Sample Site Number 501).

Common Name	Number Collected	Percent Composition	Habitat Use Class	Pollution Tolerance
White sucker	14	46.7	FD	T
Yellow bullhead	7	23.3	MG	T
American eel	5	16.7	MG	T
Pumpkinseed	1	3.3	MG	M
Redfin pickerel	1	3.3	MG	M
Brown bullhead	1	3.3	MG	T
Chain pickerel	1	3.3	MG	T
Totals:	**30**	**100.0**		

Site 4. Relative abundance and composition of fishes collected by barge shocking from the Assabet River (Sample Site Number 373).

Common Name	Number Collected	Percent Composition	Habitat Use Class	Pollution Tolerance
Blacknosed dace	72	31.6	FS	T
White sucker	46	20.2	FD	T
Bluegill	42	18.4	MG	T
Rainbow trout	13	5.7	FS	I
Fallfish	12	5.3	FS	M
Brown trout	9	3.9	FS	I
American eel	8	3.5	MG	T
Yellow bullhead	6	2.6	MG	T
Creek chubsucker	6	2.6	FS	I
Redfin pickerel	5	2.2	MG	M
Pumpkinseed	4	1.8	MG	M
Brook trout	2	0.9	FS	I
Chain pickerel	2	0.9	MG	T
Tiger trout	1	0.4	FS	I
Totals	**228**	**100.0**		

Site 5. Relative abundance and composition of fishes collected by barge shocking from the Assabet River (Sample Site Number 308).

Common Name	Number Collected	Percent Composition	Habitat Use Class	Pollution Tolerance
White sucker	12	24.0	FD	T
Bluegill	9	18.0	MG	T
American eel	9	18.0	MG	T
Brook trout	8	16.0	FS	I
Redfin pickerel	6	12.0	MG	M
Rainbow trout	3	6.0	FS	I
Pumpkinseed	3	6.0	MG	M
Totals:	**50**	**100.0**		

Site 6. Relative abundance and composition of fishes collected by barge shocking from the Assabet River (Sample Site Number 91).

Common Name	Number Collected	Percent Composition	Habitat Use Class	Pollution Tolerance
White sucker	66	31.6	FD	T
Largemouth bass	54	25.8	MG	M
American eel	17	8.1	MG	T
Yellow bullhead	17	8.1	MG	T
Redfin pickerel	14	6.7	MG	M
Redbreast sunfish	11	5.3	MG	M
Creek chubsucker	9	4.3	FS	I
Fallfish	7	3.3	FS	M
Pumpkinseed	5	2.4	MG	M
Golden shiner	4	1.9	MG	T
Blacknosed dace	2	1.0	FS	T
Brown trout	2	1.0	FS	I
Banded Sunfish	1	0.5	MG	T
Totals:	**209**	**100.0**		

Site 7. Relative abundance and composition of fishes collected by gillnet from the Assabet River (Sample Site Number 498).

Common Name	Number Collected	Percent Composition	Habitat Use Class	Pollution Tolerance
Bluegill	50	61.7	MG	T
White sucker	11	13.6	FD	T
Pumpkinseed	8	9.9	MG	M
Black crappie	5	6.2	MG	M
Chain pickerel	4	4.9	MG	T
Largemouth bass	3	3.7	MG	M
Totals:	**81**	**100.0**		

Site 8. Relative abundance and composition of fishes collected by bardge shocking from the Assabet River (Sample Site Number 306).

Common Name	Number Collected	Percent Composition	Habitat Use Class	Pollution Tolerance
White sucker	30	22.1	FD	T
Fallfish	21	15.4	FS	M
American eel	20	14.7	MG	T
Redbreast sunfish	17	12.5	MG	M
Bluegill	14	10.3	MG	T
Golden shiner	12	8.8	MG	T
Pumpkinseed	7	5.1	MG	M
Black crappie	6	4.4	MG	M
Yellow bullhead	6	4.4	MG	T
Brown bullhead	2	1.5	MG	T
Banded Sunfish	1	0.7	MG	T
Totals:	**136**	**100.0**		

Site 9. Relative abundance and composition of fishes collected by barge shocking from the Assabet River (Sample Site Number 500).

Common Name	Number Collected	Percent Composition	Habitat Use Class	Pollution Tolerance
Pumpkinseed	34	28.8	MG	M
Yellow bullhead	19	16.1	MG	T
Redbreast sunfish	16	13.6	MG	M
American eel	12	10.2	MG	T
Bluegill	9	7.6	MG	T
Largemouth bass	7	5.9	MG	M
White sucker	5	4.2	FD	T
Fallfish	5	4.2	FS	M
Golden shiner	4	3.4	MG	T
Redfin pickerel	3	2.5	MG	T
Chain pickerel	2	1.7	MG	T
Yellow perch	1	0.8	MG	M
Brown bullhead	1	0.8	MG	T
Totals:	**118**	**100.0**		

Site 10. Relative abundance and composition of fishes collected by gillnet from the Assabet River (Sample Site Number 427).

Common Name	Number Collected	Percent Composition	Habitat Use Class	Pollution Tolerance
White sucker	6	66.7	FD	T
Largemouth bass	2	22.2	MG	M
Chain pickerel	1	11.1	MG	T
Totals:	**9**	**100.0**		

Site 11. Relative abundance and composition of fishes collected by boat shocking from the Assabet River (Sample Site Number 307)

Common Name	Number Collected	Percent Composition	Habitat Use Class	Pollution Tolerance
Bluegill	142	40.5	MG	T
Pumpkinseed	110	31.3	MG	M
Largemouth bass	27	7.7	MG	M
Black crappie	15	4.3	MG	M
American eel	14	4.0	MG	T
Chain pickerel	12	3.4	MG	T
Common carp	11	3.1	MG	T
Brown bullhead	8	2.3	MG	T
Yellow bullhead	5	1.4	MG	T
White sucker	2	0.6	FD	T
Redfin pickerel	2	0.6	MG	M
Golden shiner	2	0.6	MG	T
Banded sunfish	1	0.3	MG	T
Totals:	**351**	**100.0**		

Site 12. Relative abundance and composition of fishes collected by barge shocking from the Assabet River (Sample Site Number 497).

Common Name	Number Collected	Percent Composition	Habitat Use Class	Pollution Tolerance
White sucker	18	28.1	FD	T
Redbreast sunfish	15	23.4	MG	M
American eel	14	21.9	MG	T
Fallfish	13	20.3	FS	M
Bluegill	2	3.1	MG	T
Brown trout	1	1.6	FS	I
Yellow bullhead	1	1.6	MG	T
Totals:	**64**	**100.0**		

Site 13. Relative abundance and composition of fishes collected by boat shocking from the Assabet River (Sample Site Number 499).

Common Name	Number Collected	Percent Composition	Habitat Use Class	Pollution Tolerance
White sucker	26	29.9	FD	T
Common carp	15	17.2	MG	T
Largemouth bass	13	14.9	MG	M
Redbreast sunfish	11	12.6	MG	M
Bluegill	9	10.3	MG	T
Pumpkinseed	5	5.7	MG	M
American eel	5	5.7	MG	T
Yellow perch	2	2.3	MG	M
Yellow bullhead	1	1.1	MG	T
Totals:	**87**	**100.0**		

Site 14. Relative abundance and composition of fishes collected by boat shocking from the Assabet River (Sample Site Number 527).

Common Name	Number Collected	Percent Composition	Habitat Use Class	Pollution Tolerance
Bluegill	38	27.1	MG	T
Pumpkinseed	30	21.4	MG	M
Largemouth bass	19	13.6	MG	M
White sucker	13	9.3	FD	T
Yellow perch	10	7.1	MG	M
American eel	8	5.7	MG	T
Black crappie	6	4.3	MG	M
Redbreast sunfish	5	3.6	MG	M
Brown bullhead	3	2.1	MG	T
Chain pickerel	3	2.1	MG	T
Common carp	3	2.1	MG	T
Yellow bullhead	1	0.7	MG	T
Golden shiner	1	0.7	MG	T
Totals:	**140**	**100.0**		

Site 15. Relative abundance and composition of fishes collected by barge shocking from the Assabet River (Sample Site Number 496).

Common Name	Number Collected	Percent Composition	Habitat Use Class	Pollution Tolerance
Fallfish	21	22.3	FS	M
White sucker	13	13.8	FD	T
Redbreast sunfish	13	13.8	MG	M
Spottail shiner	11	11.7	MG	M
Yellow bullhead	9	9.6	MG	T
Yellow perch	8	8.5	MG	M
American eel	7	7.4	MG	T
Bluegill	5	5.3	MG	T
Largemouth bass	4	4.3	MG	M
Chain pickerel	2	2.1	MG	T
Golden shiner	1	1.1	MG	T
Totals:	**94**	**100.0**		

APPENDIX F

CULTURAL RESOURCES IDENTIFICATION

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Assabet River Sediment Study

CULTURAL RESOURCES IDENTIFICATION

Prehistoric and historic contexts for the Assabet River Sediment Study were prepared in Phase II, as part of the completion of an Environmental Assessment. The contexts involved additional background research of town histories and archaeological investigations previously completed within each community, so that an assessment could be made of pre-contact, contact, and post-contact archaeological sensitivity for the entire Assabet River within the study area. Known historic structures, which may be eligible for the National Register of Historic Places (NR) were also identified with a recommendation that a formal determination of eligibility should be made when an alternative is selected and that the determination be coordinated with the Massachusetts State Historic Preservation Officer (MA SHPO) for their concurrence.

Project alternatives will also be subject to consultation and review with the Wampanoag Tribe of Gay Head (Aquinnah) Tribal Historic Preservation Officer (THPO), as well as the Mashpee Wampanoag THPO. This information can then be used in plan formulation when the location of staging areas, access roads, or construction zones will be identified.

Pre-contact Period Land Use and Settlement Patterns

PaleoIndian Period (13,500 – 9,000 Years Before Present [BP])

The PaleoIndian period is the earliest period of occupation in New England. The retreat of the Wisconsin glacier occurred approximately 13,500 years BP in at least a portion of Massachusetts. The environment immediately after the glacier receded was characterized by a tundra environment, which was then replaced by a coniferous and hardwood forest environment. While megafauna such as mammoth and mastodon were present during part of this period, it is now considered more likely that PaleoIndian subsistence was more reliant on caribou, elk, fish, and a variety of plants and berries (Curran 1984; Dincauze 1990; Petersen (1995). PaleoIndian sites are recognized by the characteristic fluted projectile points, as well as flake knives, unifaces, drills, awls, graving tools, and biface knives (Funk 1978; Snow 1980). Many of the tools were manufactured from exotic lithic materials from sources outside New England which suggests widespread trade networks or extensive travel during this period (Holstein and Leveillee 1989).

PaleoIndian period sites are rare in the Sudbury-Assabet-Concord River drainage. Well known sites from this period include the Bull Brook Site in Ipswich, a component of the Neponset/Wamsutta site in Canton, and the Wapanucket Site (19-PL-203) in Middleborough. Isolated, diagnostic PaleoIndian projectile points and fragments have been reported from private collections from the Sudbury and Concord river drainages. The Westborough Country Club site (19- WR-680) from the Arnold Collection contained a Clovis point which is indicative of the PaleoIndian period.

Early Archaic Period (9,000 – 8,000 B.P.)

During the Early Archaic Period, the climate became warmer and drier, sea levels rose, and the environment changed to a mixed pine and deciduous forest community, which provided conditions more conducive to a more predictable and abundant food supply. The diagnostic artifact most associated with period is the bifurcate-base projectile point and stemmed or corner-notched points of the Palmer and Kirk types (Whitney et al. 2004:11). While the prevalence of sites from this period are rare in the Northeast, bifurcate points have been found in the Taunton River area and "…in every major drainage basin in eastern and central Massachusetts: in the coastal lowlands, the central uplands and the Connecticut River Valley" (Johnson 1993:48; Clements 1996:8). The megafauna of the PaleoIndian period had disappeared and the apparent seasonally available resources would have been smaller mammals. Early Archaic period sites could be found in a variety of environmental settings including large river valleys, the confluence of rivers and streams, near wetlands, as well as small brooks, ponds, and springs.

Only one possible Early Archaic period site has been identified in the vicinity of the Assabet River, the Westborough Country Club site (19-WR-680) from the Arnold Collection contained a bifurcate-base projectile point. Ten find spots or sites with these diagnostic points have been located in the middle and lower sections of the Sudbury drainage and the upper Concord River, just below the confluence of the Sudbury-Assabet Rivers. A find spot, the Taylor Brook/Tank Site in Maynard (19-MD-545), contained the base of a projectile point that could date to this period.

Middle Archaic Period (8,000 – 6,000 B.P.)

During this period, human occupation in southern New England becomes more evident. Climatic changes produced an environment very similar to the present. Mixed pine and oak forests were succeeded by oak-hemlock forests which was a better habitat for food resources such as deer and turkey. The archaeological data for this period indicates a settlement system of planned seasonal movement oriented around major rivers, streams, and marshes (Dincauze 1974). Subsistence was based on foraging, hunting of large and small mammals, migratory birds, and anadromous and freshwater fish (Whitney et al. 2004).

Diagnostic artifacts of the Middle Archaic Period include three major types of projectile points: Neville, Merrimack, and Stark. Other tools from this period include ground stone celts and gouges, as wells as grooved axes, net sinkers, adzes, and atlatl (weights for spears).

Four sites from this period have been identified along the Assabet River or its tributaries. The Arnold Collection (Westborough Country Club site, 19-WR-680), contained two Neville-type projectile points. In Northborough, the Algonquin High School site was a multi-component short term camp with a Middle Archaic component. The Bartlett site (19-WR-767) was a camp site that was dated by the Northborough Historical Society

with Middle Archaic to Contact period cultural material. The Ironwood site (19-MD-491) in Marlborough and the Pine Hawk site (19-MD-793) in Acton were also identified as having Middle Archaic components.

Many of the large and complex multi-component sites in the Sudbury, Assabet and Concord River drainages appear to contain evidence of recurrent occupation that began during the Middle Archaic Period.

Late Archaic Period (6,000 – 3,000 B.P.)

Late Archaic Period sites in New England are much more common than in previous periods. Modern environmental conditions were present and the wild resources available were the same as those observed by the earlier European settlers. A broad spectrum of resources was exploited during this period. Sites can be found in many diverse settings, including near falls, on the banks of large and small rivers and streams, on floodplain terraces, on lake bottom soils, margins of lakes, ponds, bogs and springs, near meadowlands, the coastal wetlands caused by the rising sea level, and in upland locations such as rock shelters and quarries (MHC 1984; Carolan et al. 1990).

There are three distinct cultural traditions that are recognized in Southern New England during the Late Archaic Period: the Laurentian Tradition, the Small-Stemmed Tradition, and the later Susquehanna Tradition. The Laurentian Tradition is characterized by Brewerton and side-notched points and appears to be more commonly found in inland sites more often than eastern coastal areas of the state, although the tradition was first identified on Martha's Vineyard and New York (Ritchie 1969).. The Small-Stemmed Tradition, also known as Mast Forest Tradition is more common in eastern Massachusetts and southern Connecticut and is present at sites with a wider range of environmental zones than other traditions (Dincauze 1975). Artifacts of this tradition consist of small, thick, stemmed or notched projectile points, most often of quartz and quartzite. These Late Archaic sites are found along wetland peripheries, with larger, "base" camps situated along major river valleys, with smaller "specialized activity" camps identified in a variety of environmental zones (McBride 1984). The Susquehanna Tradition first appears in the Late Archaic Period and extends into the Transitional or Terminal Archaic Period more fully described below. The artifacts from this tradition are characterized by several varieties of broad, side-notched and stemmed projectile points, and are arguably found more often in coastal areas rather than inland locations (Pierce and Loparto 1995).

The relationship between these three Late Archaic Period traditions remains unclear and discussion is often contentious. The Laurentian Tradition is observed most often in central and western Massachusetts, suggesting to some researchers that this either represents an interior, upland adaptation, or alternatively, that this tradition may indicate that there was a movement of settlement from the Great Lakes region, where this tradition is also identified, to New England. The Susquehanna Tradition artifacts have similarities to tools found in the southeastern United States. It has been suggested that this tradition was an intrusive population that may have coexisted with the other groups in New England (Dincauze 1974, 1975). The presence of Small-stemmed and

Susquehanna points at a single site may represent either a population mixture or technological exchange (Ritchie 1969; Dincauze 1976; Snow 1980; Custer 1984; Bourque 1995; Whitney et al. 2004).

There are numerous known Late Archaic Period sites along the Assabet River. The Davenport site (19 WR-529) in Westborough is a single component, hunting/ woodworking site. The site is one of several, small riverine camps that have been found in the Assabet River floodplain. The Westborough Country Club site also has a component that dates to this period. In Northborough, the Algonquin High School and Bartlett sites (19-WR-758 and 19-WR-767) are Late Archaic sites that were used for small-scale lithic production, and functioned as small hunting camps. The Wheeler Hill, Locus 2 site (19-MD-788), Robin Hill site (19-MD-489), and the Ironwood site (19-MD-491) in Marlborough, are also small short-term sites that appear to be areas of pre-contact wetland resource exploitation in the Assabet River drainage. The Tarbell's Spring site (19-MD-148), 19-MD-158 in Concord, and the Pine Hawk site in Acton were situated on high banks overlooking the Assabet River, and could have functioned as larger base camps from which people would have set out to hunt, fish or gather.

Transitional Archaic Period (3,700 – 2,700 B.P.)

This period is characterized by the more widespread appearance of the Susquehanna Tradition, although the small-stemmed tradition also remained prevalent. During this period, vessels manufactured from steatite (soapstone) first appeared, distinguishing this period from the Early Woodland Period where ceramics were first utilized. Common diagnostic projectile points from this period include Orient Fishtail points, Atlantic-Snook Kill variant, Genesee points, and Wayland Notched points (Whitney et al. 2004).. Burials from this period are also more commonly identified, and provide evidence of complex mortuary rituals, and extensive trade networks. Subsistence during this period remained essentially the same as during the Late Archaic and included seasonal reliance on fishing, shellfishing, hunting of small and larger game, and gathering of mast-produced nuts (Snow 1980: 249; Clements 1996).

The Bartlett site (19-WR-767) in Northborough is the only known Transitional Archaic period site along the Assabet River. However, other sites such as the Pine Hawk site have been found in upland zone settings between the Sudbury and Assabet Rivers. Cremation burials have been identified within the Sudbury-Assabet-Concord drainage including the Mansion Inn site in Wayland, the Vincent site in Sudbury, and the Call site in Billerica.

Early Woodland Period (3,000 – 1,700 B.P.)

In Massachusetts, the Woodland periods are best represented in coastal regions and in the Connecticut River Valley (Carolan et al. 1990). Early and Middle Woodland period sites in the Connecticut River Valley were adapted to interior riverine resources with major settlement cores focused on the lowlands near falls and rapids Woodland sites evidence a variety of locations, sizes, and activities. Small hunting and gathering sites have been

reported in Montague and Belchertown, and large fishing middens were excavated in the Riverside District and at the WMECO site along the Connecticut River (MHC 1984). The first use of ceramics is attributed to this period, as is the introduction of horticulture with maize, beans, and squash as the major cultigens. However, hunting, fishing, and gathering remained essential subsistence activities, cultigens not being a major element of subsistence for at least 1,500 years after ceramics became established in New England (Whitney et al. 2004). The temporal periods of Woodland sites are distinguished mainly by projectile point type, and also some changes in ceramic manufacture and design. Early Woodland period sites are recognized by the presence of Meadowood, Rossville, and Adena-like projectile points and Vinette I ceramics. The quartz small-stemmed tradition also continued into the Woodland Period allowing the possibility of confusion between Late Archaic and Early Woodland sites in the absence of ceramics. Burial ceremonialism continued from the Transitional Archaic Period, with elaborate mortuary sites characterized by the presence of gorgets, birdstone, pottery pipes, copper beads, and red ocher (Ritchie and Funk 1973). These artifacts are evidence of established trade routes extending to the Midwest, where the Adena culture was firmly established (Pierce and Loparto 1995).

The Early Woodland Period in southern New England is generally underrepresented in the regional archaeological record. Settlement patterns and land use during this period appear to have been characterized by limited use of upland areas and more intensive use of coastal and estuarine resources as well as coastal habitation. There is evidence, however, of Early Woodland land use along the Assabet River found at three sites in two towns. The Robin Hill Site in Marlborough, and the Algonquin High School, and Bartlett sites in Northborough are all small, multi-component sites with evidence of Early Woodland period short-term use. Larger riverine settlement sites have been identified in the broader, Sudbury-Assabet-Concord drainage. These include the Heard Pond, Rice Farm, Sand Hill, and Weir Hill 3 sites in Wayland and Sudbury, and the Cedar Swamp 3 site in Westborough.

Middle Woodland Period (1,600 – 1,000 B.P.)

Cooler climatic conditions which began in the Early Woodland Period continued through this period as well. Site locations are much the same as the preceding period, which included riverine and coastal sites. The use of marine resources increased as indicated by large shell middens in coastal areas (Holstein and Leveillee 1989). A higher level of sedentism in settlement patterns is indicated, in addition to a population increase, the introduction of horticulture, regional trade networks, and more elaborately decorated ceramics (Whitney et al. 2004). Diagnostic artifacts from this period include, Fox Creek, Jack's Reef Pentagonal and corner-notched, Woodland stemmed, Woodland lanceolate, Woodland corner notched, and Greene projectile points. Some argue that trade of exotic lithic materials increased during this period with the presence of jasper from Pennsylvania and chert from New York. Un-grooved adze blades, pestles, and bone and antler tools, and the introduction of the bow and arrow are also diagnostic of the later Woodland periods (Holstein and Leveillee 1985; Pierce and Loparto 1995; Whitney et al. 2004).

Only two possible Middle Woodland period sites were identified within the Assabet River area. The presence of a diagnostic projectile point in a private collection from the Honeypot Orchard site (19-MD-971 in Stow, dates this site to the Middle Woodland period. The multi-component Ironwood site (19-MD-491) in Marlborough also has a Late Woodland period presence. Other sites from this period can be found along the Sudbury River drainage.

Late Woodland Period (1,000 – 450 B.P. [AD 1500])

Late Woodland period settlement appears to have increased over the earlier periods. The population tended to gather into larger groups. Major nucleated villages located in defensible positions such as river confluence points and the heads of estuaries were favored for large base camps, while smaller camps were used for specialized activities such as farming, hunting, and harvesting shellfish. Many of the large base camp locations later became the sites of European settlement, thus many of these sites may have been destroyed.

Due to a climatic warming trend after 1,000 B.P., horticulture became a more reliable food supply, and was well established during this period with the production of corn, beans, squash, and gourds. Riverine floodplains may have been more intensively used for agriculture. Diagnostic artifacts from this period include diverse pottery styles with cord-wrapped impressions, linear stamping, and incising, as well as collared necks, castellated rims, and thinner walls (Luedtke 1985; Holstein and Leveillee 1989; Clements 1996). Diagnostic projectile points include Levanna and Madison types. Levanna projectile points, manufactured from local volcanics are widely recognized and distributed in Massachusetts, while Madison points, made from New York chert, are rarely found in eastern Massachusetts (MHC 1984).

The distribution of Late Woodland sites in upland settings is not well known in the Sudbury-Assabet-Concord River drainages. The confluence of the Sudbury and Assabet Rivers may have been a focal point of Late Woodland activity because of the presence of favorable conditions for fishing with weirs. Known sites along the Assabet River are the Marlborough Middle School site (19-MD-778) and the Bartlett site (19-WR-767 in Northborough. The Arnold Collection from the Westborough Country Club site also contained Late Woodland period projectile points.

Contact Period (AD 1500 – 1630)

The native land use and settlement pattern at the beginning of the Contact Period was essentially the same as during the Late Woodland Period. Semi-permanent camps were situated near fields, and were sometimes surrounded by palisades. Large pits were dug for storing food. Smaller sites in upland areas were used for specialized activities such as lithic procurement, hunting, trapping, or fishing. Coastal areas were heavily occupied for fishing and shellfish. Subsistence patterns consisted of seasonal hunting and gathering, with horticulture as a significant component (Holstein and Leveillee 1989). By this

period native groups had established their territories and core areas of settlement. In southern New England, tribal nations included the Pequots, Wampanoags, Narragansetts, Mohegans, Nipmucs, Mohicans, Massachusetts, Nonotucks, Agawams, Pawtuckets, and Nehantics (Pierce and Loparto 1995; Whitney et al. 2004).

The Bartlett site in Marlborough purportedly contained Contact period cultural material. The Marlborough Middle School site is a Contact period habitation site. The general vicinity of this site is the area documented to be the Praying Indian town of Okommakemesit, settled by John Eliot in the seventeenth century.

Known and Expected Pre-contact Resources

Massachusetts Historical Commission (MHC) Reconnaissance Survey Reports for each town in which the Assabet River traverses, note that these towns were known for aboriginal settlement and activity along rivers as well as ponds, and wetland areas. Sites were most often found on terraces overlooking waterbodies. Identified sites represent all phases of New England prehistory from the PaleoIndian Period (12,500 – 10,000 BP [Before Present] to the Contact Period (450 – 300 BP/A.D. 1500 – 1620). These sites include short-term hunting or fishing stations or campsites, fish weirs, seasonal camps, and lithic production or repair sites.

The MHC Site Files for prehistoric sites were also checked to see where known sites for each town were located on the Assabet River from Westborough (headwaters) to Concord (confluence with Sudbury River). Five sites were identified along the Assabet River in Westborough, dating from possibly the PaleoIndian Period, through the Early to Late Archaic Periods (10,000 – 3,000 BP), with two sites also having Woodland Period components (3,000 – 450 BP). Two of the sites were located in the Assabet River floodplain, while the other three were located on terraces overlooking the river. These included small campsites as well as a locus of a larger site, and one tool-making site.

Five sites were also identified in Northborough. These sites were small, short-term campsites, and lithic re-working sites. One site was identified by artifacts eroding out of a terrace on the edge of the Assabet River.

Nine sites were identified along the Assabet River in Marlborough. Seven of the sites were represented by a few stone flakes and burnt rock, representative of a pattern of wetland resource exploitation with short-term campsites common during the Late Archaic Period (5,000 – 3,000 BP). Two of the sites were small, habitation or base campsites dating from the Late Archaic to the Early to Late Woodland Periods, with possibly a Contact Period component.

Ten sites were identified in Stow. The majority of these sites are find spots where only a small number of artifacts were found. Two were short-term camps or single event sites on elevated terraces overlooking the Assabet River that may be related to other, larger base camps along the river.

Two sites along the Assabet River were identified in Maynard, with only one site in Acton. The dearth of sites in these communities may be due to the amount of archaeological investigations or avocational collecting that was reported, rather than a true absence of prehistoric settlement in these areas.

The Sudbury-Assabet-Concord River drainage is an area that has been heavily studied by avocational archaeologists and has also been documented by professional cultural resource management investigations. It appears that the Assabet River was moderately used by prehistoric groups for resource procurement, and seasonal or short-term settlement. The potential exists for other prehistoric sites to be identified in the floodplain, on terraces or surrounding wetlands adjacent to the river.

Post-contact Period Land Use and Settlement Patterns

Historic contexts in towns within the study area are described here. The dams along the Assabet River powered industries that, in some cases, created the towns surrounding them, so their histories are described separately, from upstream to downstream.

The historic inventories for each town were examined for all of the dams being considered for possible removal. Some towns have very detailed, up to date inventories, while others have little or no information on the historic resources of the respective community. All of the dams are listed in the MHC Historic Inventory in their respective towns, with the exception of the Aluminum City Dam in Northborough. While NR eligibility has not been determined for most of these structures, many of the dams can be considered contributing elements of larger, historic areas and potentially historic districts.

Northborough

Northborough was originally part of the 1660 Marlborough grant. In 1717, the area of Northborough was set off with Westborough, and later became the second parish of Westborough in 1744. In 1766, Northborough was established as a district, and then made a town in 1775 (MHC 1983:1).

The first Colonial settler in Northborough, John Brigham, arrived around 1672, built a cabin and established a saw mill. However, the area was abandoned during King Philip's War. Increased settlement from Westborough took place after 1713. In 1726, the area became the North School District of Westborough. Thirty-seven families had settled in the Northborough area by 1744, when the area became a precinct. A meetinghouse was built in 1746. Early mill development began on Cold Harbor Brook (1711), the Assabet River (1720, with a fulling mill in 1749), and Howard Brook (1766) (MHC 1983:3). During this period, the raising of cattle, sheep and goats, and agricultural production, notably grain and fruits, were the economic base of the community.

During the Federal Period (1775-1830), water-powered mills and the network of roads continued to increase. By 1826, there were four grist mills and five saw mills. In 1814, the Northborough Manufacturing Co., producer of cotton and woolen cloth and yarn, was

started at Woodside on the Assabet River. Agricultural production remained the mainstay of the economy.

The greatest decade of growth in Northborough took place from 1830 to 1840 during the Early Industrial Period (1830-1870). The Northborough Manufacturing Co. erected a second manufactory and village in 1832 at Chapinville on the Assabet River. Their two mills were able to produce 220,000 yards of cotton and woolen cloth in 1837, valued at $30,400. Other industries in Northborough at this time included the manufacture of combs, jewelry, and buttons, and the production of boots and shoes.

During the Late Industrial Period (1870-1915), Northborough had a population high of 2,104 in 1900, but that number decreased to 1,797 by 1915. The textile industry was the major industry and employer in the 1880s and 1890s. The two textile mills and two clothing manufactories provided about 75% of the manufacturing jobs, and 90% of the value of manufactured goods for the town. The comb, jewelry and button manufacture and woodworking industries continued, while several other industries, notably musical instruments, metal goods, corset stitching, rubber and elastic goods, and cameras had their start at this time. Agriculture remained vital to the economy (MHC 1983:8).

Beginning upstream on the Assabet River, the first dam being investigated for removal is the Aluminum City dam, also known as the Old Mill Pond Dam, in Northborough. The dam was built c. 1925 and was associated with a wood-frame building on the right (looking upstream) side of the stream. A local informant suggested the building was the old mill. The building now houses apartments and offices. It appears to date from the nineteenth century, which would indicate that an earlier dam was most likely present at this location. The informant also indicated that a sluiceway from the dam ran beneath the Aluminum City structure. It is hard to date this business as it has been enlarged and modified. No mention of this dam and associated industry are included in town histories reviewed to date. There is no way to tell whether there is indeed a sluiceway under the parking lot or building. The dam is unremarkable in appearance, and any associated structures appear to have been extensively modified. For this phase of the study, the determination is that this dam and surrounding area are not eligible for the NR. An archaeological reconnaissance study to determine archaeological sensitivity and the possible need for intensive archaeological investigations should be completed if removal of this dam is considered.

The Allen Street Dam in Northborough (also known as the Gothic Craft or Woodside Dam) is listed in the MHC Historic Inventory as the Assabet River Bridge and Dam. The bridge and dam are part of the Woodside Area, earlier known as Davisville, which has been a mill site since c. 1720. The stone bridge (topped with later concrete repairs) spans a mid-nineteenth century millpond and the upper end of a power canal, which led to the existing early twentieth century mill building, converted to apartments. The power canal is still visible as are stone foundations that may have been associated with earlier industries. The dam is constructed of stone, topped with concrete that may have been added c. 1900, when the mill building was erected. Just upstream of the millpond, is the Wachusett Aqueduct, which is part of an historic district comprised of nineteenth century

water supply structures for the metropolitan Boston area. The Wachusett Aqueduct Linear District was listed on the NR in 1990. The Woodside Area, including the Allen Street Dam appears to be eligible for the NR. The factory has been converted to housing, but remains fairly unaltered. Buildings associated with the old manufactory abut the dam. The former Northborough Manufacturing Co. had a significant impact on Northborough, turning it from primarily an agricultural community to a small industrial center. The dam is the centerpiece of this industrial village area. In addition, the power canal is still visible as are stone foundations which could have been associated with earlier mill structures. There was an industrial component at this site for over one hundred years. For this phase of the study, the determination is that this dam and the surrounding area are potentially eligible for the NR. Archaeological investigations of the surrounding area will be necessary as will documentation (possibly historic and photographic) of the dam, factory, and surrounding village if removal of this dam is considered. An updated MHC Inventory Form will also need to be prepared in order to get concurrence with the determination of NR eligibility from the MA SHPO.

Hudson

The town of Hudson was incorporated in 1866 from lands originally part of Marlborough and Stow. The current configuration resulted from the annexation of lands from Bolton in 1868 and the definition of boundaries between Hudson and Stow in 1905. The first white settler in the area was John Howe in 1656. A tavern was operating in the town by 1661 and the first meetinghouse was completed in 1666. Population at this time was approximately 200 individuals. Agriculture was the mainstay of the frontier economy.

The town was mostly destroyed during King Philip's War, and was slowly re-settled during the early eighteenth century. In 1698, John Barnes developed an acre of land on each side of the falls on the Assabet River and established a grist mill on the north side. Shortly after, Joseph Howe took over Barnes' grist mill and it is conjectured that Howe added a saw mill to the site. Jeremiah Barstow took over the mill complex in 1712. Emory Maynard also established a grist mill on the river in what is now Hudson.

By the end of the eighteenth century, "the Mills" village center had expanded. Joel Cranston built a store and public house which opened in 1794. Silas Felton, a prosperous merchant, hotelier and postmaster, helped to establish several small businesses and attracted more people to settle in the village. A tannery and saw mill were established on Tannery Brook, and the first schoolhouse opened in 1799.

Hudson witnessed continual growth throughout the nineteenth century, and became known as Feltonville by 1812. At that time, the village was made up of a small cotton mill, a fulling mill, several tanneries, and a distillery. In 1821, Daniel Stratton established a small shoemaking factory. By 1844, Silas Stuart operated a box manufacturing plant to provide shoe boxes for the growing shoe industry. Large-scale shoe manufacturing began mid-century, with at least five shoe factories. In 1847, the Fitchburg Branch Railroad was laid through the town, and in 1855 the Marlborough Branch Railroad Company opened between Marlborough and Feltonville. By 1860, the

town had a population of 1800 with eight stores, two meetinghouses, 140 houses, and 17 factories employing 975 people. The Washington Street Dam provided the waterpower for the textile and shoe factories. Feltonville was officially set off from Marlborough in 1866, at which time the population was 1,900. A town vote changed the name to Hudson, after local historian and benefactor Charles Hudson.

In 1885, the Goodyear Gossamer Company was established in Hudson to manufacture materials waterproofed by rubber. Lamson's Ice Business opened in 1887, and the Knight Fuel Plant was in operation by the close of the century. A massive fire in 1894 almost completely destroyed Hudson's business district, but by the turn of the century 14 new brick and granite buildings had been built in the town's center. The importance of Hudson's historical structures as symbols of the town's industrial and architectural growth is recognized today, by the Silas Felton Historic District, of which the Washington Street Dam is a contributing element.

The Route 85 Dam in Hudson, also known as the Washington Street Dam, was first constructed c. 1866, and was most recently repaired in 1987. It is likely, however, that earlier dams may have been constructed at this site. A gristmill was built at the natural falls at this location c. 1698, and the first bridge over the Assabet River was built just downstream of the dam by the Town of Marlborough (of which Hudson was once a part) in 1699. The current bridge was built in 1864 and consists of a three-arch stone bridge with an 18-foot span. The bridge and dam are contributing elements of the Silas Fenton Historic District, an area bounded by Cox Square, Main Street, Broad Street, and the Assabet River. The Silas Felton Historic District has been listed on the NR. The dam and bridge are surrounded by modern architecture (a hardware store, gas station and McDonalds), but earlier foundations may be present closer to the water's edge. Since the dam is a contributing structure to the Silas Felton Historic District, removal would have an adverse effect on the NR district. Archaeological resources could also potentially be affected by dam removal. In addition, there may be archaeological resources of the earlier industries present. Historic, photographic, and archaeological documentation may be necessary prior to any work at this site.

Stow

European settlement in the Stow area began during the early to mid-seventeenth century in Sudbury. Hudson was the second settlement in 1666, and Stow was incorporated as a town in 1683. At that time, the area was known as Pompossitticutt. The first white settler was Matthew Boon, on the west side of Boon Hill in 1660. Additional settlements occurred along the Great Road after 1670. Subsistence agricultural and hunting was the economic base for the residents of this area.

Stow was abandoned during King Philip's War, and resettlement began around 1680. The first meetinghouse was built in 1685 in the Lower Village, with the minister's house, which was also a garrison house, being completed in 1687. A second meetinghouse was built in 1711. Settlement shifts in the eighteenth century resulted in three village centers in Stow; Stow Center where the third meetinghouse was built in 1754, the Lower Village

(original settlement), and Gleasondale (Rocky Bottom), the industrial village. A saw mill and a grist mill were located at Gleasondale by 1735. Stow had somewhat less desirable topography which resulted in slower development and population growth than in adjacent towns, such as Marlborough.

An increase in population in 1810 was due mainly to the growth of mills at Rocky Bottom (Gleasondale). The Methodist Episcopal Society formed in this village in 1821. There were few exclusively commercial structures built within Stow prior to the mid-nineteenth century. There were several taverns, two stores at the Lower Village by 1816, one store at Stow Center by 1823, and a store in Gleasondale around 1830.

A fire destroyed the mill in Gleasondale in 1852, but the factory was rebuilt in brick and expanded soon after. The population remained relatively stable at around 950 to around 1,000 during the late nineteenth century to early twentieth century. There was little settlement during much of the early to mid-twentieth century with the exception of small growth as a suburb of the manufacturing town of Maynard.

Gleasondale was the only area of expansion in Stow, due to the increase in manufacturing of textiles at the Gleasondale Mill.

The MHC Historic Inventory lists the village of Gleasondale, the Gleasondale Mill, and the Gleasondale milldam and canal as historic resources within the Town of Stow. The village as listed on the Gleasondale Area Form contains over 60 buildings and structures, which date from c. 1750 to the twentieth century. The village emerged as a result of the development of the waterpower on the Assabet River at this location. The first dam to be built on this site was constructed between 1735 and 1750 by an Ebenezer Graves who also constructed a saw and gristmill. After changing hands several times, the mills were purchased in 1776 by Abraham Randall, and the village became known as Randall's Mills. In 1813, a cotton mill was built on the west side of the river, opposite the saw and gristmill. Legend had it that upon building the cotton mill, the workers hit ledge, or Rock Bottom, and the name of the village was changed to Rock Bottom c. 1820. The Randall Mills were bought by Joel Cranston, Silas Felton, and Elijah Hale between 1819 and 1822. By 1820, the mills were being operated under the name Rock Bottom Cotton and Woolen Company.

After changing hands several times again, the mills were purchased by Benjamin W. Gleason and Samuel J. Dale in 1849. The mill building burned in 1852, and the present mill building was constructed in 1854. The mill was owned by succeeding generations of the Gleason family. In 1898, the village's name was changed to Gleasondale. The mill was prosperous through the two World Wars but ended wool production after World War II. It is currently occupied by a number of light industries. The mill is a good example of a Greek Revival style of industrial architecture. The surrounding village retains its cohesiveness and character as a mill community with the Assabet River and the dam at its northern end. The current dam, called the "stone dam" is the third dam at this location. The first dam constructed here was built c. 1735, and the second c. 1836 along with the canal, which extended under the mill building. The current dam was built in 1883 and

connected to the existing canal, with a canal gate and overflow spillway to service the C.W. Gleason's Sons textile mill. Although a determination of eligibility has not been made for the dam, mill or surrounding village, it appears that the dam is a contributing element of a potential NR eligible historic district. Removal of the dam would have a possible adverse effect on the village of Gleasondale. It is likely that archaeological resources (pre-contact and post-contact) would also be impacted by dam removal. An updated MHC Inventory Form will also need to be prepared in order to get concurrence with the determination of NR eligibility from the MA SHPO.

Maynard

Much of the land now included in the town of Maynard was a section of the northwest corner of the town of Sudbury added to this plantation town in 1649. The "Two Mile Grant", set aside by the General Court extended north from a line between White Pond in Stow, Willis Pond (Sudbury) and White Pond in Concord to the area just northwest of the Assabet River and Pompositticut or Summer Hill.

The New Grant or Two-Mile Grant Lots were divided and granted to individual families. Early settlement in what was called the "Northwest District" of Sudbury was limited in the late seventeenth century to a few outlying farmsteads. By 1708 only fifteen dwellings had been built in the district, and settlement was quite dispersed.

The population was quite small until the late eighteenth century, with several petitions presented to the General Court to allow the creation of a new parish on the west side of the Sudbury River. Sometime before 1820 a paper mail was constructed on the Assabet River near the corner of Summer and Parker Streets and saw, grist, and cider mills had been built near Mill Street. By the early nineteenth century, some clustering of structures began to the south of the William Parker Paper Mill on the Assabet River. These manufactories were the first of many new structures that began to appear in Assabet Village. The impetus for the increase in population and structures was due primarily to the expenditure of capital by a single individual, Amory Maynard.

In 1845, Amory Maynard and William Knight began planning to build a carpet mill. They bought land in Assabet village and water privileges on both sides of the Assabet River. The men wanted to stabilize the potential source of waterpower for the new mill. In 1846, Maynard had the dam constructed across the Assabet just east of the old Ben Smith Bridge. The contract went to his good friend and advisor, Artemus Whitney. At the time Amory Maynard began to purchase land in the village for the mill, Whitney owned the site of the future millpond. Whitney built the dam, canal, the millpond, and the foundation of the mill. Artemus Whitney was one of the original petitioners to the Commonwealth for the incorporation of Maynard in 1871. He was also one of the first assessors and highway surveyors for the town. At the time of incorporation, the population of Assabet Village was twice as large as that of Sudbury or Stow.

The Assabet Manufacturing Company became insolvent in 1898, and it was acquired by the American Woolen Company in 1899. It was at that time the largest woolen mill in

the nation, and continued to expand until the year immediately following the end of World War I.

The town of Maynard experienced a rapid growth in population in the late nineteenth century and again after 1900. To accommodate the increase in population, residential development in the center of Maynard expanded. Several subdivisions were built along various streets (Concord, Parker, Waltham), and the American Woolen Company built 160 tenements near its mill complex in 1901 – 1902.

There are multiple historic properties in Maynard associated with the woolen mill complex that are listed or eligible for listing on the NR. These include the Assabet Mills and appurtenant waterpower system, as well as the Sudbury Street Area, Railroad Street Area, Pine Street Area, Martin Street Area, High Street Area (all former mill worker housing areas demonstrating different styles, types and age ranges). The Maynard Downtown Historic District, Main Street Area, and Great Road Area, contain commercial and residential properties associated with the former mills. St. Bridget's Roman Catholic Church served as a house of worship for the immigrants who arrived to work.

The Ben Smith Dam is recorded as a contributing element in the MHC Historic Inventory, Assabet Mills Area Form and as a contributing feature of the Ben Smith Bridge Area. The dam is also recorded on a MHC Historic Inventory Structures Form and is recommended for individual listing on the NR. The Ben Smith Dam was constructed in 1847 of large, dry-laid granite blocks, 1.5 to 2 ft. in depth and 4 to 6 ft. long. The dam is 120 ft. long and 8 ft. high and stretches across the Assabet River just southwest of the canal that leads to the Mill Pond. Shortly after the water-rights were purchased by Amory Maynard in July 1846, the dam was built. This created the opportunity for water to be diverted from the river down a canal to the millpond where it would be used as power for newly constructed carpet mill (Epsilon Associates, Inc. 2006).

Not withstanding the dam's importance to the development of Maynard's industry, it is also associated with a well-known local figure. Removal of the dam would constitute an adverse effect to a NR eligible historic resource and an adverse effect on the Assabet Mills Historic District, and perhaps other districts, sites or structures associated with the mills. Archaeological resources could be affected as a result of a drawdown of the impoundment. Removal of the Ben Smith Dam would have the largest negative impact on the historic industrial resources along the Assabet River.

Acton

The present-day town of Acton was originally contained within a parcel of land granted to a Mr. Wheeler of Concord by the Massachusetts General Court in 1643. The tract was originally known as New Village or Concord Village. Acton's early economy based primarily on pasturing sheep and cattle as well as subsistence agriculture. Industries during this early period between 1660 and 1670 included Thomas Wheeler's grist mill on

Nashoba Brook, and the extraction of bog iron and charcoal production for a small iron smelting operation in West Concord.

Settlement in Acton did not begin in earnest until after King Philip's War, although dwellings continued to remain sparse throughout the eighteenth century. Acton remained a part of Concord until 1735 when it was incorporated as a separate town. The following year the first meetinghouse was built adjacent to the town common. There were two main areas of development, East Acton and South Acton. Small industry developed in South Acton along streams such as Nashoba and Fort Pond brooks and included saw, grist, and fulling mills. Coopering was another important activity. Taverns were established in Acton Center, South Acton, and along the Great Road in the mid to late eighteenth century. Acton's town center began to form at this time. Acton Center became the focus of government and religious activity while an industrial/commercial district developed in South Acton near sufficient waterpower.

The shoe and boot industry, long a cottage industry, increased with the establishment of a shoe and boot factory by John Fletcher in 1815. This industry reached its peak during the Civil War, but did remain an active component of the town's economy until the end of the nineteenth century.

The manufacture of gunpowder at mills along the Assabet River began in 1835. Nathan Pratt is credited with starting what was then known as the Acton Powder Mills when he constructed a dam across the Assabet River to power the mill's machinery. The mills were built on the former site of a saw mill. The American Powder Company, incorporated in 1842, was located adjacent to the river on the Acton/Maynard town line. The most hazardous of the powder company's processes were geographically isolated from the mill and were situated in Powder Mill Woods. Other manufacturers operating during this period were the boot and shoe factory, laundry bluing manufacturers, and a woodenware factory in West Acton. A piano stool factory and a wool shoddy mill operated in South Acton.

The American Powder Company expanded it facilities during the late nineteenth century to include the production of smokeless powder and owned several hundred acres land in the towns of Acton, Maynard, Concord, and Sudbury. A small nucleus of residential and commercial buildings called Powder Mill Village developed along the present Route 62.

The American Powder Company mills reached a peak of production during World War I with the exportation of gun-cotton to Russia. A victim of the Great Depression, the American Powder Mills closed in 1940. The facilities were purchased by American Cyanamid and Chemical Company which manufactured smokeless powder during World War II. Powder production came to an end after the war. The Dewey and Almy Chemical Company purchased the mills in 1954 and produced synthetic rubbers products.

The Powdermill Dam in Acton appears to be a historic timber-crib dam with a rock face. The first dam at this site was pre-1835. While portions of this dam could be from the original construction, it appears to have been partially reconstructed and repaired,

perhaps as part of the development of hydropower at this site. There is a small, brick building adjacent to the dam, which contains a turbine. This building has 1923 inscribed on a brick in the center face of the structure. The dam and powerhouse are covered under an active FERC license, which is generating electricity for Acton Light and Power.

Powdermill Dam is located at the site of historic manufacturing activity, so removal of the dam could possibly have an effect on significant historic or archaeological resources. However, the current owner holds an active FERC license, has repaired the dam, and is generating power. It is unlikely that the removal of Powdermill Dam will be considered as part of this study.

CONCLUSIONS

The Aluminum City Dam in Northborough does not appear to be eligible for the NR. While there is a possibility that the dam is associated with an adjacent structure, the structure has been extensively modified as has the area surrounding the dam. However, dam removal, dredging, and possible staging areas all have the potential to affect archaeological resources. An archaeological reconnaissance survey is recommended if any alternatives are chosen that would impact this site.

The Allen Street Dam, as part of the Woodside Area appears to be potentially eligible for the NR. An intensive archaeological survey is recommended if dam removal and/or dredging are planned for this structure. There are visible stone foundations most likely relating to earlier industries at this area. There is also the possibility that intact pre-contact archaeological resources may be present. Photographic and historic documentation of the dam, factory, and surrounding village will most likely be necessary if removal of the dam is considered. An updated MHC Inventory Form will also need to be prepared in order to get concurrence with the determination of NR eligibility from the MA SHPO.

The Route 85 Dam in Hudson, also known as the Washington Street Dam is a contributing structure to the Silas Felton Historic District. Dam removal will have an adverse effect on the NR district. Pre-contact and industrial archaeological resources could also potentially be affected by dam removal. Historic, photographic, and archaeological documentation may be necessary prior to any work at this site. The determination of effect will be coordinated with the SHPO and the THPOs as part of this study.

The Massachusetts Historical Commission Inventory lists the village of Gleasondale, the Gleasondale Mill, and the Gleasondale milldam and canal as historic resources within the town of Stow. Although a formal determination of eligibility has not been made for the dam, mill or surrounding village, it appears that the dam is a contributing element of a NR eligible historic district, so removal would be considered an adverse effect on the village of Gleasondale. It is likely that archaeological resources (pre-contact and post-contact) would also be impacted by dam removal. An intensive archaeological survey is recommended prior to any work at this site. An updated MHC Inventory Form will also

need to be prepared in order to get concurrence with the determination of NR eligibility from the MA SHPO.

The Ben Smith Dam in Maynard has been determined individually eligible for the NR as well as a contributing element of the Assabet Mills Historic District. The dam is historically important to the development of Maynard's industry as well as the development of the town itself. Removal of the dam would constitute an adverse effect to a NR eligible historic resource and an adverse effect on the Assabet Mills Historic District, and perhaps other districts, sites or structures associated with the mills. Archaeological resources could be affected by the associated drawdown of the impoundment after dam removal. Removal of the Ben Smith Dam would have the largest negative impact on the historic industrial resources along the Assabet River.

Powdermill Dam in Acton is located at the site of historic manufacturing activity, so removal of the dam could possibly have an effect on significant historic or archaeological resources. However, the current owner holds an active FERC license, has repaired the dam, and is or will soon be generating power. It is unlikely that removal of the Powdermill Dam will be considered as part of this study.

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APPENDIX G

REAL ESTATE INFORMATION

REAL ESTATE APPENDIX
ASSABET RIVER, MASSACHUSETTS

GENERAL PROJECT AREA DESCRIPTION: The Assabet River is located in central Massachusetts and flows for about 33 miles from its headwaters in Westborough through the towns of Northborough, Marlborough, Hudson, Stow, Maynard, and Acton, to its confluence with the Sudbury River. Along the way, the river passes through a series of small towns and mixed land-use areas. The wastewater treatment plants in Westborough, Marlborough, Hudson, and Maynard discharge nutrient-rich effluent to the river which contributes to the eutrophic state of the river. This condition is more obvious where the river is impounded by a series of dams which served to power the mills that constituted the economic bases for the towns along the river. Modern industries have also substantially contributed to the area's economic development and the area has become more suburban with an increase in the number of single-family homes, roads, and commercial development; this has strained the basin's water resources and affected water quality.

The purpose of this Appendix is to present information on ownership of the six dams of interest to the study. This research is provided for planning purposes only. If the deed did not specify that the owner of the property is also the owner of the dam (although indications are that the owner of the property is the owner of the dam), then the chain of title was included in the research. Information from the National Inventory of Dams was also reviewed. This work was completed in January 2007.

DAM NAME	TOWN	ID	Year Completed
Aluminum City Dam	Northborough	MA02843	1925
Allen Street Dam	Northborough	MA00995	1900
Hudson Dam	Hudson	MA00447	1860
Gleasondale Dam	Stow	MA00820	1924/1883
Ben Smith Dam	Maynard	MA00752	1850
Powdermill Dam	Acton	MA00128	1921

Northborough
Aluminum City (Old Mill Pond) Dam

Location: Dam is located off Main Street, Northborough (between Assessor's Map 64, Lot 21 and Lot 20)

National Inventory of Dams: NID ID: MA02843
County: Worcester
River: Assabet River

Owner: 86-88 Main Street LLC (Map 64, Lot 21 & adjoining Lot 22)
P.O. Box 253
Southborough, MA 01772

Following is chain of title: Note: This is the parcel that has Ernest Laurence in the chain of title and NID states the owner as John F. Laurence.

Grantor/Grantee: RSJ Realty Co., Inc. to 86-88 Main Street, LLC
Worcester Registry of Deeds, Book 25203, page 336
Consideration: $520,000
Dated: November 7, 2001

This deed includes 2 parcels, parcel #21 containing 9,583 SF of land (with improvements) that runs along the river and parcel #22 containing 4,356 SF of land (with improvements) that runs west of parcel #21. There is a 12-foot wide easement on the east side and one on the west side of parcel #21 (west of Assabet River). Deed states that the dam is not to be raised above its height as it was in 1881 and the grantee, heirs, assigns, etc. has the right to enter upon land of Eames (east of Assabet River) on east side of stream to repair said dam.

Grantor/Grantee: Ronald P. Aspero to RSJ Realty Co., Inc.
Worcester Registry of Deeds, Book 12372, page 168
Consideration: $100,000
Dated: October 2, 1989
This includes 2 parcels, same as above.

Grantor/Grantee: Judith Ellis Pucci, f/k/a Judith G. Ellis to Ronald P. Aspero
Worcester Registry of Deeds, Book 11114, Page 295
Consideration: $165,000
Dated: February 5, 1988
This includes 2 parcels, same as above.

Grantor/Grantee: John L. Ellis, Jr. to Judith G. Ellis
Worcester Registry of Deeds, Book 8094 Page 1
Consideration: Less than $100
Dated: February 24, 1984
This includes 2 parcels, same as above.

Grantor/Grantee: John L. Ellis, Jr. to John L. Ellis, Jr. and Judith G. Ellis
Worcester Registry of Deeds, Book 7727, Page 18
Consideration: Less than $100
Dated: April 11, 1983
This includes 2 parcels, same as above.

Grantor/Grantee: Judith G. Ellis, f/k/a Judith G. Kwiat to John L. Ellis, Jr.

Worcester Registry of Deeds, Book 7083, Page 86
Consideration: Less than $100
Dated: September 12, 1980
This includes 2 parcels, same as above.

Grantor/Grantee: Alice Laurence, a/k/a Alice E. Laurence to
John L. Ellis, Jr. & Judith G. Swiat, as joint tenants
Worcester Registry of Deeds, Book 6782, Page 172
Consideration: Less than $42,900
Dated: July 20, 1979
This includes 2 parcels, same as above.

Grantor/Grantee: Estate of Emma L. Cranston to Ernest Laurence and Alice Laurence, as tenants by the entirety
Worcester Registry of Deeds, Book 2805, Page 571
Consideration: $1,500
Dated: January 30, 1941
This was Lot 22, 86 Main St. (the parcel not on river).

Grantor/Grantee: Hermon L. Sparrow to Ernest C. Laurence
Worcester Registry of Deeds, Book 2699, Page 583
Consideration: $1,000
Dated: July 2, 1937
This lot is upstream of river & along west side of river.

The property consists of a commercial, mixed-use structure that contains office space and residential units. The structure is very close to the river. The dam is located a short distance from the bridge.

Water Rights: The parcel located east of the Assabet River has water rights to the Assabet River. The owner of this property (Map 64, Lot 20 & Lot 19) is as follows:

> Stone Euclid L. & Kelly Susan E. Trsts.
> Euclid Stone Trust
> 94 Main Street
> Northborough, MA 01532

Staging Area for Dam Removal: The property adjacent to the Assabet River, owned by Euclid Stone Trust (which also has deeded water rights to the Assabet River), has a large, unimproved area adjacent to the river that could be utilized for a contractor's staging area for dam removal.

Northborough
Allen Street Dam (Gothic Craft Dam)

Location: Dam is located at 200 Hudson Street (between Hudson & Allen Street) Northborough, Assessor's Map 46, Lot 95

National Inventory of Dams: NID ID: MA00995
County: Worcester
River: Assabet River

Owner: Montrose Northborough LLC
C/o Micozzi Management Inc.
159 Cambridge Street, 3rd floor
Allston, MA 02134

Following is chain of title:

Grantor/Grantee: MLS Associates Limited Partnership to Montrose Northborough LLC (Note: NID ID still lists MLS Associates as owners.)
Worcester Registry of Deeds, Book 2110, page 139
Consideration: $2,140,000
Dated: March 2, 1999
Grantor/Grantee: Mark L. Schmid to MLS Associates
Worcester Registry of Deeds, Book 18503, page 156
Consideration: $400,000 plus assumption of a note and mortgage
Dated: December 27, 1996

The property consists of a multi-unit apartment complex that contains 8 residential units on 1.85 acres of land. The apartment unit spans both sides of the river, with most of the units being located on Hudson Street and a few having frontage on Allen Street. The structure is very close to the river. The dam is located a short distance from the bridge.

Staging Area for Dam Removal: At this site, the contractor's staging area could be on the southwesterly portion of the property, Map 46, Lot 95, which contains 1.85 acres of land. Also, additional space for access or staging, could be obtained from the abutting commercial property owner (Richard Record & Son, Inc., Map 46, Lot 96), a 2.62 acre parcel having 52± feet of frontage on Allen Street, 271± feet of frontage on the Assabet River, and 260± feet of frontage on Allen Court. Both properties have easy access to the dam, are level flat, and have sufficient open space for a staging area.

Hudson
Hudson Dam (Washington Street, Route 85 Dam):

Location: Dam is located on Washington Street (Rt. 85), Hudson, MA and shown on Assessor's Map 29, Lot 275 and Lot 38

National Inventory of Dams: NID ID: MA00447
County: Middlesex
River: Assabet River

Owner: Town of Hudson (per Town e-mail March 2009)
Town Hall, Main Street
Hudson, MA 01749

Grantor/Grantee: Hudson Properties, Inc. to Inhabitants of the Town of Hudson
Middlesex Registry of Deeds, Book 9154, page 278
Consideration: $12,000
Dated: May 24, 1958

Grantor/Grantee: Broad's Garage Inc. to Hudson Properties, Inc.
Middlesex Registry of Deeds, Book 9154, page 273
Consideration: Less than $100
Dated: May 22, 1958
Note: According to town of Hudson, there is a question as to whether the town gave the property to Hudson Light & Power in the 1980's. Hudson Light & Power wanted to remove the dam, but the town didn't want it removed, so they transferred ownership back to the town.

The town has a letter from Anthony Monteiro (then project manager) of Notice of Project Alteration for the Washington Street Hydro Project and a copy of Environmental Notification Form, dated March 15, 1985, wherein Hudson Light & Power sets forth its ownership of the Dam. There is mention in the 1986 Annual Report of the Hudson Light & Power referencing the Department's progress for the hydro-electric project at the Washington Street Dam. There is nothing in the town records that indicate a transfer of the Washington Street Dam back to the town from the Light & Power. However, Article 33 of the Annual Town Meeting of May 5, 1980, the town opposed a study to repair the Washington Street Dam.

Staging Area for Dam Removal: The town owns property abutting the dam that might be used for construction staging areas

Stow
Gleasondale Dam

Location: Assabet River, Off Gleasondale Road, Assessor's Map U-8, Lot 4
National Inventory of Dams: NID ID: MA00820
County: Middlesex
River: Assabet River

Owner: F L B Inc.
501 Gleasondale Road
Stow, MA 01775

Following is chain of title:

Book 12601, page 82 $185,000 March 15, 1974
Assabet Realty Trust to F.L.B. Corp.

This includes 3 parcels with improvements, parcel #1 contains 15 square rods (4,083.75 square feet); parcel #2 contains 4.54 acres, and parcel #3 encompasses the 3 reservoirs that were reserved from deed of M.J. Stevens & Sons to Jennie V. McClellan on August 16, 1944 (Book 6790, page 554).

Book 11149, Page 429 $85,000 June 28, 1966
Colrow Realty Trust to Assabet Realty Trust

This includes parcel #1, #2, and #3 which covers 3 reservoirs excepted in the description of 10th parcel in deed from M.T. Stevens & Sons Co. to Jennie V. McClellan (Book 6790, page 554).

Book 10058, Page 270 $77.55 in stamps June 19, 1962
L.O. Nichols et al to Colrow Realty Trust

This includes parcel 1, together with all rights to & in to land under river & canal. Parcel 2, containing 4.54± acres, of land comprising the mill property by Assabet River, over the river & canal formerly of McClellan. Parcel 3 Consists of land covered by 3 certain reservoirs excepted on description of 10th parcel in deed from M.T. Stevens & Sons Co. to Jennie V. McClellan (Book 6790, page 554).

Book 6790, Page 554 $22.00 in stamps August 16,1944
M.T. Stevens & Sons Co. to Jennie McClellan

The town of Stow has a note on the deed , recorded in the South Middlesex Registry of Deeds Book 12601, Page 82, from Russell Robb III and Leslee W. Robb, Trustees of Assabet Realty Trust, that lists the address of F.L.B. Inc., as Gleasondale Industrial Park, Route 62, Stow, MA

Note: The town shows the parcel containing 4.54 acres of land (the deed states 4.63 acres plus 3 reservoirs) and is improved with industrial buildings. The previous deed mentions the dam; this previous deed also mentions all water rights appurtenant to the premises conveyed and subject to all easements of flowage. The grantor reserved the fee in the canal and the right to go upon so much of the premises conveyed as necessary for purposes of operating (etc.) the old bridge (etc.).

Staging Area for Dam Removal: There is ample, unimproved land adjacent to the dam to accommodate a staging area and access to and from the dam.

Maynard
Ben Smith Dam (Cock Tower Place)

Location: Dam is located on the Assabet River, Assessor's Map 18, Lot 201
National Inventory of Dams: NID ID: MA00752
County: Middlesex
River: Assabet River

Owner: Wellesley/Rosewood/Maynard Mills Limited Partnership
80 Waverly Street
Framingham, MA 01702

Grantor/Grantee: Wellesley/Rosewood Mills, LLC to
Wellesley/Rosewood/Maynard Mills Limited Partnership
Middlesex Registry of Deeds, Book 27896, Page 474
Consideration: Nominal
Dated: September 5, 1997

Company also owns adjoining properties (Map 19, Lot 29; Map 14, Lot 201; Map 19, Lot 266; and Map 19, Lot 272). Originally built to divert water into Mill Pond to run the mills (generate electricity). The owners recently repaired the dam and they have a FERC license to generate electricity at the ponds; the water goes from the Assabet River into a canal and then into Mill Pond. Dredging could be done at the water capture area and behind the dam (the algae that accumulates behind the dam causes an odor).

Staging Area for Dam Removal: The owners of the dam also own the adjoining land that could be utilized for access and for a staging area for either dam removal or dredging.

ACTON
Powdermill Dam

Location: Dam is located on the Assabet River, 305 & 316 Old High Street
Assessor's Map J3, Lot 41-1 and 33-2

National Inventory of Dams: NID ID: MA00128
County: Middlesex
River: Assabet River

Owner: Acton Hydro Company, Inc.
9 Mayflower Drive
Northborough, MA 01532

Owner/Representative: Michael E. Coates
9 Mayflower Road
Northborough, MA 01532
Tel: 508-351-6023

Grantor/Grantee: A & D Hydro, Inc. /Acton Hydro Company, Inc.
Middlesex Registry of Deeds, Book 28063, Page 306
Consideration: $20,000
Dated: January 9, 1998

Acton Hydro Co., Inc. has filed a Notice of Intent with the Acton Conservation Commission seeking permission to remove, fill, dredge or alter an Area Subject to Protection under the Wetlands Protection Act.

They (Acton Hydro Co.) has a FERC application (FERC Project No. 7148-MA) to renovate/repair the dam and sell power to Concord Electric.

Staging Area for Dam Removal: There appears to be potential staging areas near the dam. Ownership of lands would need to be determined and appropriate construction easements obtained.

APPENDIX H

PHOTO DEPICTIONS OF DAM REMOVALS



Massachusetts Department of Environmental Protection

US Army Corps of Engineers

CDM

Existing

Aluminum City Dam

Northborough, MA

September 12, 2007



Massachusetts Department of Environmental Protection

US Army Corps of Engineers

CDM

Photo-Simulation
Aluminum City Dam Removal

Assabet River

Northborough, MA

September 12, 2007



Massachusetts Department of Environmental Protection

US Army Corps of Engineers

CDM

Existing Impoundment

Allen Street Dam

Northborough, MA

Photo Taken
October 12, 2007 by
Thomas Haas Associates



Massachusetts Department of Environmental Protection

US Army Corps of Engineers

CDM

Photo Simulation
Allen Street Dam Removal
Assabet River
Northborough, MA



Massachusetts Department of Environmental Protection

US Army Corps of Engineers

CDM

Existing

Hudson Dam

Hudson, MA

September 12, 2007



Massachusetts Department of Environmental Protection

US Army Corps of Engineers

CDM

Photo-Simulation
Hudson Dam Removal
Assabet River
Hudson, MA

September 12, 2007



Massachusetts Department of Environmental Protection

US Army Corps of Engineers

CDM

Existing Impoundment

Hudson Dam

Hudson, MA

Photo Taken
October 12, 2007 by
Thomas Haas Associates



Massachusetts Department of Environmental Protection

US Army Corps of Engineers

CDM

Photo Simulation
Hudson Dam Removal

Assabet River

Hudson, MA



Massachusetts Department of Environmental Protection

US Army Corps of Engineers

CDM

Existing

Gleasondale Dam

Stow, MA

Photo Taken
September 12, 2007



Massachusetts Department of Environmental Protection

US Army Corps of Engineers

CDM

Photo-Simulation
Gleasondale Dam Removal

Assabet River

Stow, MA

Photo Taken
September 12, 2007



Massachusetts Department of Environmental Protection

US Army Corps of Engineers

CDM

Existing Impoundment

Gleasondale Dam

Stow, MA

Photo Taken
October 12, 2007 by
Thomas Haas Associates



Massachusetts Department of Environmental Protection

US Army Corps of Engineers

CDM

Photo Simulation

Gleasondale Dam Removal

Assabet River

Stow, MA



Massachusetts Department of Environmental Protection

US Army Corps of Engineers

CDM

Existing

Ben Smith Dam

Maynard, MA

Photo Taken
September 12, 2007



Massachusetts Department of Environmental Protection

US Army Corps of Engineers

CDM

Photo-Simulation
Ben Smith Dam Removal

Assabet River

Maynard, MA

September 12, 2007



Massachusetts Department of Environmental Protection

US Army Corps of Engineers

CDM

Existing Impoundment

Ben Smith Dam

Maynard, MA

Photo Taken
October 12, 2007 by
Thomas Haas Associates



Massachusetts Department of Environmental Protection

US Army Corps of Engineers

CDM

Photo Simulation
Ben Smith Dam Removal

Assabet River

Maynard, MA

Photo Taken
October 12, 2007 by
Thomas Haas Associates

APPENDIX I

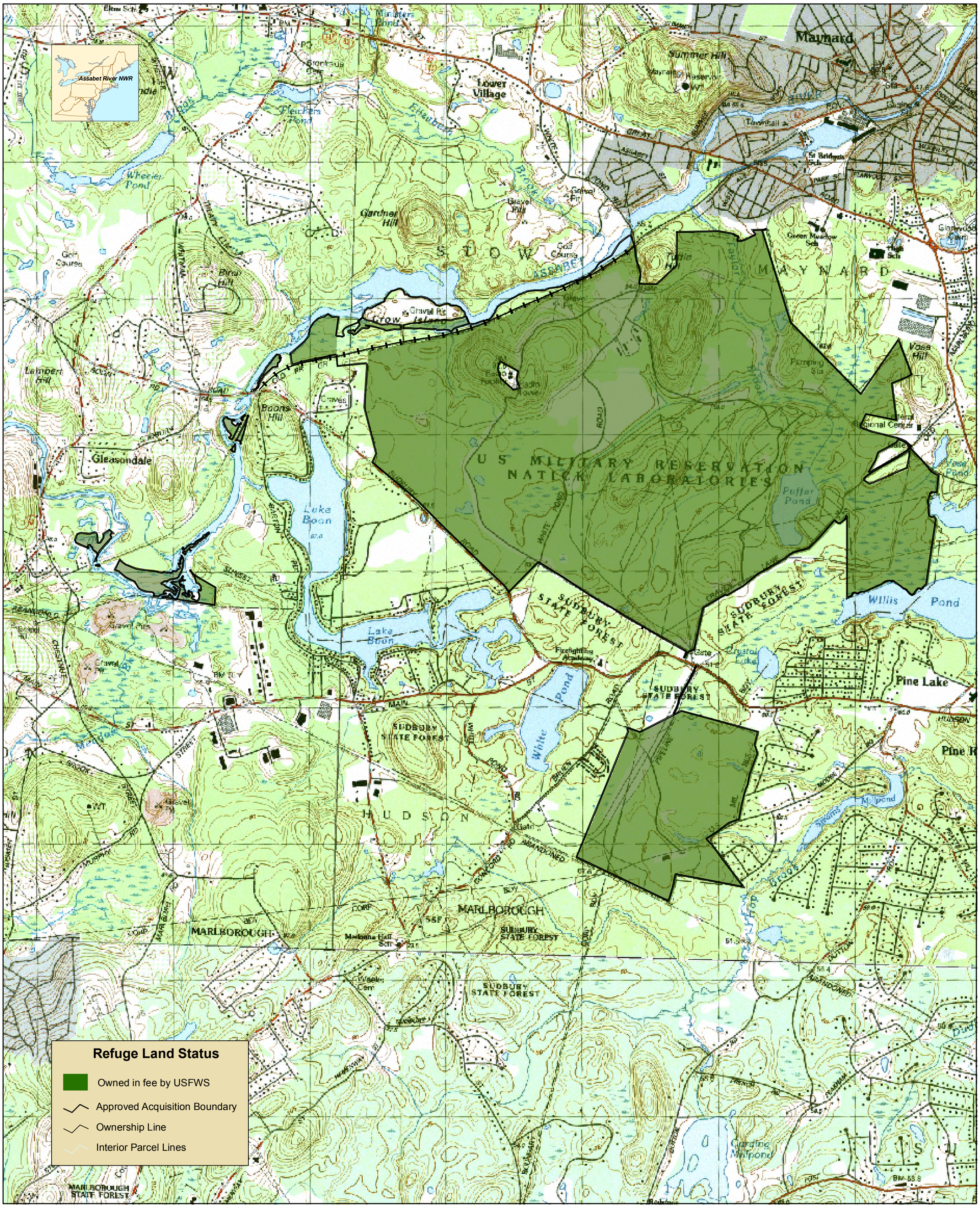
ASSABET RIVER NATIONAL WILDLIFE REFUGE

U.S. Fish & Wildlife Service

Land Status

Assabet River National Wildlife Refuge

Middlesex County, Massachusetts



Produced in the Division of Realty, Hadley, Massachusetts
Land Status Current to: Calendar Date not entered for Asr_FwsInterest
Basemap: USGS 1:24,000 topographic map
Refuge boundaries: compiled from USFWS sources
Datum & Projection: NAD_1983_UTM_Zone_19N
Map Print Date: 9/10/2008

0 0.125 0.25 0.5 0.75 1 1.25 Miles

0 0.2 0.4 0.8 1.2 1.6 2 Kilometers

1:20,016

This map is designed for refuge management.
It is not intended for use as a land survey or
as a representation of land for conveyance or tax purposes.
For more information visit the USFWS Northeast Region GIS
website at http://northeast.fws.gov/gis/

N W E S