# Patch Pond Dam Removal Feasibility Study

## Final Report


**City of Worcester, Massachusetts**

June 2014

CDM Smith

# Table of Contents

# List of Figures

# List of Tables

# Appendices

# Executive Summary

## ES.1 Background and Purpose

In 2014, the City of Worcester, Massachusetts (the City) began a study to evaluate the feasibility of removing of the Patch Pond Dam (PPD). The dam is owned by the City of Worcester and it is located along Tatnuck Brook in the western section of the City, east of Mill Street and to the north of June Street. The dam is a tax levy dam and is supported by funding from general property taxes. The City recognizes that removing the dam would restore natural fluvial processes and improve riparian habitat in the dam impoundment and the adjacent reaches of the Tatnuck Brook. In addition, since the dam serves no purpose its removal would eliminate potential liability and costs associated with ownership of the dam, and improve public safety.

**The Patch Pond Dam**

The Massachusetts Executive Office of Energy and Environmental Affairs (EEA) awarded a $119,040 grant to the City to conduct a feasibility study of the removal of the PPD. The grant is part of the Sustainable Water Management Initiative (SWMI), which is an EEA effort to maintain healthy rivers and streams and improve degraded water resources. The SWMI grant program is aimed at assisting water suppliers with planning projects for specific watersheds, developing implementation projects to improve ecological conditions, and managing projects aimed at reducing the demand for water within a municipality or watershed.

All alternatives considered in this feasibility study included full dam removal, along with a range of scenarios for management of the accumulated sediment within Patch Pond. Partial dam removal was not considered for ecological restoration and long-term safety reasons. While the scope of this study was limited to evaluating the feasibility of removing the dam, the City is also assessing the major repairs that would be needed to bring the Patch Pond Dam in compliance with dam safety regulations. Evaluation of dam repairs is the subject of a separate evaluation.

## ES.2 Physical Characteristics of the Site

A drainage area of approximately 9.8 square miles contributes flow to the PPD, which impounds an area of approximately 4.8 acres. Sediment has accumulated behind the dam to various depths of up to about 5 feet. Sediment depths and elevations were determined with a bathymetric survey of the impoundment and sediment sampling.

The dam is located upstream of a residential neighborhood, with most homes located above the elevation of the reservoir. However, a number of homes adjacent to June Street are below the downstream toe elevation of the dam. Given the potential for loss of life and/or property due to failure of the dam, the dam was assessed to be a High Hazard potential structure by CDM Smith in 2007.

The condition rating of Patch Pond Dam is Unsafe in accordance with the Office of Dam Safety criteria (ODS). The primary factors contributing to this rating include a breach area at the east abutment and partial collapse/breach of the primary spillway.

## ES.3 Existing Resources

As part of this feasibility study, existing resources were identified in the areas around the Patch Pond Dam. These resources included watersheds, water resources, wetlands, wildlife habitat, fisheries, floodplains, rare and sensitive habitats, historic and archeological resources, land uses, and nearby utilities. It was determined that removal of PPD would not have a permanent negative effect on any of these resources and in fact would improve the quality of water resources and fisheries.

## ES.4 Hazardous Waste Sites and Characterization of Sediment/ Soil

Twelve sites regulated under the Massachusetts Contingency Plan (MCP) located within 1.8 miles of the PPD were identified. Two of the sites are open sites; five of the sites are closed sites with an Activity and Use Limitation (AUL); and five of the sites are closed sites with no AUL. At this time, it is expected that these twelve sites will not impact the Patch Pond Dam.

Six locations in and around the Patch Pond Dam were sampled for sediment and underlying soil characteristics. Two of the sample locations were within the impoundment, two were upstream of the impoundment, and two were downstream of the impoundment. At each location, an upper sample was collected for sediment and a lower sample was collected into the native soil material. Sediment samples were tested for general chemistry, total organic carbon (TOC), total metals, volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), polychlorinated biphenyl (PCB) congeners, total petroleum hydrocarbons (TPH), extractable petroleum hydrocarbon (EPH) ranges, polycyclic aromatic hydrocarbons (PAH), herbicides, pesticides and hazardous waste characteristic parameters. The native soil samples were tested for grain size analysis.

Sediment samples showed levels of metals and PAHs that exceeded some of the MCP RCS-1 criteria and Stage I ecological risk criteria. The primary metal of concern was arsenic. Arsenic levels in Patch Pond were elevated, which could be attributed to the naturally occurring elevated arsenic levels in the Worcester area. The concentration of arsenic in the Patch Pond were higher than at the locations downstream that were sampled, indicating a potential impact should there be a release of this material when the dam is removed.

Some PAHs exceeded the Stage I criteria in Patch Pond, but the concentrations were not significantly higher than the criteria and were actually lower than that found downstream. There is not likely to be an adverse impact due to PAHs from the removal of the dam.

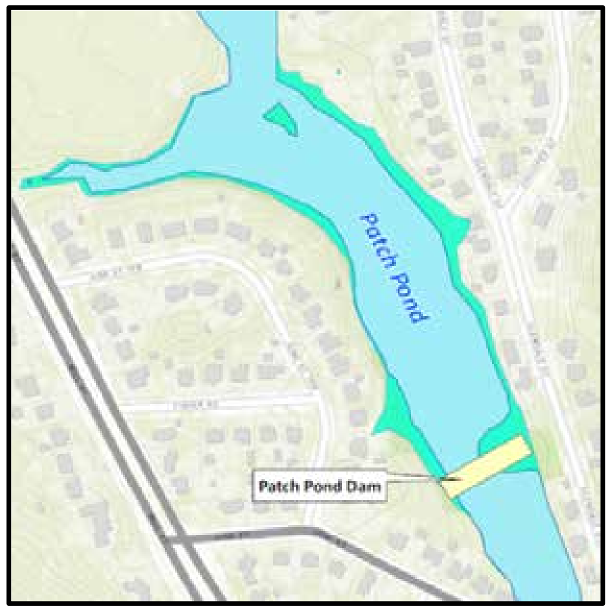
The highest concentrations of arsenic and PAHs were found in the upstream sample collected from the storm drain/unnamed stream at Mill Street. This area should be investigated as a possible source of elevated concentrations of arsenic and PAHs, and may be a candidate for installation of stormwater Best Management Practices (BMPs).

The results of the sampling conducted under this feasibility study and recent discussions with Massachusetts Department of Environmental Protection (MassDEP) indicate that the sediments in Patch Pond can be either removed or stabilized in place (or a combination thereof). They should not be released to areas downstream of the dam unless subsequent sampling shows that the levels of arsenic in the pond sediments are at or below the levels seen in the downstream sediments. Should the City elect to move forward with removal of the dam, a more extensive sampling program focused on metals (arsenic, in particular) would be required. The results obtained from this future sampling would then be used to refine the approach to sediment management and determine when and if disposal, release or in-place stabilization are appropriate.

## ES.5 Hydrologic and Hydraulic Analysis

A hydrologic and hydraulic analysis was conducted for the Patch Pond watershed using a HEC-RAS and a HEC-HMS model. The HEC-RAS model was built to simulate the hydraulic profiles of the existing conditions and potential removal of the Patch Pond Dam. The HEC-HMS model was developed for the hydrologic analysis and was based on an already existing model. Further detail such as updated basin characteristics was incorporated into the existing HEC-HMS model in the study area upstream and downstream of the Patch Pond Dam.

The existing HEC-HMS model extends south from the Holden No. 1 and No. 2 Reservoirs to the Patch Pond Dam and extends to Coes Reservoir, which is downstream of the Patch Pond Dam. The analysis focused within the immediate vicinity of the Patch Pond Dam and focused on the average day flow and the 100 year storm event, although other larger storm events were considered in the model. The removal of the Patch Pond Dam would have little or no effect on the flood stage from the existing conditions outside the vicinity of the existing dam. However, in the area Patch Pond Dam, removal would and lower the peak flood stage.




**Patch Pond Dam Flood Analysis**

## ES.6 Sediment Transport and Evaluation

A sediment transport model (MBH's HEC-6T) was run using best available representative data on the native soils in the area. The model was run for long-term erosion and short-term extreme flood scenarios.

Within the impoundment, the bottom of the accumulated sediment layer was used as the maximum erodible depth since the streambed downstream of the dam and upstream of the impoundment consists of gravel and cobbles. Based on this assumption, the model predicted that a portion of the accumulated sediment will still remain within the impoundment 20 years after the dam removal. This is assumed to be due to the fact that natural streams are often in a state of equilibrium with sediments entering and leaving at generally constant rates.

The sediment transport evaluation recommended either allowing the stream to erode the native soil until a more resistant non-erodible streambed layer is reached, or armoring the native soil in the channel to resist further erosion after the dam removal.

Should the City elect to move forward with dam removal, further investigation of the grain size characteristics of the native soil below the accumulated sediment to be removed during dam removal is recommended to better predict the stabilized channel profile in the Patch Pond. Detailed boring information should be collected in final design to confirm the model results. These recommendations were made with no consideration of the level of contamination of the sediments.

## ES.7 Alternatives

Three feasible alternatives were considered for removal of the Patch Pond Dam – all involve full removal of the dam structure along with various approaches for handling the sediment, ranging from removal of ***all*** of the sediment in Patch Pond to stabilizing all sediment in-situ.

Based on the anticipated provisions of Amendments to Wetlands Protection Regulations that would establish a General Permit for Ecological Restoration, a qualifying dam removal project would need to involve removal of the full vertical extent of the dam. In addition, removing the full vertical extent will eliminate the potential for any structure remnants to become a barrier in the future as streamflow would likely cause scour on the downstream side. As such, partial removal of the dam was not considered in this feasibility study.

Table ES-1 presents a summary of the alternatives.

**Table ES-1**
**Patch Pond Dam Removal Alternatives**

| *Alternative* | *Removal of the Full Vertical Extent of the Dam* | *Removal of Sediment in Patch Pond* | *Pond Stabilization* | *Channel Details* |
|---|---|---|---|---|
| 1 | Yes | 19,000 cubic yards | Erosion Controls: Seed Mixture / Stabilization Mats | Simple Channel With Stable Materials Added for Structural Support |
| 2 | Yes | 4,000 cubic yards | Strict Erosion Controls: Seed Mixture / Stabilization Mats | Engineered Channel using Rip Rap or Advanced Natural Channel Design Techniques |
| 3 | Yes | None; in situ sediment stabilization | Strict Erosion Controls: Seed Mixture / Stabilization Mats | Engineered Channel using Rip Rap or Advanced Natural Channel Design Techniques |

The first alternative consists of removing the spillway, lowering the dam apron to the estimated natural stream grade, and removing all traces of the dam structure(s). A full removal would demolish portions of the dam above finished grade. Approximately 19,000 cubic yards of sediment would be removed from within the impoundment, and the natural bottom of the pond restored. A channel would be constructed in the existing native soils to simulate the historic natural alignment of Tatnuck

Brook. This alternative would use native seed mixtures to establish natural wetland vegetation throughout the project area.

The second alternative also consists of removing the spillway, lowering the dam apron to the estimated natural stream grade, and removing all traces of the dam structure(s). A full removal would demolish portions of the dam above finished grade. For this option, however, approximately 4,000 cubic yards of sediment would be removed and a channel would be constructed in the existing sediment to simulate the historic natural alignment of Tatnuck Brook. This alternative focuses on establishing new natural wetland vegetation to stabilize the surrounding area. Any sediment remaining within the Patch Pond would require strict erosion controls and stabilization to ensure the sediment does not erode downstream.

The third alternative also consists of removing the spillway, lowering the dam apron to the estimated natural stream grade, and removing all traces of the dam structure(s). A full removal would demolish portions of the dam above finished grade. A channel would be constructed to simulate the historic natural alignment of Tatnuck Brook. For this option, however, all sediment within the new channel as well as immediately behind the dam would be stabilized within the existing impoundment utilizing strict erosion controls and stabilization techniques to ensure the sediment does not erode downstream. New natural wetland vegetation would provide long-term stabilization to the surrounding area.

Under all alternatives, a flood channel approximately 20 feet wide would be excavated through the sediment and/or the natural stream bottom. This channel would be sized to pass the 10-year peak discharge (1,240 cfs) flow. Within the flood channel, a smaller flow channel would be constructed using "natural channel design techniques" to form a suitable armored bottom and habitat during average flows.

After the dam is removed, the existing channel on the east side of the dam formed from the partial breach of the dam would be eliminated. The flow would be diverted to the west side of the dam to where the natural channel of Tatnuck Brook exists. Removing the stream formed as a result of the breach would promote better habitat for fluvial fish, and restore Tatnuck Brook to a more natural condition.

## ES.8 Environmental Permitting

Permitting for this project is assumed to be conducted after the proposed revisions to the Massachusetts Wetlands Protection Act (310 CMR 10.00) and proposed revisions to the 401 Water Quality Certification Regulations (314 CMR 9.03(8)) have been promulgated. These revisions are expected to establish a simplified General Permit for Ecological Restoration. The revisions also allow exemptions for dredging or discharge of dredged or fill material for qualifying ecological restoration projects such as dam removals. Additional permits would be required prior to construction, but the overall process is anticipated to be streamlined under the forthcoming regulatory revisions, which are aimed at encouraging ecological restoration projects.

## ES.9 Costs

The total opinion of probable project cost is estimated to be between $7.24M and $8.11M for the full sediment removal alternative (Alt 1), between $2.72M and $3.17M for the limited sediment removal alternative (Alt 2), and between $1.50M and $1.70M for the in-situ sediment stabilization alternative (Alt 3). A range of costs for each alternative are presented because several viable methods for bypassing the streamflow around the dam during construction were considered. The cost components are presented in Table ES-2.

**Table ES-2**
**Patch Pond Dam Removal Opinion of Probable Project Costs**

| Cost Item | Alternative 1 Full Removal of the Dam and Full Removal of the Sediment | Alternative 2 Full Removal of the Dam and Limited Removal of the Sediment | Alternative 3 Full Removal of the Dam and In-Situ Sediment Stabilization |
|---|---|---|---|
| Construction[1] | $5,660,000 to $5,770,000 | $2,130,000 to $2,250,000 | $1,060,000 to $1,190,000 |
| Escalation to Mid-Point of Construction[2] | $370,000 to $380,000 | $140,000 to $150,000 | $70,000 to $80,000 |
| Project Contingency, Engineering and Implementation[3] | $1,210,000 to $1,960,000 | $450,000 to $770,000 | $362,000 to $405,000 |
| **Total[4]** | **$7,240,000 to $8,110,000** | **$2,720,000 to $3,170,000** | **$1,500,000 to $1,700,000** |

**Notes:**

[1]*Construction includes construction contingency of 25%.*

[2]*Escalation to mid-point of construction assumes mid-point of construction occurs in August 2016. Escalation is assumed to be 3% per year of the sum of the construction and construction contingency.*

[3]*Project contingency is 10% of the sum of the construction, and escalation to mid-point of construction. Engineering and Implementation is 20% of the sum of construction, and escalation to mid-point of construction.*

[4]*The range of costs for each alternative is presented to account for various flow bypass methods and various project contingencies that would be further defined in the final design should the project move forward.*

## ES.10 Preferred Alternative

A list of non-cost criteria was considered in addition to costs for selecting a preferred dam removal alternative under this feasibility study. Out of 10 criteria considered, only two were materially different between the alternatives. Given the significant cost savings of Alternatives 2 and 3 and the comparatively small increase in liability for the requirement to stabilize contaminated sediment in place, the limited sediment removal alternative (Alt 3) is the preferred alternative.

Given the complexities of a natural brook environment, inspection and monitoring of the site after dam removal would be necessary to assess vegetation growth, erosion, scour, debris accumulation, water quality, etc. Additional work would also be needed during design and permitting to finalize the balance between a fully natural brook restoration and engineered brook restoration.

## ES.11 Acknowledgment

This project has been financed partially with State Capital Funds from the Massachusetts Department of Environmental Protection (the Department) under a Sustainable Water Management Initiative Grant. The contents do not necessarily reflect the views and policies of the Department, nor does the mention of trade names or commercial products constitute endorsement or recommendation for use.

# Section 1
# Introduction

## 1.1 Background and Purpose

In 2014, the City of Worcester, Massachusetts (the City) began the process of developing a feasibility study to look at possible options for the removal of the Patch Pond Dam (PPD). The dam is owned by the City of Worcester and is located along Tatnuck Brook in the western section of the City, east of Mill Street and to the north of June Street.

The City is interested in assessing the feasibility of removal versus major repairs to the Patch Pond Dam, which is in poor condition. Removing the dam to restore natural fluvial processes and improve riparian habitat in the dam impoundment and the adjacent reaches of the brook. In addition, since the dam serves no purpose its removal will eliminate potential liability and costs associated with ownership of the dam, and improve public safety.

## 1.2 Project Scope

The Massachusetts Executive Office of Energy and Environmental Affairs (EEA) awarded a $119,040 grant to the City to conduct a feasibility study of the removal of the PPD. The grant is part of the Sustainable Water Management Initiative (SWMI) program, which is an EEA effort to maintain healthy rivers and streams and improve degraded water resources. The SWMI grant program is aimed at assisting water suppliers with planning projects for specific watersheds, developing implementation projects to improve ecological conditions, and managing projects aimed at reducing the demand for water within a municipality or watershed.

This feasibility study provides a detailed evaluation of those aspects of dam removal that will lead to a better definition of the viability of removal as well as the overall cost. At the conclusion of the study, the City of Worcester will have a more detailed understanding of the potential project benefits, costs, and funding availability for implementation.

While the scope of this study was limited to evaluating the feasibility of removing the dam, the City is also assessing the major repairs that would be needed to bring the Patch Pond Dam in compliance with dam safety regulations. Evaluation of dam repairs is the subject of a separate evaluation.

The overall scope of this project includes the following:

- Site reconnaissance and review of background data

  An evaluation of potential infrastructure that could be impacted by dam removal was conducted. This included a review of available information on the dam such as archival reports, utilities crossing through or downstream of the dam, and potential stability issues in and around the dam.

- Evaluation of habitat for state-listed rare or endangered species, cultural resources, and resource areas

  An evaluation of the dam impoundment, land immediately adjacent to the impoundment, and land immediately downstream was undertaken to ascertain if it is within priority or estimated habitat for state-listed rare or endangered species. This evaluation was based on maps published by the Massachusetts Natural Heritage & Endangered Species Program and the Historic Register and looked for the presence of cultural resources that could be affected by the dam removal.

- Evaluation of topographic data; sediment characterization with transport and mobility studies

  Survey data including LiDAR (Light Detection and Ranging), supplemented by a land and bathymetry field survey, was used in this feasibility study.

  The quantity and characteristics of the sediments upstream of the dam were reviewed. Information on current and past upstream land uses were reviewed from databases and past reports.

  Sediment samples were obtained upstream and downstream of the dam and were analyzed for physical characteristics as well as heavy metals and organic constituents for comparison to sediment screening standards available from MassDEP for landfill reuse and sediment dredging. Samples were analyzed for VOCs, SVOCs, Pesticides, PCBs, and Primary Pollutant Metals.

  Finally, transport capabilities and potential mobility of sediments were assessed upstream and downstream of the dam. Appropriate sediment management options were evaluated.

- Hydrologic and hydraulics analyses

  Hydrologic and hydraulics analyses were conducted for the PPD watershed. This included the dam, impoundment, and surrounding areas to predict water surface and velocity profiles for both existing and post-removal conditions. Options for site stabilization and stream channel restoration were included.

- Alternatives analysis and cost evaluation

  An analysis was performed that identified alternatives for deconstruction and removal of the dam, including affected upstream and downstream areas and potential areas requiring restoration or reclamation. Structural stabilization requirements were also identified. Cost estimates were developed that include permitting, engineering, design and construction for each alternative.

- Community interests/concerns workshop

A community workshop was held with the City and various stakeholders and interested parties to present the preliminary assessment and inquire about potential community interests and concerns with removal of the dam.

# 1.3 Project Description and History

## 1.3.1 Project Description

The City of Worcester owns 29 dams in and around Worcester and adjacent communities. Some of the dams are no longer in use and/or no longer used for their intended purpose. These dams require continuous maintenance and in some cases, upgrading so as to not present a public safety hazard, as a failure could cause the sudden release of water in addition to affecting river flows and fish passage. Such dams have been identified by the City as candidates for removal in order to restore natural processes to local rivers, improve public safety, and relieve the City of the liability and the economic burden of construction and maintenance work.

## 1.3.2 Project History

While the exact date is unknown, the Patch Pond Dam is thought to have been built in the late 1700s to provide water power to a saw and grist mill. Dams were erected on the many smaller streams throughout the City, including Tatnuck Brook, in an effort to generate water power. Grist and saw mills sprung up in the area throughout the 1700s and mill ponds dotted the landscape. The grist mill would process the Indian corn into a meal which then later could be made into bread. According to the 1793 Census, Worcester County had 90 saw mills in 1793. The first saw and grist mill in the City was established on the Mill River by Captain John Wing in 1684 during the failed second of three attempts of creating a settlement in the area. The Patch Pond Dam and saw and grist mill owned by W.W. Patch is shown on a map of Worcester dating back to 1886 (source: Worcester Historical Museum archives). As the road network improved the need for so many mills vanished and only the more efficient ones survived. The map of Worcester from 1911 shows the property being owned by C. Rebboli and no longer shows the saw and grist mill. The local grist mill to a great extent disappeared with the arrival of the railroad which brought flour from mid-western mills to the area.

The 1886 map also shows an ice house indicating that the upstream impoundment was used by W. W. Patch for manufacturing of ice during the winter months. Subsequently, Rebboli Pond Inc. used Patch Pond for manufacturing ice during the turn of the century. By the 1940s the icebox in homes had been replaced by artificial refrigeration. The dam became the property of the City of Worcester in 1961. The dam currently serves no purpose aside from maintaining the upstream impoundment and providing aesthetics to the surrounding residential development.

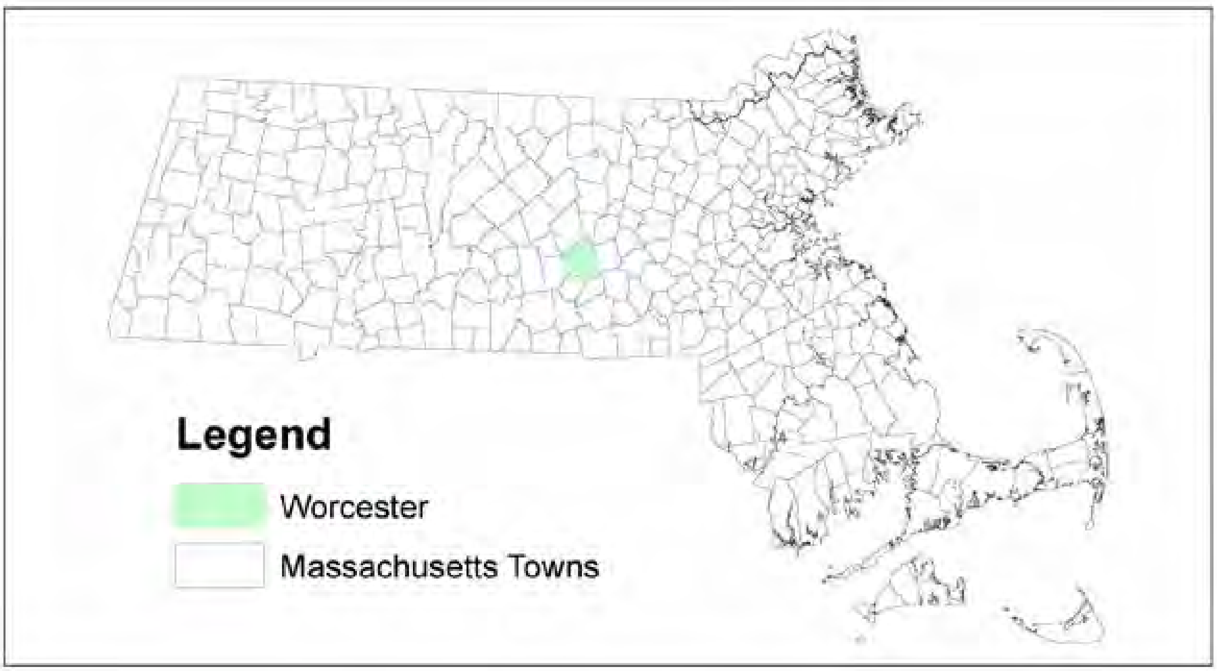
Over the years, dams in the Commonwealth received little attention until 2002 when major revisions were made to the Dam Safety Statute, MGL Chapter 253 §§ 44-50. These revisions established more stringent responsibilities for both public and private dam owners relative to registration, inspection, and maintenance of dams to ensure that they are kept good operating condition. In 2005, the Dam Safety Regulations (302 CMR 10.00-10.16) were amended to reflect the 2002 statutory changes. Minor revisions to the regulations were also made in 2009. The Department of Conservation and Recreation (DCR) is responsible for enforcing the dam safety program and regulations through its Office of Dam Safety (ODS).

The Patch Pond Dam has a structural height of 12 feet and impounds a maximum volume of 60 acre-feet, and is therefore a Small-size dam according to the criteria established in the ODS Regulations. The dam is assigned a High Hazard potential classification because it is located upstream of a residential neighborhood and a number of homes are located below the toe elevation of the dam.

### 1.3.3 Project Location

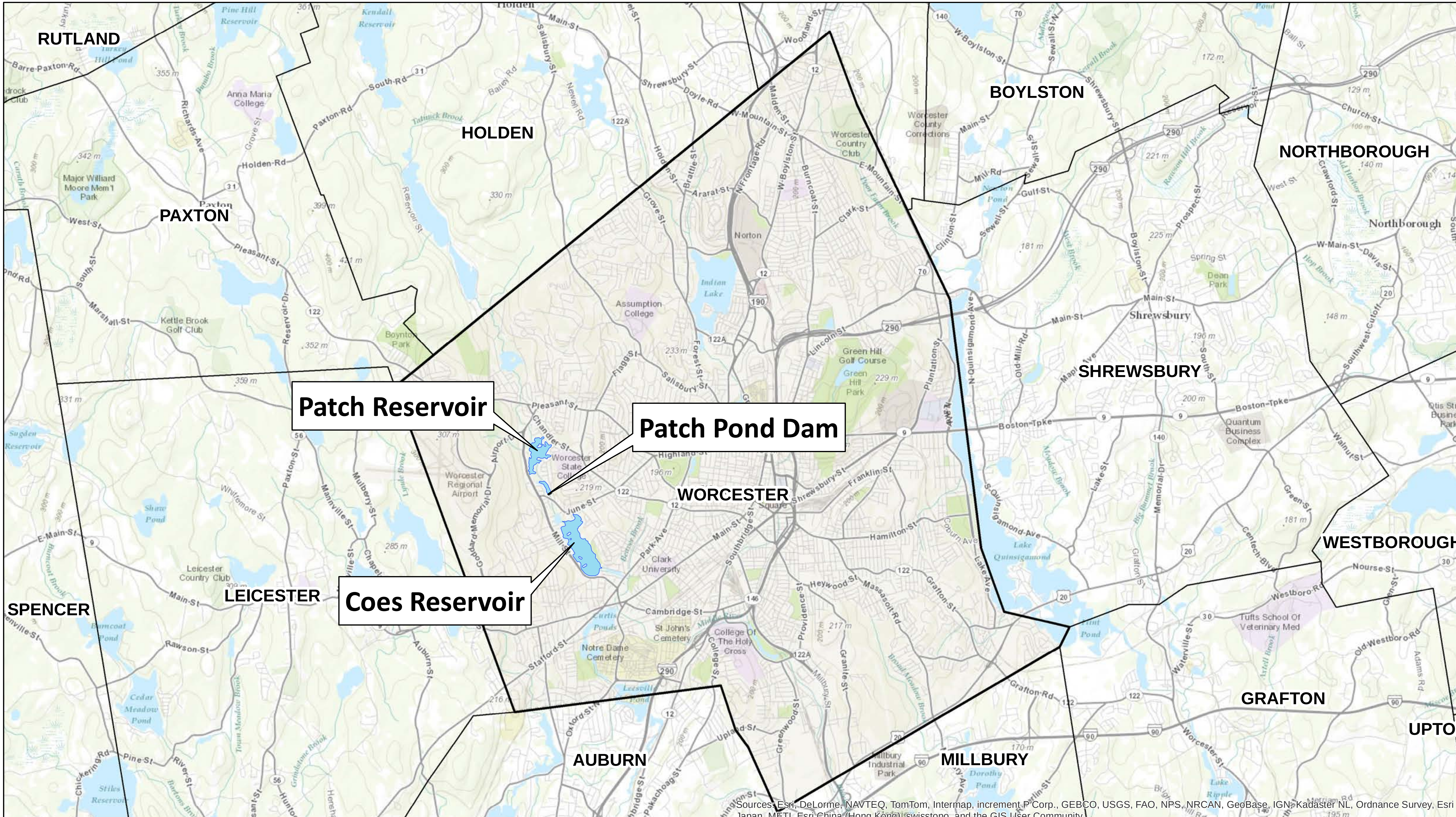
The City of Worcester is located in central Massachusetts, as shown on Figure 1-1. The City is bordered by the communities of Holden, West Boylston, Shrewsbury, Grafton, Millbury, Auburn, Leicester and Paxton. Worcester is the second largest city in New England, and is located approximately 40 miles west of Boston and 38 miles east of Springfield.

**Figure 1-1**
**Site Vicinity**




The planning area for the PPD, shown on Figure 1-2 encompasses the area immediately upstream of the dam to Patch Reservoir and the area immediately downstream of the dam, extending to Coes Reservoir.

The PPD (State Dam ID No. 3-14-348-10, NID No. MA03341) is located on Tatnuck Brook and is tributary to Coes Reservoir. The size of the upstream impoundment area is approximately 4.82 acres at normal pool. It is located at 42.2637 N, 71.8483 W, approximately 3 miles west of downtown. Figure 1-2 shows the site of the dam and the adjacent area from Patch Reservoir to Coes Reservoir. The existing site conditions are shown on Figures 1-3, 1-4 and 1-5.




4/7/2014

CDM Smith

Worcester, MA

Water Bodies
Dam
Towns

**Worcester, Massachusetts**
**Patch Pond Dam Removal Feasibility Study**

N

0 3,000 6,000 12,000 Feet

**Figure 1-2**
**Study Area**

SHEETSIA \\dacgis02\projects\Worcester\PatchPond_Dam_Removal\MXD\Study_Area_11x17.mxd 4/7/2014


6/4/2014

Water
Dam

**Worcester, Massachusetts**
**Patch Pond Dam Removal Feasibility Study**

N

0 250 500 1,000 Feet

**Figure 1-3**
**Existing Conditions**

CDM Smith


6/4/2014

Water

Dam

**CDM Smith**

## Worcester, Massachusetts
## Patch Pond Dam Removal Feasibility Study

N

0 250 500 1,000 Feet

## Figure 1-4
## Existing Conditions

SHEETSIA \\dacgis02\projects\Worcester\PatchPond_Dam_Removal\MXD\Existing_conditions_topo_11x17.mxd 6/4/2014


| REV. NO. | DATE | DRWN | CHKD | REMARKS |
|---|---|---|---|---|

DESIGNED BY: J.COY
DRAWN BY: J. COY
SHEET CHK'D BY: X
CROSS CHK'D BY: X
APPROVED BY: R. MUSCI
DATE: JUNE 2014

CDM Smith
50 Hampshire Street
Cambridge, MA 02139
Tel: (617) 452-6000

CITY OF WORCESTER, MASSACHUSETTS
DEPARTMENT OF PUBLIC WORKS AND PARKS

PATCH POND DAM REMOVAL
FEASIBILITY STUDY

EXISTING CONDITIONS
PLAN

PROJECT NO. 0198-103419
FILE NAME: CBRPL001.DWG
SHEET NO.
1-5

30% SUBMITTAL - NOT FOR CONSTRUCTION

## 1.4 Regulatory Requirements

Should the City of Worcester elect to move forward with removal of the Patch Pond Dam, environmental permitting requirements for the project will include local, state, and federal regulatory coordination and permits. It is recommended that pre-application coordination with the Worcester Conservation Commission and other local, state, and federal environmental regulatory agencies be scheduled after completion of the Preliminary Design to ensure that all regulatory requirements are addressed and to facilitate the permit approval process. Under the proposed revisions to the Massachusetts Wetlands Protection Act (MWPA, 310 CMR 10.00) dam removal projects would qualify for a General Permit for Ecological Restoration provided they meet the eligibility criteria set forth in the regulations. A proposed revision to the 401 Water Quality Certification Regulations (314 CMR 9.03(8)) exempts an ecological restoration project eligible for a general permit from the requirement to apply for a 401 Water Quality Certification (WQC), provided the project does not require an individual 404 permit from the U.S. Army Corps of Engineers. The Patch Pond Dam removal project is anticipated to require authorization under Category 2 of the General Permit from the Army Corps of Engineers, and as such would not require a 401 WQC as long as the work complies with the performance standards for dredging listed in 314 CMR 9.07(3). Furthermore, since the project meets the criteria for an Ecological Restoration Project, it would be exempt from the environmental review process under the Massachusetts Environmental Policy Act (MEPA). A detailed discussion of permitting requirements is presented in Section 8.

Approval from the Office of Dam Safety (ODS) is also required under 302 CMR 10.09, which requires that any person(s) who proposes to construct, repair, materially alter, breach or remove a dam, must file with the Commissioner and obtain a Chapter 253 Dam Safety Permit unless the Commissioner specifically waives the permit under specific exemptions stated in the regulations.

### 1.4.1 Patch Pond Dam Removal and SWMI Framework

Patch Pond Dam and Tatnuck Brook are located in Subbasin 23024 of the Blackstone River. According to the SWMI GIS viewer, http://www.mass.gov/eea/agencies/massdep/water/watersheds/sustainable-water-management-initiative-swmi.html, the Tatnuck Brook is a Coldwater Fishery from its origin in the Town of Holden to the inlet to Patch Reservoir, which is immediately upstream of Patch Pond. Within the context of the SWMI Framework, this subbasin is categorized as Biological Category 5 (BC5), having 65% or greater alteration of fluvial fish indicative of fish communities that have undergone severe changes to their structure and function. (See Appendix A for supporting SWMI data layers)

The total habitat assessment score for the segment of Tatnuck Brook between Patch Pond Dam and Williams Mill Pond was one of the highest in the Blackstone Basin per MassDEP's Water Quality Assessment (WQA). (See Appendix B). Observed fluvial fish counts in Tatnuck Brook just below the Patch Pond Dam were the highest density of all the tributaries sampled in the entire Blackstone Basin even though the habitat is restricted to about 1,100 feet of stream between the dam and the inlet to Williams Mill Pond. Removal of Patch Pond Dam would create an additional 800 feet of stream and increase the available habitat by 70 percent.

The WQA does note that impoundments (i.e., Patch Pond Dam) just upstream of this reach of Tatnuck Brook may contribute to the presence of organic particulates and their resulting effects (reduced EPT index) on the benthic community. This is supported by the 2003 MassDEP Nonpoint Source Action Strategy for the Blackstone River Basin (Appendix C), which suggests that the area suffers from organic enrichment. The Patch Pond impoundment serves as a sink for detritus that subsequently underdoes decomposition and is likely one (of several) sources of organic enrichment. Removing the Patch Pond Dam and educating the local residents about dumping refuse and yard waste will eliminate this condition that contributes to the enrichment process.

In addition, under the Phase II Stormwater Regulations, Tatnuck Brook in the vicinity of Patch Pond is a Category 5 (Waters Requiring a TMDL) Impaired Water Body (Other Habitat Alterations; Turbidity; Objectionable Deposits) (Appendix C). Removal of the dam would restore this stretch of Tatnuck Brook and result in more natural flow variations. In turn, this could lead to less accumulation of periphyton as a result of exposing the river bottom, and eliminating the dampening effect on flow that the impoundment likely has.

The City of Worcester currently maintains Water Management Act (WMA) Registrations for its drinking water supply withdrawals in both the Blackstone and Nashua River Basins, as well as a WMA Permit in the Nashua River Basin. Under the November 2012 SWMI Framework and subsequent proposed revisions to the Water Management Act Regulations, the City will be required to evaluate measures to mitigate any withdrawals in excess of the baseline withdrawal volume, and ultimately implement such mitigation measures prior to withdrawals exceeding the baseline. While the Patch Pond Dam is located in the Blackstone River Basin, MassDEP has indicated that communities in multiple basins would be given flexibility and as such, removal of the dam would apply toward the City's mitigation credits.

Based on updated flood profile mapping (301P-303P) published by FEMA in 2013, it appears that removal of Patch Pond Dam would have no impact on the flood profile (including the 0.2% chance flood level) in Tatnuck Brook. Hydraulic investigations conducted as part of this feasibility study (Section 5) confirm the FEMA information.

Removal of the Patch Pond Dam would restore a segment of Tatnuck Brook for unimpeded fish passage, improved water quality and aquatic habitat, and improved recreation conditions by eliminating barriers to navigation and access. It will also improve public safety by eliminating an aging structure that poses a risk of failure and carries a large financial burden to maintain.

## 1.5 Existing Data

Existing data used for this feasibility study includes previous inspection reports, supporting sketches, drawings, topographic and locus maps, and photographs. Information on the permitting process, including Massachusetts Executive Office of Energy and Environmental Affairs dam removal guidance (December 2007), and applicable federal, state, and local regulations were used during this assessment.

## 1.6 Data Collected Specifically for this Study

Data collected for this study include site photographs, physical and chemical sampling information for soils and sediment upstream of the dam, and other detailed site-specific information necessary to fully assess the existing conditions of the dam site, upstream and downstream of the spillway, and all areas that could be affected by the dam removal process.

The stability of the dam impoundment was based on dam safety inspection reports. Other information including river and stream characteristics, local topography, bathymetry, rare and sensitive species, historical and archaeological resources, and local utilities were also gathered for this report. A detailed assessment to characterize the sediment and soils was completed to develop a sediment transport model of current and future conditions, following dam removal. A Hydrologic and Hydraulic analysis was completed for current and future conditions using topographic, rainfall and field sampling data.

## 1.7 Organization of this Feasibility Study

This report is divided into an Executive Summary and ten sections. The sections are as follows:

- Section 1 Introduction
- Section 2 Physical Characteristics of the Site
- Section 3 Existing Resources
- Section 4 Hazardous Waste Sites and Characterization of Sediment / Soils
- Section 5 Hydrologic and Hydraulic Analysis
- Section 6 Sediment Transport Model and Evaluation
- Section 7 Alternatives
- Section 8 Environmental Permitting Requirements
- Section 9 Costs
- Section 10 Preferred Alternative

The appendices contain backup analyses, figures, laboratory data, and other documentation.

## 1.8 Acknowledgment

This project has been financed partially with State Capital Funds from the Massachusetts Department of Environmental Protection (the Department) under a Sustainable Water Management Initiative Grant.  The contents do not necessarily reflect the views and policies of the Department, nor does the mention of trade names or commercial products constitute endorsement or recommendation for use.

# Section 2

# Physical Characteristics of the Site

## 2.1 Ownership

The Patch Pond Dam is owned by the City and managed by the Worcester Department of Public Works and Parks. The dam is a tax levy dam and is supported by funding from general property taxes. The State Identification Number is 3-14-348-10 and the National Identification Number is MA03341.

## 2.2 Physical Characteristics of the Site

### 2.2.1 Dam Impoundment

The upstream impoundment is relatively small and moderately shallow at the normal pond level which is equivalent to the spillway weir elevation. The normal pool area of the impoundment is about 4.82 acres. The deepest water depth at normal pool level is estimated to be about eight feet. Photograph 1 in Appendix D shows the impoundment area. The general topography surrounding the pond slopes moderately up from the pool to residential backyards. The topography at the northwestern side of the pool slopes steeply up from the pool and is heavily vegetated. It is anticipated that complete removal of the dam resulting in a reduction in the water surface area of the pond could cause erosion of the exposed pond sediments until permanent vegetation is established. Precautionary measures to minimize erosion potential of the exposed surfaces were considered and are discussed in more detail in Section 7. Removal of the dam is expected to have little or no effect on the stability of the surrounding transition slopes up to higher ground elevations.

### 2.2.2 River and Stream Characteristics

Tatnuck Brook is a 20-mile long perennial stream that has its headwaters in Holden and flows through Holden Reservoir No. 1 and Holden Reservoir No. 2. Both of these reservoirs are part of the City of Worcester's drinking water supply system, which consists of ten active reservoirs. Below Holden Reservoir No. 2, Tatnuck Brook flows through Cook Pond and Patch Reservoir before reaching Patch Pond. All of these waterbodies have active dams. The contributory watershed to Patch Pond is approximately 10 square miles and residential areas are located both above and below the PDD. Photographs 4-13 in Appendix D show Patch Pond upstream of the impoundment area.

Tatnuck Brook immediately downstream of the PPD flows in two channels separated by a gravel bar, one below the primary spillway and the other below a partial breach on the east end of the dam. The area below the dam is a forested riverine corridor. A 15-foot by 20-foot plunge pool is located at the base of the primary spillway. The main discharge channel has a rocky substrate with large stones and flat boulders (see Photographs 2 and 3 in Appendix D). Tatnuck Brook flows beneath the June Street Bridge and through Williams Mill Pond before discharging into Coes Reservoir. Coes Reservoir is located approximately 2,000 feet downstream of the PPD.

### 2.2.3 Photography

Photographs of the dam, impoundment, and dam site are included in Appendix D.

### 2.2.4 Geology

The topography and the varying elevations of an area are determined by the geology. The surficial materials of Central Massachusetts are deposits of the last two glaciers (the most recent being the Wisconsin glacier) that covered the area in the Pleistocene ice age. Glacial deposits are divided into glacial till that was laid down directly by the glacier forming drumlins and glacial stratified deposits that were laid down by melt water in valleys and low lying areas. The Worcester North Surficial Geology map shows that the surficial geology east of the PPD impoundment consists of glacial till, most likely well graded materials. The surficial geology of the areas north and west of the upstream impoundment are categorized as glacial stratified deposits laid down by glacial melt water in the form of coarse deposits, which includes variations of sands and gravels (See Figure 2-1). Sand deposits consist mainly of very coarse to fine sand. Particle size distribution of these deposits range from 0.125 mm for the fine sand up to boulder-size materials.

The small triangular peninsula downstream of the PPD is mapped as alluvial post-glacial deposits. The stream flow carried particulates (i.e., fine sand and silt) downstream that, over time, settled in at the downstream toe of the dam. Northwest of the upstream impoundment and adjacent to Mill Street is an area of artificial fill extending from the drainage swale associated with a 36-inch diameter drain.

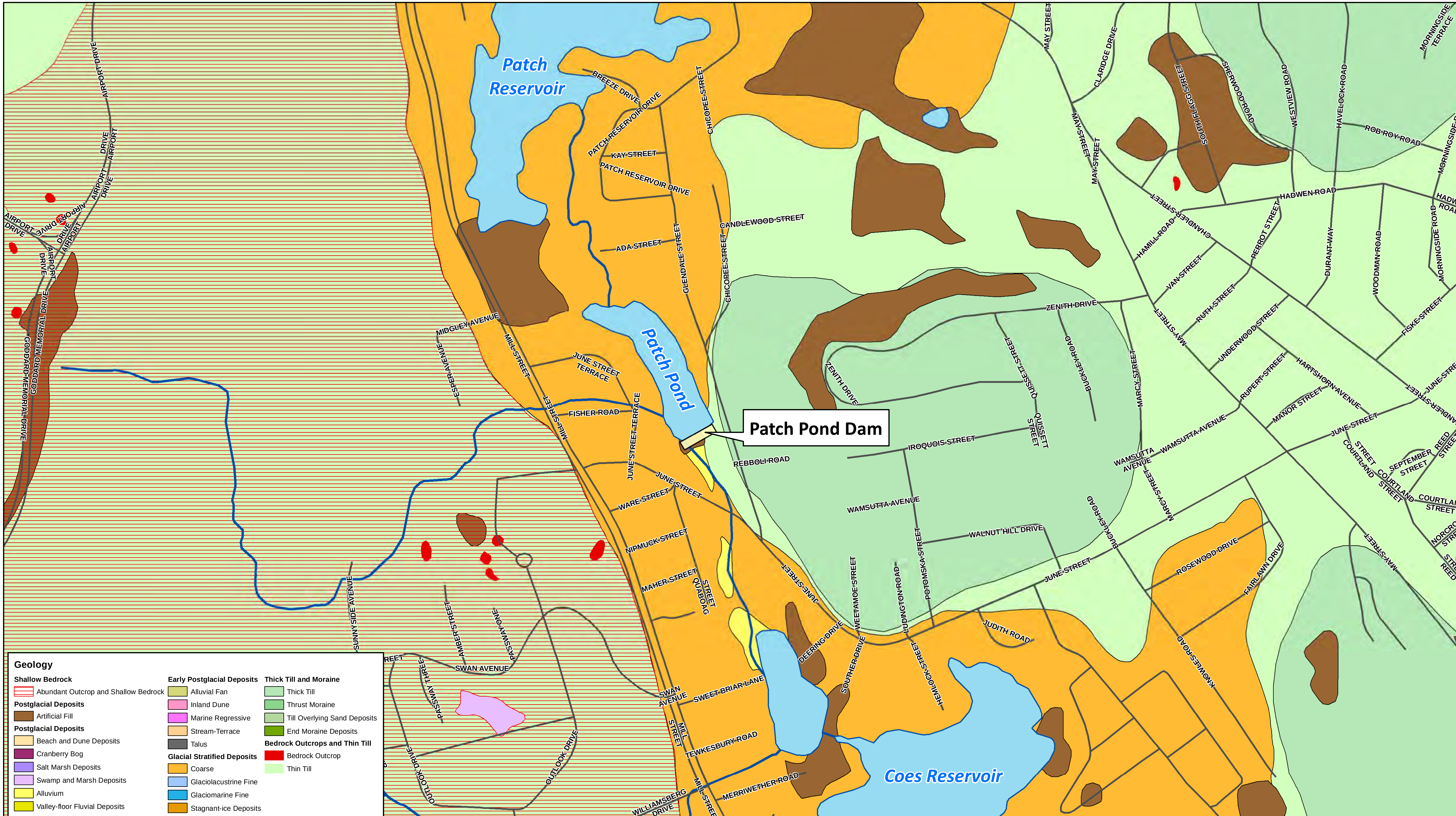
### 2.2.5 Soils and Topography

The drainage characteristics of soils are derived from the surficial parent material. As discussed above the deposits in the area are predominantly glacial tills and stratified glacial sand and gravel deposits. The soils in the area of the PPD consist of fine sandy loam and sandy loam. The topography of the land adjacent to the upstream impoundment consists of steep slopes along the west side and gradual slopes to the east where residential lawns border the impoundment. Soils on the developed hillsides to the west and northeast of the upstream impoundment are mapped as Hinckley (sandy loam)-Urban land complex with 0 to 15 percent slopes. The forested riparian system immediately south of the dam and north of the upstream impoundment area mapped as Walpole fine sandy loam, 0 to 3 percent. The area to the northwest of the impoundment is mapped as Udorthents; this area is undeveloped and shows evidence of having been used as a demolition debris site. The area downstream of June Street is mapped as Hinckley –Urban land complex. Figure 2-2 shows Natural Resources Conservation Service Soil Codes.

### 2.2.6 Bathymetry

A bathymetric survey was completed for the Patch Pond by Surveying and Mapping Consultants Inc. (SMC Inc.), of Braintree, Massachusetts. The survey was performed in May 2014 utilizing Real Time Kinematic (RTK) Differential Global Positioning System (DGPS) and land-based total station equipment. The bathymetric survey plan utilized survey data and landside/shoreline features from a provided site plan. Elevations are referenced to the North American Vertical Datum of 1988 (NAVD88), as determined using the Keynet Virtual Reference System (VRS). Coordinates (horizontal datum) are referenced to the Massachusetts Coordinate System, Mainland Zone, referenced to the North American Datum of 1983 (NAD83), as determined from the KeyNet GPS Virtual Reference System (VRS), made April 9 through 15, using Trimble R8 GNSS GPS receivers.

The bathymetric survey (Figure 2-3) shows the top of the sediment layer from a high elevation of 528 ft (NAVD88) at the northern end of the impoundment to 522 ft (NAVD88) within the lowest part of the impoundment. The spillway that determines water level is at an elevation of 528.7 ft (NAVD88).




4/7/2014

Dam
Roads
Rivers
Water Bodies

CDM Smith

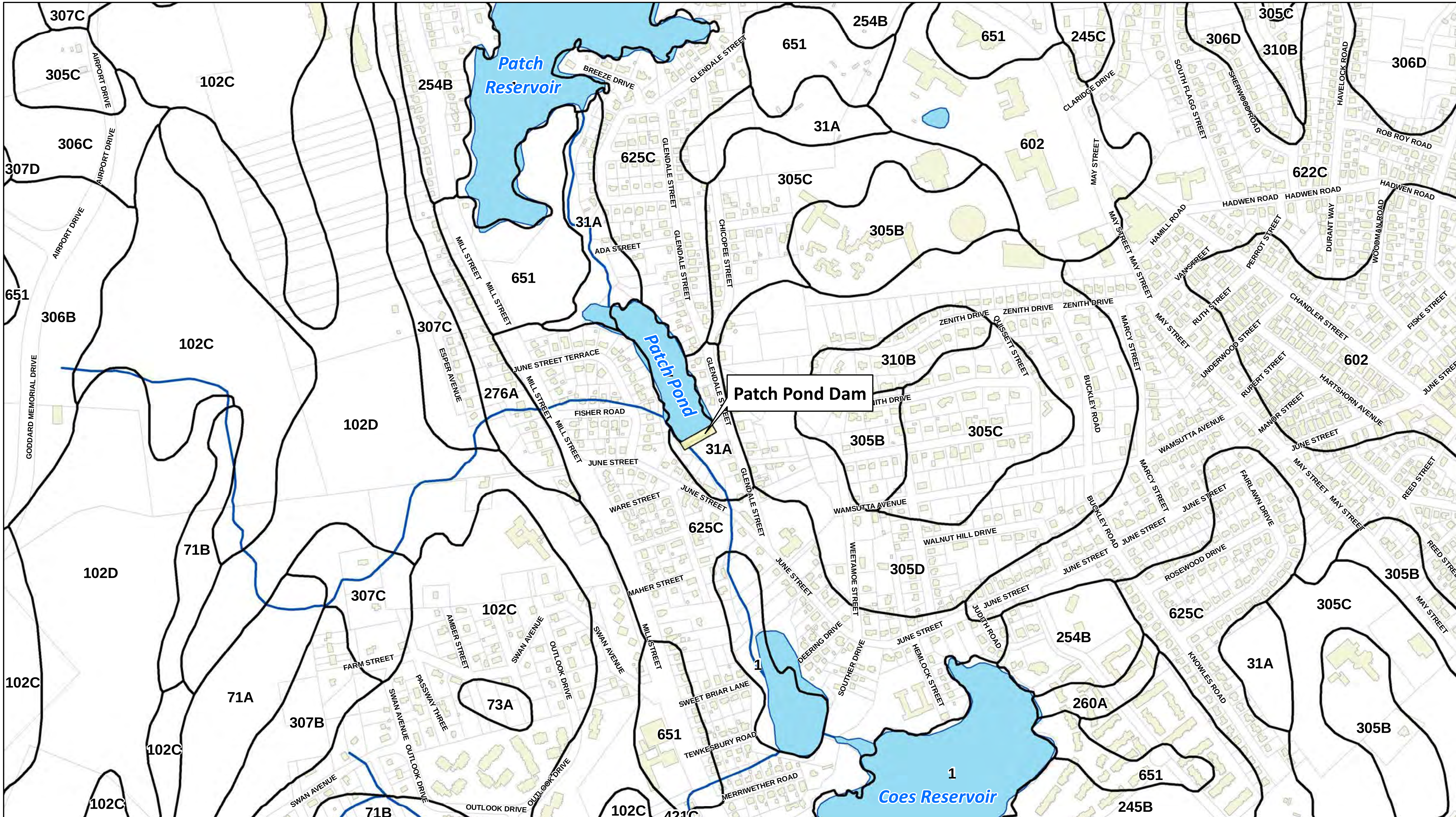
**Worcester, Massachusetts**
**Patch Pond Dam Removal Feasibility Study**

**Figure 2-1**
**Surficial Geology**

N

0 250 500 1,000 Feet

SHEETSIA \\dacgis02\projects\Worcester\PatchPond_Dam_Removal\MXD\Surficial_Geology_11x17.mxd 4/7/2014




4/7/2014

| | | | |
|---|---|---|---|
| Dam | | Rivers | |
| NRCS Soil Codes | | Water Bodies | |
| Buildings | | | |
| Parcels | | | |

CDM Smith

# Worcester, Massachusetts
## Patch Pond Dam Removal Feasibility Study

N

0 250 500 1,000 Feet

**Figure 2-2**
**Natural Resources Conservation Service (NRCS) Soil Codes**

SHEETSJA \\dacgis02\projects\Worcester\PatchPond_Dam_Removal\MXD\Soil_11x17.mxd 4/7/2014


| REV. NO. | DATE | DRWN | CHKD | REMARKS |
|---|---|---|---|---|

DESIGNED BY: J.COY
DRAWN BY: J. COY
SHEET CHK'D BY: X
CROSS CHK'D BY: X
APPROVED BY: R. MUSCI
DATE: JUNE 2014

CDM Smith
50 Hampshire Street
Cambridge, MA 02139
Tel: (617) 452-6000

CITY OF WORCESTER, MASSACHUSETTS
DEPARTMENT OF PUBLIC WORKS AND PARKS
PATCH POND DAM REMOVAL
FEASIBILITY STUDY

EXISTING CONDITIONS
WITH CONTOURS INCLUDING BATHYMETRY
PLAN

PROJECT NO. 0198-103419
FILE NAME: CBRPL001.DWG
SHEET NO. 2-3

30% SUBMITTAL - NOT FOR CONSTRUCTION

XREFs: [CDMS_2436, Y11000WS] Images: []
Last saved by: COYJR Time: 5/29/2014 10:48:02 AM
pw:\\docpwapp1:PW_XM1\0198\103419\03 Reports and Studies\09 CADD Figures and Graphics\02 CIVIL\CBRPL001.dwg

## 2.3 Dam Characteristics

The dam is an earthen embankment about 12 feet high and 120 feet long with an un-mortared masonry wall on the downstream face. The embankment dam is comprised of one straight section that is flanked by a spillway at the west abutment and a breach area at the east abutment. The crest of the dam is at approximately El. 532.5 feet (NAVD88) and is about 16-25 feet wide (crest width varies). The crest is covered with dense vegetation. The upstream side of the embankment has a 4-foot-high un-mortared masonry wall that is leaning over towards the pond. In some areas there is hand-placed riprap with stones of approximately 6 to 12 inches in diameter.

The spillway is broad-crested weir stone masonry spillway that is approximately 39 feet long and is located on the west side of the dam. Initially the spillway was constructed with un-mortared stone which was at some point later covered with a 6-inch thick concrete overlay. The east training wall has collapsed into the spillway and much of the east side of the spillway has collapsed causing the overlain concrete to break into large fragments. The west training wall also has some cracks and loss of concrete overlay. The discharge channel is very rocky with stones of approximately 6 to 18 inches in diameter. At the base of the spillway there is a 15-foot by 20-foot plunge pool.

### 2.3.1 Past Dam Safety Inspection Reports

Dam inspection reports on file with the Department of Conservation and Recreation Office of Dam Safety are listed below. The current dam condition is listed as Unsafe with a significant breach in the east abutment and a partial collapse of the spillway. The City was issued a Certificate of Non-Compliance and Dam Safety Order in 2008 by the ODS to repair or remove the dam.

- Letter Report on Hydraulic Investigations at Patch Pond, Metcalf and Eddy, April 18, 1989, revised March 1990
- Patch Pond Dam Phase I Inspection/Evaluation Report, September 25, 2007, CDM Smith
- Patch Pond Dam, Poor and Unsafe Condition Dam Follow-up Inspections on December 15, 2009 March 25, 2010, October 4, 2010, April 19, 2011, November 9, 2011, and May 11, 2012, CDM Smith

### 2.3.2 Dam Classification

Patch Pond Dam has a structural height of about 12 feet and an approximate storage capacity of 60 acre-feet. Therefore, in accordance with the DCR Office of Dam Safety classification, under Commonwealth of Massachusetts dam safety rules and regulations stated in 302 CMR 10.00 as amended by Chapter 330 of the Acts of 2002, Patch Pond Dam is a Small size structure.

The dam is located upstream of a residential neighborhood, with most homes located above the elevation of the reservoir. However, a number of homes adjacent to June Street are below the downstream toe elevation. Given the potential for loss of life and/or property due to failure of the dam, the dam was assessed to be a High Hazard potential structure by CDM Smith in 2007. The Office of Dam Safety lists Patch Pond Dam as being a “significant” hazard potential structure.

The condition rating of Patch Pond Dam is Unsafe in accordance with the Office of Dam Safety Criteria (ODS). The primary factors contributing to this rating include a breach area at the east abutment and partial collapse/breach of the primary spillway.

# Section 3

# Existing Resources

## 3.1 Introduction

Patch Pond Dam (PPD) is located on Tatnuck Brook, which from its headwaters in Holden flows through the drinking water supplies of Holden Reservoirs No. 1 and No. 2. From there, Tatnuck Brook continues in a southerly direction capturing runoff from the western portion of the City and flows through Cook Pond and Patch Reservoir, before it reaches Patch Pond (the impoundment behind the dam). Downstream of the PPD, Tatnuck Brook flows through Williams Mill Pond before entering Coes Reservoir and merging with Beaver Brook immediately downstream of Coes Pond.

Tatnuck Brook from the outlet of Holden Reservoir No. 2 to the inlet of Coes Reservoir, including the PPD, is on the list of impaired waters known as the "303d list." MassDEP is required by the Federal Clean Water Act to develop an approach or what could be referred to as a "pollution budget" to restore the health of the impaired waters and meet the Massachusetts Surface Water Quality Standards.

The PPD is located on a narrow parcel of conservation land that includes the upstream impoundment; however, residential homes directly abut the impoundment limiting the recreational and aesthetic values of the project area.

## 3.2 Historical, Cultural and Ecological Resources

### 3.2.1 Major Watersheds

Patch Pond Dam is located on Tatnuck Brook in Worcester and lies within the Upper Blackstone River – Singletary Brook Watershed Basin as shown on Figure 3-1. The drainage area for Patch Pond Dam (PPD) is approximately 10 square miles according to Massachusetts StreamStats. The limits of the delineated PPD drainage area are shown in Section 5 on Figure 5-1. The drainage area extends as far north as Route 31 in Holden to the drainage divide between Kendall Reservoir and Holden Reservoir No. 1, and spans the municipal boundary between Paxton and Worcester to the east. The western limit of the drainage area is the ridge west of Salisbury Street. The closest control structure within the watershed is the downstream June Street Bridge. The area upstream adjacent to Patch Pond consists of moderate to steep slopes with residential developments along both the west and east shores.

### 3.2.2 Water Resources

#### 3.2.2.1 Surface Water Quality

Patch Pond and Tatnuck Brook are classified as Class B waters by the Massachusetts Surface Water Quality Standards (314 CMR 4.00). The MassDEP is responsible for monitoring the waters in the state under Section 303(d) of the Clean Water Act (CWA) and required to develop lists of impaired waters and reasons for impairment.


4/7/2014

Upper Blackstone River-Singletary Brook Basin
Rivers
Water Bodies
Dam
Buildings
Parcels

CDM Smith

# Worcester, Massachusetts
# Patch Pond Dam Removal Feasibility Study

N

0 250 500 1,000 Feet

# Figure 3-1
# Watersheds

SHEETSJA \\dacgis02\projects\Worcester\PatchPond_Dam_Removal\MXD\Watersheds_11x17.mxd 4/7/2014

Section 303(d) of the CWA requires that states establish priority rankings for impaired waters and develop Total Maximum Daily Load (TMDLs). A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet the Surface Water Quality Standards. Tatnuck Brook and Patch Pond are on the list of impaired waters (better known as the 303(d) list) that do not meet the state surface water quality standards. According to U.S. EPA Guidance, impaired waters requiring one or more TMDLs are classified as Category 5. Waters that exhibit impairment for one or more uses but not requiring TMDLs are classified as Category 4. Category 4 is further divided into three sub-categories 4a, 4b and 4c depending upon the reason that TMDLs are not needed.

Tatnuck Brook (Segment MA51-15) from the outlet at Holden Reservoir No. 2 to the inlet of Coes Reservoir (including Patch Reservoir and Patch Pond) does not meet the Class B designation under the surface water quality standards and is therefore on the 2012 Integrated List as a Category 5 (Waters Requiring a TMDL)(see Appendix C). A TMDL has not been developed. Impairment causes for the 3.3 mile long brook stretch are listed as impaired biota with unknown cause, turbidity, and objectionable deposits/sediments. The impaired water quality is the result of conversion of seasonal homes on Patch Reservoir without the installation of public sewers, stormwater runoff, and the development and maintenance practices at the Worcester municipal airport. A Comprehensive Management Plan for the upstream Patch Reservoir was completed in 1997 through funding from the City and the Department of Environmental Management's Lakes and Ponds Program, which included a variety of watershed and in-reservoir techniques to improve water quality.

Removal of the Patch Pond dam would restore this stretch of Tatnuck Brook and result in more natural flow variations. In turn, this could lead to less accumulation of periphyton as a result of exposing the river bottom, and eliminating the dampening effect on flow that the impoundment likely has. Removal of the PPD as proposed would also increase dissolved oxygen levels in the brook. The dam removal would not impact other pollutants entering the brook from stormwater runoff. The current impoundment may provide some pollutant removal; however, with sediments in the impoundment reaching the top of the spillway height, the impoundment is probably in equilibrium so pollutant constituents tend to pass directly through downstream to Williams Mill Pond and Coes Reservoir.

### 3.2.2.2 Groundwater Resources

The City of Worcester adopted two Water Resources Protection Overlay Districts in April 1991, which in addition to the City's Zoning Ordinance, protects the quality and quantity of the two gravel packed wells (Shrewsbury Well and Quinsigamond Well) used as emergency water supplies by regulating land uses in the district overlaying the aquifer and its recharge areas. The PPD is not located within the City's Water Resources Protection Overlay Districts but does fall with within an Aquifer Recharge Area as defined by Mass GIS which is based on USGS Water Resource Division data. Figure 3-2 shows that the Patch Pond Dam is within the aquifer recharge area.

Removal of the dam is anticipated to have little effect on groundwater resources.


6/5/2014

| | |
|---|---|
| Dam | Rivers |
| Aquifer | Water Bodies |
| Wellhead Protection Areas | |
| Parcels | |
| Buildings | |

CDM Smith

# Worcester, Massachusetts
# Patch Pond Dam Removal Feasibility Study

N

0 250 500 1,000 Feet

## Figure 3-2
## Aquifer Recharge Area

### 3.2.3 Wetlands

On March 24, 29, and April 1, 2014 CDM Smith wetland scientists completed a delineation of the wetland resource areas in the area of the PPD along Tatnuck Brook including the upstream impoundment. Existing field delineated wetland resource boundaries were evaluated for conformance with the Massachusetts Wetlands Protection Act (MGL c.131, s.40)(WPA) and Regulations (310 CMR 10.00, referred to as the Regulations) and the U.S. Army Corps of Engineers 1987 Wetlands Delineation Manual (Environmental Laboratory, 1987) and Regional Supplement for the North Central and Northeast Region (January 2012). The wetland boundary was determined by the limit of wetland vegetation, limit of plant community dominated, 50% or more cover, by species adapted to living in wetland conditions by visual inspection, as well as indicators of hydric soils and wetland hydrology.

There are no Bordering Vegetated Wetlands along Patch Pond or Tatnuck Brook downstream of the PPD.  A 36-inch diameter drain pipe beneath Mill Street outlets into a drainage channel upstream of Patch Pond.  There is Bordering Vegetated Wetlands associated with this drainage channel, and Tatnuck Brook upstream of Patch Pond, further described below.

The following wetland resource areas regulated under the Regulations are present on the site: Inland Bank, Land Under Waterbodies/Waterways (LUW), Bordering Vegetated Wetlands (BVW), Bordering Land Subject to Flooding (BLSF), and 200-foot Riverfront Area (RFA).

The wetlands boundaries (flagged) described below were shown in Section 2 on Figure 2-3.

#### *Patch Pond*

Wetland resource areas associated with the upstream impoundment consist of Inland Bank, LUW, and BLSF. Wetland flags 4-1 through 4-42End demarcate the top of bank along the west shore of Patch Pond.  The west bank along the northern end is very steep with slopes greater than 2:1 (Horizontal: Vertical).  Further south, the bank is not nearly as steep and residential lawns extend to the water's edge. A storm drain outlets into Patch Pond near the PPD along the western shore. This drain conveys limited street drainage from June Street Terrace and Fisher Street (further discussed in Section 3.3 below).  The west bank is vegetated by red maple (*Acer rubrum*), silver maple (*Acer saccharinum*), red oak (*Quercus rubra*), European buckthorn (*Rhamnus frangula*), northern arrowwood (*Viburnum recognitum*), Oriental bittersweet (*Celastrus orbiculatus*), and poison ivy (*Toxicodendron radicans*).

Wetland flags 7-1 through 7-46End demarcate the top of bank along the east shore of Patch Pond. The east bank of Patch Pond abuts directly to residential lawns.  The bank consists of either eroded vegetated natural banks or concrete retaining walls.  Dominant vegetation along the east bank includes red maple, Japanese knotwood (*Polygonum japonicum*), multiflora rose (*Rosa multiflora*), red-osier dogwood (*Cornus alterniflora*), oriental bittersweet, and poison ivy.

#### *Tatnuck Brook*

Tatnuck Brook split into two channels immediately upstream of the impoundment.  A gravel bar is present between the two channels (further described below). The banks along Tatnuck Brook upstream of Patch Pond are approximately 2 feet high. A BVW is associated with Tatnuck Brook upstream of Patch Pond on the west side of the brook. This BVW can be characterized as a Palustrine Forested Wetland (PFO1) dominated by red maple, American elm, and gray birch (*Betula populifolia*) in the overstory.   Silky dogwood (*Cornus amomum*), speckled alder (*Alnus incana*), northern arrowwood, willow (*Salix* sp.), and Japanese knotweed dominate the shrub layer. Sensitive fern (Onoclea sensibilis), cinnamon fern (*Osmunda cinnamomea*), and sedges (*Carex* sp.) dominate the herbaceous layer. The east bank upstream of Patch Pond is bordered by an American beech dominated forest.

Regulated wetland resource areas immediately downstream of the dam are Inland Bank, LUW, RFA, and BLSF. Two channels are present, one below the primary spillway and the other below the east breach. The west bank of the main channel was flagged in the field by flags labeled TOB 5-1 through TOB 5-18End. 5-18End was placed by the June Street Bridge. The east bank of the smaller channel was flagged in the field by flags labelled TOB 6-1 through TOB 6-14End. TOB 6-14 was placed immediately downstream of the dam. Both banks are steep with slopes exceeding 1.5:1 (H:V). A portion of the west bank near June Street has been reinforced by granite blocks. Vegetation along the bank, downstream of the PPD, is dominated by red oak, white ash (*Fraxinus alba*), American beech (*Fagus grandifolia*), American elm (*Ulmus americana*), sumacs (*Rhus* sp.), and black cherry (*Prunus serotina*) in the overstory and sapling layer. The shrub layer is dominated by European buckthorn, sweet pepperbush (*Clethra alnifolia*), northern arrowwood, and multiflora rose. Vines, including oriental bittersweet and poison ivy, are also common.

### *Upstream Drainage Channel*

A 36-inch diameter drain pipe is present beneath Mill Street upstream of Patch Pond. Flow from this drain is conveyed via a drainage channel, located in a steep gulley, to Patch Pond. There are between 5 to 10 feet of Bordering Vegetated Wetlands (BVW) on both sides of the channel. Wetland flags 1-1 through 1-44End demarcate the northern boundary of the BVW along the drainage channel. Wetland flags 3-1 through 3-21End demarcate the southern boundary of the BVW. The Mean Annual High Water (MAHW) line along the channel extends to the wetland flags.

### *Gravel Bars*

A gravel bar is located between the two channels of Tatnuck Brook immediately upstream of Patch Pond. The gravel bar is not entirely submerged during high flows). Soils in the gravel consist of low chroma (10 YR 2/1) gravelly coarse loamy sand with refusal encountered at approximately 12 inch depth. The gravel bar is vegetated by hydrophytic vegetation including speckled alder, silky dogwood, willows, sensitive fern, and purple loosestrife (*Lythrum salicaria*).

A gravel bar is also present downstream of the PPD between the channels of Tatnuck Brook (see Photograph 14 in Appendix D).

### *Beneficial Wetland Impacts*

Removal of the PPD will improve wildlife, fisheries, and pollution prevention interests of the WPA. The dam removal will reduce Land Under Water and reduce the upstream impoundment to a channel. It is anticipated that Bordering Vegetated Wetlands will establish in the area of the upstream impoundment as a result of the change. The regulatory assumption is that the dam removal will have a long-term ecological gain by restoring the upstream stagnant impoundment to a naturally flowing riverine system.

### *Adverse Wetland Impacts*

The long-term adverse impact from the removal of the PPD is the loss of Land Under Water habitat, as the upstream impoundment would cease to exist. In addition, there will be a number of short term direct impacts to Land Under Water and Inland Bank during the actual removal of the PPD and from heavy construction equipment.

For the various dam removal scenarios discussed in Section 7, a flow channel will be created upstream of the dam starting from the existing spillway to convey the 10-year storm with a width of approximately 20 feet and approximately 2:1 (H:V) side slopes. This channel will follow the natural slope upstream to join the existing channel for Tatnuck Brook. This flow channel would carry up to the 10-year flood flows through the impounded sediments that have been assumed to be removed at this time (see discussion in Section 5). The adjacent overbank areas (currently the pond bottom) will be allowed to revegetate with a combination of seeded mats and natural selection. A riverine system is expected to develop over a relatively short time adjacent to the new channel.

Additional short-term wetland impacts consist of the re-grading of the breach area along the eastern end of the dam to naturally direct runoff toward the main flow channel with the objective of creating a single flow channel downstream to June Street. This will improve fish passage and habitat by creating a single, deeper channel that carries all of the flow from the upstream reaches. This proposed single stream of flow will generally remain colder and deeper than the two shallower streams as they exist now.

## 3.2.4 Wildlife Habitat and Fisheries

### 3.2.4.1 Wildlife Habitat

The project site is located within an undeveloped 6.45-acre parcel of land owned by the Worcester Conservation Commission consisting predominantly of the PPD and upstream impoundment along with the riverine wetland system and gravel bar downstream of the dam. The shores of the upstream impoundment are bordered by moderate and steep slopes leading up to residential back yards. Tatnuck Brook flows through an 11-acre undeveloped forested upland tract of land to the north of the upstream impoundment. This parcel is located between Patch Reservoir and Patch Pond. Downstream of the dam, Tatnuck Brook flows through a Riverine wetland system until it reaches the shrub and wooded swamp associated with Williams Mill Pond downstream. Patch Pond provides open water habitat to a number of waterfowl species including geese, ducks, and herons. Please see below for a list of waterfowl and other bird species observed during the wetland delineation on April 1, 2014. Turtles (mainly snapping turtles and painted turtles) inhabiting Patch Pond nest in the sandy soils of the nearby residential back yards. Deer are frequent visitors to the upstream gravel bar as indicated by the droppings observed. The northern section of Patch Pond, including the upstream gravel bar, vegetated by tall trees and smaller shrubs, is prime bird habitat. The more densely vegetated areas are good perching habitat for bird species that prefer scrub-shrub habitat. There are also large, dead trees with tall stumps in the northern gravel bar that provide excellent habitat for woodpeckers. In summary, the area provides habitat for a number of birds and mammals common in suburban settings such as gray squirrels, eastern cottontail rabbits, woodchucks, raccoons, opossums, bats, deer, red foxes, and shrews. The drainage channel and associated wetland at the upstream end of Patch Pond provide habitat for a variety of amphibians and reptiles.

The following birds were observed during wetland delineation on April 1, 2014: Canada geese, mallards, sparrows, common grackle, red-bellied woodpeckers, northern cardinals, mourning doves, downy woodpecker, red tailed hawk, red winged black bird, blue jay, and white-breasted nuthatch.

Removal of the dam is anticipated to have an adverse impact to wildlife using the pond area, such as waterfowl (ducks and geese), turtles, and other species. Reduction in geese in the area will contribute to water quality improvements. Removal of the dam is also anticipated to have short-term construction related impacts on wildlife in the area.

Beneficial impacts from the dam removal on wildlife include increase of cover and food sources from the anticipated natural establishment of an emergent marsh/shrub wetland adjacent to the new channel.

### 3.2.4.2 Fisheries Habitat

Tatnuck Brook is classified as a Coldwater Fisheries Resource from its origin in the Town of Holden to the inlet to Patch Reservoir, which is immediately upstream of Patch Pond. The Department of Fish and Game, Division of Fisheries and Wildlife, performed fish sampling at one station along Tatnuck Brook immediately downstream of June Street and just upstream of Williams Mill Pond in August 1998 (Leanda Fontaine, DFW). The sampling results are shown in **Table 3-1**.

**Table 3-1**
**Fish Sampling Results for Tatnuck Brook**

| *Sampling Location* | *Sample Year* | *Species* | *Count* |
|---|---|---|---|
| Downstream of June Street (immediately upstream of Williams Mill Pond) | 1998 | Fallfish<br>Tesselated Darter<br>Blacknose Dace<br>Longnose Dace<br>White Sucker | 162<br>35<br>33<br>26<br>12 |

The most common fish species in Tatnuck Brook is the fallfish (*Semotilus corporalis*); the largest member of the minnow family in the Northeast (see Table 3-1). The fallfish can reach lengths of 12 to 18 inches and prefers large streams and small rivers with gravel, sand, and rubble bottoms but can also live in silt bottomed pools. Fallfish is rare in waters that exceed 82°F. Its pollution tolerance is intermediate according to the U.S. EPA. The presence of a fair number of tessellated darters (*Etheostoma olmstedi*) may indicate high water quality since this species is intolerant of high water temperatures, muddy waters, and other problems associated with impaired streams. The tessellated darter is a bottom-dwelling forage fish, only about 3 inches in length and prefers sandy, muddy, or gravel stream beds and can be found in both flowing and standing waters. Similar counts of longnose dace (*Rhinichthys cataractae*) and blacknose dace (*Rhinichthys atratulus*), were found. The Longnose Dace is a small minnow, approximately 3 inches in length that prefers swift moving water with riffles over boulder, cobble, or pebble and gravel-bottom streams and avoids pools and quiet water. The blacknose dace is very similar in appearance to the longnose dace but with a dark band along snout and body. Its habitat tolerance is greater, although it prefers moderate to rapid waters and swift riffles it is also found in shade pools along cut banks with overhanging vegetation. The bottom feeding white sucker (*Catostomus commersoni*) was present in low numbers. The white sucker is very adaptable and can be found in just about any habitat. It is one of the most common fish in

Massachusetts and found in both warm and cold water fishery habitats. The data collected showed that very few cold water fish species is present in the area.

The Massachusetts Division of Fisheries and Wildlife stocks the downstream Coes Reservoir annually in the spring with rainbow, brook and tiger trout.

The dam is a barrier to upstream movement of fish and the removal of the dam is anticipated to restore fish passage in the Tatnuck Brook. Fisheries habitat and the prevention of pollution interests of the WPA is expected to improve with the dam removal as the water quality improves by converting the slow moving water of the impoundment to a free flowing stream.

### 3.2.5 Floodplains and FEMA Flood Mapping

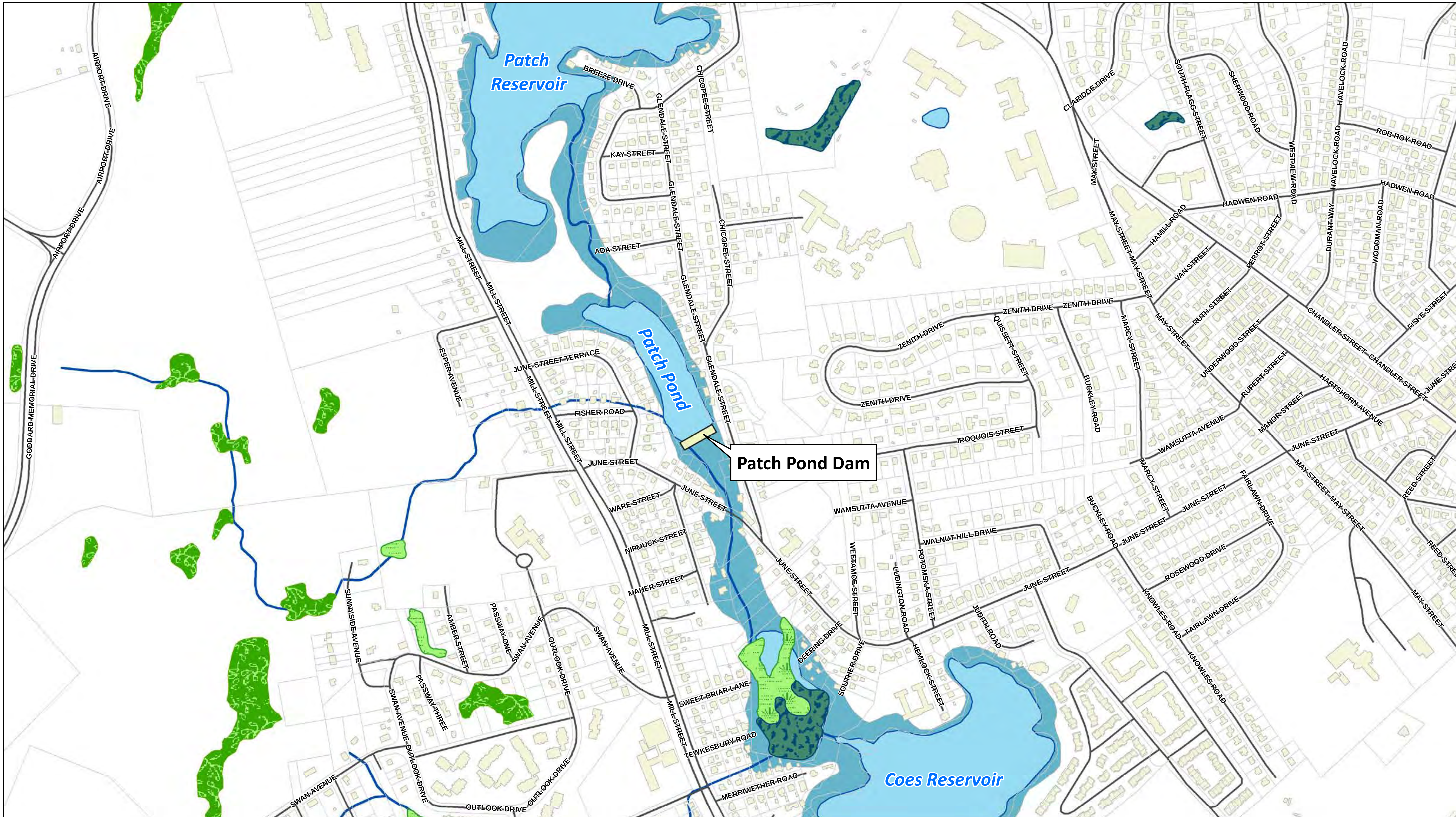
FEMA Flood Insurance Rate Map of the area identifies the 100-year floodplain in the project area. The Patch Pond Dam and upstream impoundment is located within the 100-year floodplain (see Figure 3-3). The FEMA Map of the area (Panel ID. 25027C0613E) identifies the 100-year flood elevation at elevation 534 feet (NAVD 88) on the upstream side of the dam and at elevation 527 feet (NAVD 88) immediately downstream of the dam.

Removal of the Patch Pond Dam will improve the flood control and storm damage prevention interests of the WPA. The upstream impoundment will over time be replaced by a vegetated wetland that can moderate flow and absorb floodwaters. Dam removal also eliminates the potential risk of a catastrophic dam failure resulting in uncontrolled release of flood waters and potential downstream flooding.

### 3.2.6 Rare and Sensitive Habitats around the Dam

Patch Pond is not located within state-listed Estimated or Priority Habitat mapped by the Massachusetts Natural Heritage and Endangered Species Program (NHESP) based on review of the Natural Heritage Atlas 13th Edition (2008)(see Figure 3-4). However, NHESP has mapped a polygon of Estimated Habitat of State-listed Rare Species in the forested upland area west of Mill Street. This mapped polygon coincides with the BioMap 2 Core Habitat #1592, further described below.

In 2001, with funding from the EOEA, the NHESP developed a BioMap for the entire Commonwealth in order to identify the areas most in need of protection to ensure native biodiversity. The BioMap identifies Core Habitat areas based on verified data that corresponds to actual locations on the ground. The areas mapped were determined by biologists to be those most suitable to support viable plant and wildlife species. Review of the BioMap 2 for the City of Worcester produced in 2012 shows two Core Habitats within the upstream PPD drainage area, one (#1592) is located approximately 1,000 feet from Patch Pond, in the upland forest west of Mill Street and Goddard Memorial Drive, and consists of a 167-acre Core Habitat for marbled salamanders (*Ambystoma opacum*), a Species of Conservation Concern in Massachusetts. The adult and juvenile marbled salamanders spend the majority of the year in small mammal burrows or other subsurface areas in upland forests. Contrary to other species of locally found mole salamanders, the adult marbled salamander migrate to breed in late summer/early fall. Eggs are laid under logs, leaf-litter, or grass tussocks in dried portions of vernal pools, swamps, marshes or other fish free wetlands. Eggs hatch after being inundated by fall rains and the larvae metamorphose in late spring. There are no BioMap 2 Core Habitats downstream of the PPD.




6/5/2014

| Legend | |
|---|---|
| DEEP MARSH | Rivers |
| SHRUB SWAMP | Roads |
| WOODED SWAMP DECIDUOUS | Dam |
| Water Bodies | Parcels |
| 100-yr Flood Zone | Buildings |

CDM Smith

**Worcester, Massachusetts**
**Patch Pond Dam Removal Feasibility Study**

N

0 250 500 1,000 Feet

**Figure 3-3**
**Wetland and Floodplains**


6/5/2014

| | | | |
|---|---|---|---|
| Certified Vernal Pools | | Rivers | |
| Potential Vernal Pools | | Roads | |
| NHESP Estimated Habitats of Rare Wildlife | | Parcels | |
| NHESP Priority Habitats of Rare Species | | Buildings | |
| Water Bodies | | Dam | |

CDM Smith

## Worcester, Massachusetts
## Patch Pond Dam Removal Feasibility Study

N

0 250 500 1,000 Feet

# Figure 3-4
# Vernal Pools and Sensitive Habitats

SHEETSJA \\dacgis02\projects\Worcester\PatchPond_Dam_Removal\MXD\Vernal_Pools_&_Sensitive_Habitat_11x17.mxd 6/5/2014

The area of impact from the dam removal does not contain vernal pools, wet depressions, swamps, or marshes that could provide breeding habitat for marbled salamanders. Mill Street and residential developments along Mill Street and June Street Terrace are located between the forested upland area mapped as BioMap 2 Core Habitat 1592 and Patch Pond.

BioMap 2 Core Habitat 1625 is located further west by the Worcester Airport and consists of a 1,061-acre Core Habitat for Eastern whip-poor-wills (nocturnal ground nesting bird of dry oak and pine forests) and grasshopper sparrows, both species of Conservation Concern. The grasshopper sparrow nests in dry grasslands and has adapted well to anthropogenic habitats including airports.

The dam removal is anticipated to have no effect on rare and sensitive habitats.

### 3.2.7 Opportunities for Habitat Enhancement around the Dam

Patch Pond Dam acts as a barrier to movement of fish and other aquatic species by interrupting the migration of resident species to upstream spawning and nursery habitat. Removal of the existing dam will transform the existing slow moving impounded water to a flowing stream with improved water quality, lower water temperatures, and increased dissolved oxygen.

### 3.2.8 Historic and Archeological Resources

A Project Notification Form was submitted to the Massachusetts Historical Commission (MHC) on April 4, 2014. MHC states in their response dated April 22, 2014, that after review of their files and the materials submitted that the removal of the existing patch Pond Dam is unlikely to affect significant historic or archaeological resources.

Based on the review of the Worcester Historical Museum's archives, the dam lacks any historical significant features or value. Refer to Section 1 for a detailed history of the PPD.

Based on available information it appears that no historic or archeological sites are located in the area of the PPD. The dam's removal would not have an impact on historic or archeological sites, and based on the response from MHC no further review of historic or archaeological resources is required during the permitting phase.

### 3.2.9 Conservation Areas and Recreational Resources

The PPD and upstream impoundment is located on a 6.45-acre parcel held by the Worcester Conservation Commission as conservation land (see Figure 3-5). The parcel includes Tatnuck Brook downstream of the PPD, north of June Street. The Worcester Conservation Commission owns about 43 properties throughout the City encompassing nearly 400 acres of land of which the PPD parcel is one of the smaller holdings. Article 97 (Mass. Const. Art. XCVII) protects land acquired for natural resources purposes. These lands and easements taken or acquired for natural resources purposes cannot be used for other purposes or otherwise disposed of except by laws enacted by a two thirds vote in the state legislature. Article 97 Approval is not anticipated to be required for the removal of the PPD since dam removal would not change the land use as it would remain as land held for environmental management purposes and as conservation land.


6/5/2014

| Legend | | | |
| --- | --- | --- | --- |
| City Owned Land (Municipal) | | Roads | |
| Non-Profit Onwed Land | | Parcels | |
| Water Bodies | | Buildings | |
| Rivers | | Dam | |

CDM Smith

**Worcester, Massachusetts**
**Patch Pond Dam Removal Feasibility Study**

N

0 250 500 1,000 Feet

**Figure 3-5**
**Conservation Lands and City Owned Property**

SHEETSJA \\dacgis02\projects\Worcester\PatchPond_Dam_Removal\MXD\Conservation_Lands_11x17.mxd 6/5/2014

Public recreation uses of the upstream impoundment and Tatnuck Brook are very limited within the project area since private properties extend to the water's edge on both shores. Access to the PPD is limited, without trespassing on private property, and only for a short distance along Glendale Street which will bring you to the breach in the dam described above. Current recreation uses of the land is also very limited and basically only available to the abutting homes. The aesthetics of the parcel is of high quality but again of limited public use.

The downstream Coes Reservoir/Pond has historically been an extraordinary recreational resource for the City providing swimming, boating, fishing, and ice skating. However, the buildup of silt and sediment over time has reduced water depths in many sections of the pond and making boating nearly impossible in some areas. A group called *Friends of the Coes Pond*, with the assistance of the City officials, is hoping to restore and renew the open space and recreational value of Coes Pond and also the entire Mill Street corridor including the City-owned Patch Reservoir upstream of PPD. Additional local groups involved in this effort include the *Tatnuck Brook Watershed Association*, the *Tatnuck Brook Neighborhood Association*, and the *Columbus Park Neighborhood Association*.

Another nearby recreational resource is a section of Mill Street by Coes Pond designated as the Major Taylor Bikeway.

The removal of the PPD would result in the conversion of the upstream impoundment to a wetland system. Current recreation use of Patch Pond is limited due to lack of public access to the property.

### 3.2.10 Surrounding Land Uses

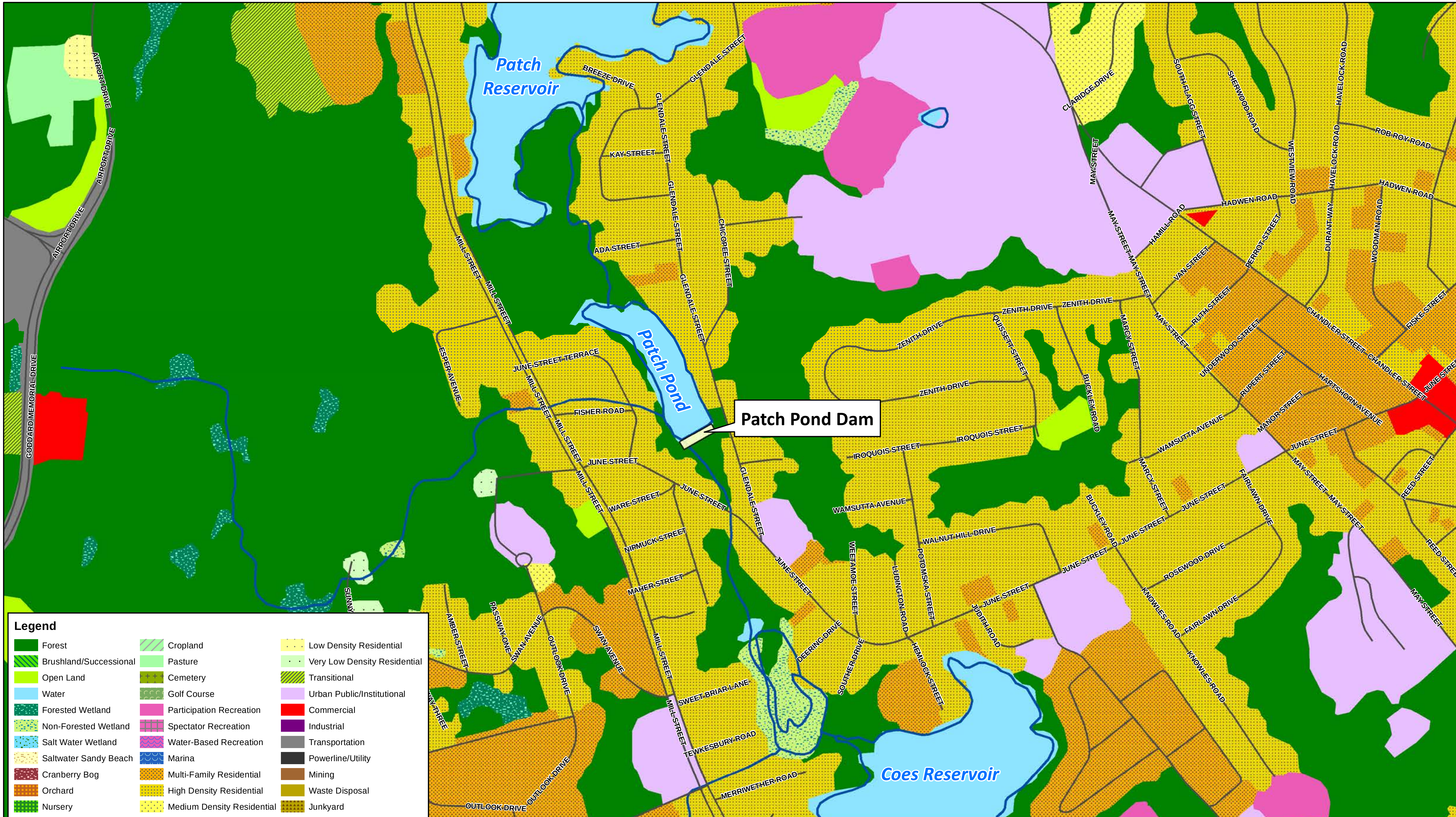
The surrounding land use is residential properties; many are waterfront properties with direct access to the pond, primarily along the southwest and east sides of the upstream impoundment as the steep slope at the northwest side prevents direct access. The adjacent parcel upstream of the impoundment (parcel ID 30-29A-00001) is an 11-acre parcel also owned by the City. This parcel is an undeveloped forested area that extends as far north as Patch Reservoir and west to Mill Street (see Figure 3-6). There is evidence of historic dumping on the southern portion of this parcel, north of the drainage channel described in Section 3.2.3 above; concrete and other demolition debris is clearly visible (see Photograph 12 in Appendix D).

Land use downstream of the June Street Bridge is forested along Tatnuck Brook and Williams Mill Pond, with a large wetland system further downstream before Tatnuck Brook discharges into Coes Reservoir.

Glendale Street borders the site to the east, forested City owned land to the north, June Street Terrace to the west and June Street to the south.

The dam under existing conditions is considered a public safety hazard and its removal would improve safety even though public use of the land is restricted.

A public presentation of the proposal to remove the Patch Pond Dam and the information collected for the preparation of this feasibility study was made by the Department of Public Works and Parks and CDM Smith Inc. on June 18, 2014 as part of a regularly-scheduled meeting of the City Council Public Works Committee. A summary of the meeting is provided in Section 7.6.




6/5/2014

Dam

Roads

Rivers

CDM Smith

# Worcester, Massachusetts
## Patch Pond Dam Removal Feasibility Study

N

0 250 500 1,000 Feet

**Figure 3-6**
**Land Use in 2005**

SHEETSJA \\dacgis02\projects\Worcester\PatchPond_Dam_Removal\MXD\Landuse_11x17.mxd 6/5/2014

### 3.2.11 Zoning

The parcel (48-022-00009) is zoned as RS-7, i.e. Residential Single Family housing with a minimum lot size of 7,000 square feet. The project area is located with the Airport Environs (AE) Overlay District since it is near the Worcester Municipal Airport. The requirements of the AE Overlay District are not applicable to the dam removal since it pertains to construction of new buildings and interior noise levels.

## 3.3 Nearby Utilities

Prior to removing any dam or dam structure an accurate assessment of the existing utilities must be completed. Part of that assessment includes a local survey, a records search, and confirmation by Dig Safe® that all utilities in the area are accounted for.

For this feasibility study, utilities information was gathered from the site survey activities, discussions with the City of Worcester, and site visits. At this time, it is believed that there are no public utilities at the site that will affect the removal of the dam and associated structures; however, a final confirmation of the existing utilities will be conducted once the design phase is initiated should the project move forward. Electrical services to the surrounding residential area along Glendale Street are not expected to be impacted by dam removal.

# Section 4

# Hazardous Waste Sites and Characterization of Sediment/Soil

A file review of hazardous waste sites and characterization of sediments and soil was conducted to determine potential environmental concerns and off-site disposal issues.

## 4.1 File Review

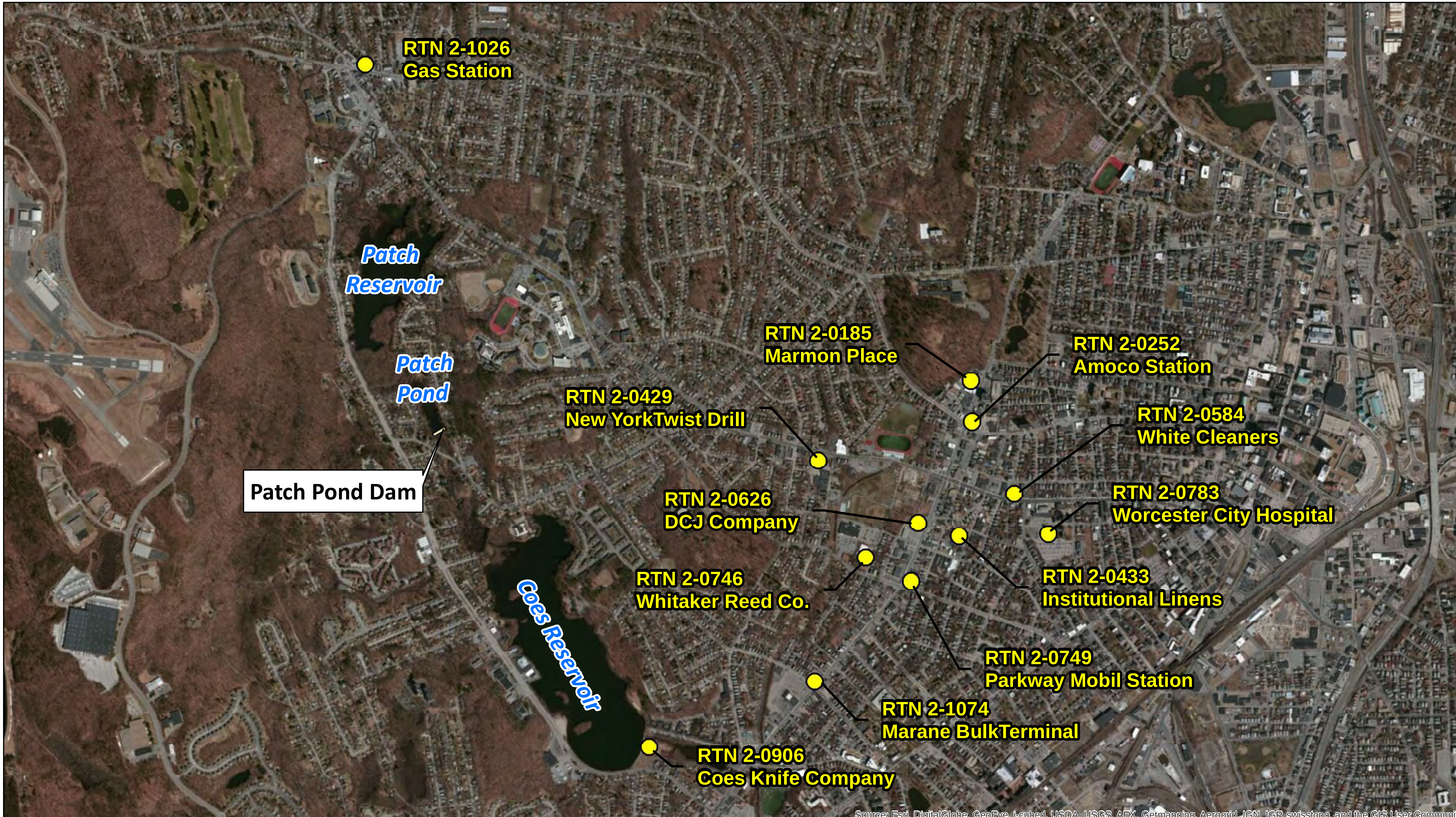
A file review of existing nearby sites regulated under the Massachusetts Contingency Plan (MCP) by the MassDEP was conducted. Twelve release tracking numbers (RTNs) were found within 1.8 miles of the Patch Pond Dam. These sites are discussed below and the locations are shown on Figure 4-1. Two of the sites are open sites; five of the sites are closed sites with an Activity and Use Limitation (AUL); and five of the sites are closed sites with no AUL.

### 4.1.1 Open Sites

***1. RTN 2-0252 (Amoco Station – 281 Park Ave.)***

The site was a commercially owned gas station since 1930, and was listed as a Location to be Investigated (LTBI) by MassDEP as of 1989 due to Underground Storage Tank (UST) removals. In 1987, five USTs were removed on the north end of the site. The Tanks were believed to be between 20-25 years old. They were previously used for gasoline, diesel, fuel oil, and waste oil storage. Some of the USTs were reported to have holes and were leaking gasoline at the time of removal. No known tanks exist on the property to date. In 2003, 45 ft of Non Aqueous Phase Liquid (NAPL), petroleum/petroleum impacted groundwater was reported and removed from the site. A soil vapor extraction and air sparging (SVE/AS) remedial system was installed later that year and continues to operate.

On November 1, 2002, a Release Notification Form (RNF) was submitted to the MassDEP for the detection of arsenic in soil at a concentration greater than the Reportable Concentrations (RCS- 1) of 30 mg/kg. In January 2003, background soil samples were collected throughout the site. On February 28, 2003, a Background Evaluation and Class B-1 Response Action Outcome for arsenic was submitted to the MassDEP. Based on the background evaluation, the concentrations of arsenic in soil detected at the site are attributable to naturally-occurring geologic conditions and are considered background.




6/16/2014

Hazardous Waste Sites

Dam

CDM Smith

**Worcester, Massachusetts**

**Patch Pond Dam Removal Feasibility Study**

N

0 500 1,000 2,000 Feet

**Figure 4-1**

**Hazardous Waste Sites**

### 2. RTN 2-0783 (Worcester City Hospital – 26 Queen Street)

The site was the Worcester City Hospital but is now owned by University of Massachusetts (UMASS) as a health care facility. The abutting properties were first developed as a shoe and boot factory but have since been used as machine tool manufacturing and repair, retail stores and plumbing supplies. A #6 fuel oil release from USTs with a combined capacity of 90,000 gallons was first documented in 1986 and the tanks were immediately decommissioned in-place. The area around the former hospital laundry room shows signs of chlorinated solvent release. There have been numerous cases of minor spills and leakages of hazardous materials and oil on the hospital site and surrounding sites.

On December 1, 1998, MassDEP assigned Release Tracking Number (RTN) 2-12529 to Macera & Martini Transportation Inc. in response to an oil spill during a fuel delivery at the UMASS USTs. The spill was estimated at less than 1,000 gallons and remediation occurred via emergency response activities and subsequent soil excavation. As of 2013, NAPL and dissolved petroleum constituents have been found down-gradient of the former USTs. This was the only location were concentrations were above applicable regulatory standards for groundwater.

On August 16, 2001, MassDEP assigned Release Tracking Number (R.TN) 2-13932 to UMASS in response to the detection of 99 ppm Arsenic in soils. This concentration is above the applicable reporting standard. Following subsequent investigations, it was determined that the arsenic found on site is likely attributed to naturally occurring background levels.

## 4.1.2 Closed Sites with AUL

### 1. RTN 2-0906 (former Coes Knife Company – 72 Coes Street)

The property operated as a Knife Company immediately after construction of the Coes Reservoir Dam in 1866. It was a manufacturing facility of knives and tools until 1991. The property was foreclosed in 1997 and the City of Worcester took ownership. In 2001, the City demolished the existing buildings and removed several underground storage tanks. The Site has been vacant since that time.

In September 1992, the MassDEP issued RTN 2-0906 to the former Coes Knife property after several metals and petroleum hydrocarbons were detected in soil above the applicable Reportable Concentrations (RCS-1) under the MCP. In 2002, a second RTN, 2-14384, was issued after chromium and polychlorinated biphenyls (PCBs) were detected in soil at concentrations exceeding the Imminent Hazard thresholds. The Imminent Hazard conditions were addressed as part of the Coes Reservoir Dam rehabilitation in 2006. In January 2008, RTN 2-14384 was linked with the original RTN 2-0906.

Remedial activities were completed at the site in the summer of 2013. Approximately 142 cubic yards of contaminated soil were excavated and disposed of off-site and an approximate 5,800 square foot area of residual PCB-impacted soil was capped with 6 inches of asphalt. An Activity and Use Limitation (AUL) was placed on the property and the site was closed out with a Class A-3 Response Action Outcome (RAO) Statement.

### 2. RTN 2-0429 (New York Twist Drill – 10 Mann Street )

The property has been a site since 1989 due to a petroleum release from some underground storage tanks. Floating petroleum product has been found on the water table. The site is currently in Remedy Operations Status (ROS) recovering floating product and monitoring the groundwater concentrations and monitoring indoor air. An AUL was place on the property in 2006.

### *3. RTN 2-0746 (Whitaker Reed Co. – 90 May Street)*

Whitaker Reed Company owned the site until 1989 when it was abandoned. Prior to abandoning the site, a 1000 gallon fuel oil UST was removed and was found to be fully intact and no contaminants were observed or found in subsequent laboratory testing of the surrounding excavated soil. A 100 sq. ft oil stained area of the site contained high levels of perchloroethylene (PCE), particularly in the soil close to the surface. The soil was removed and recycled. In 1992, PCE was detected in groundwater below the site, but well below applicable standards.

### *4. RTN 2-0749 (Parkway Mobil Station – 409 Park Street)*

The site has been a gasoline filling station since 1926 and has been owned and operated by Exxon Mobil since 1967. USTs on site in 1989 contained 550 gallons of waste oil, 550 gallons of heating oil, and 23,000 gallons of gasoline. In 1990 they were all removed after being found to be leaking and were replaced with fiberglass tanks (1,000 gallons waste oil, 1,000 gallons fuel oil, and 20,000 gallons gasoline) with leak detection sensors. A product recovery and groundwater treatment system was installed in 1990 and the site has been monitored since. LNAPL was initially found in groundwater monitoring wells in 1991 but was not detected after 1995. LNAPL has not been detected in any off-site wells.

### *5. RTN 2-0185 (Marmon Place)*

The site is occupied by several commercial businesses including an auto body repair shop, auto parts store, and an entertainment store. The site was listed as an LTBI in 1987 after removal of six USTs from previous site operator's Charles Chevrolet car dealership. Concentrations found in soil samples collected in 1995 indicated high levels of petroleum hydrocarbons. An AUL was implemented to restrict excavation in the area around the old fuel oil UST location, the only area with contaminant concentrations above applicable standards.

## 4.1.3 Closed Sites with no AUL

### *1. RTN 2-1026 (Gas Station - 1107 Pleasant Street) (update fig 4-1 to "Gas Station")*

This gas station property was identified as a site in 1986 based on fuel oil releases to the soil and groundwater. Two related RTNs for this site are RTN 2-11404 and RTN 11490. The site was closed out with an RAO A-2 in 2005.

### *2. RTN 2-1074 (Marane Bulk Terminal – 501 Park Ave)*

The site was owned by Jim Toohil from 1941 to 1978 as a gas station and bulk fuel facility with 15 USTs (550 to 30,000 gallons containing gasoline, diesel, and #2 fuel oil). Marane Oil (now JEMS) bought the property in 1978 and removed nine tanks in 1993 (four gasoline tanks were decommissioned in 1978 and left in place until 1993), revealing contamination. The other six remained in place for bulk fueling and five ASTs were added containing fuel additives, waste oil, fuel oil, and motor oil. In 1996, free product (NAPL) was discovered in the monitoring wells. Fueling ceased in 1998 when the remaining USTs were removed. Regular detection of contaminates was observed in on-site monitoring wells, though mostly below GW-3 standard levels. The site was closed out with an RAO A-2 in 1999 with a condition of No Significant Risk.

### 3. *RTN 2-0626 (DCJ Company – 360 Park Ave)*

A 5,000 gallon UST with #2 fuel oil was removed from the DCJ site in 1988 revealing contaminated soil and groundwater. All piping was removed by 1989 and 144.7 tons of soil was removed, down to 10 ft below groundwater. In 2006, injections began for an active biological/chemical treatment which was installed to satisfy Method One Cleanup Standards for S-1/GW-2. Biological treatment was performed from 2006 to 2007. The site was closed in 2007.

### 4. *RTN 2-0433 (Institutional Linens – 46A-48 Mason Street)*

This site, formerly an Institutional Linens (IL) commercial laundromat from 1930 through 1984 when the facility was abandoned, was acquired by the city of Worcester as a vacant lot in 1993. All buildings were cleared from the property in 2006. Three RTNs were submitted for the site, one for chlorinated solvents, one for oil and petroleum release of a 4,000 gallon fuel oil UST, and one for an oil/hazardous material release in the former below grade oil change pit. All three RTNs were later combined under one RTN. Contaminated soil was removed starting in 2007 and an RAO was submitted in 2010.

### 5. *RTN 2-0584 (White Cleaners – 199 Chandler Street)*

The site has been used by White Cleaners, a dry cleaning company since 1935. In 1987, a 6,500 gallon UST of naphthalene was removed. It ruptured in the process, contaminating the surrounding soil and groundwater with an unknown amount of product. In 1988, a 10,000 gallon #6 fuel oil UST was removed which subsequently caused a release. Three of the four remaining USTs (5,000 gallon #4 fuel oil tank and 21,500 dry cleaning solvent tanks) were decommissioned in place in 1999. The 4th, a 6,500 gallon naphthalene UST, was removed in 1999 along with 175 cubic yards of contaminated soil from nearby tanks. The site was closed by an RAO report in 2003 under the condition of No Significant Risk.

## 4.2 Sediment Sampling

On April 24, 2014, CDM Smith personnel were on-site and conducted sediment sampling.  These sites are discussed below and the sample locations are shown on Figure 4-2. update sample locations on 4-2

### 4.2.1 Sample Locations

CDM Smith collected six sediment core samples from the following locations for physical and chemical analysis, as described in the 401 Water Quality Regulations (314 CMR 9.00).

- From within Patch Pond: Patch-1-04-2014 and Patch-2-04-2014 update on Figure 4-2
- Upstream – from Tatnuck Brook downstream of Patch Reservoir: Patch-US-01-04-2014
- Upstream – from 36-inch storm drain/unnamed stream entering Patch Pond at Mill Street: Patch-US-02-04-2014
- Downstream – from Tatnuck Brook  leading from Patch Pond to Williams Mill Pond: Patch-DS-04-2014
- Downstream – from Williams Mill Pond (Composite sample): Williams-Comp-04-2014

Sampling locations were selected based on obtaining representative coverage of the pond as well as upstream and downstream conditions.


6/16/2014

Water
Dam

**Worcester, Massachusetts**
**Patch Pond Dam Removal Feasibility Study**

**Figure 4-2**
**Approximate Sampling Locations**

N
0 100 200 400 Feet

CDM Smith

SHEETSJA \\dacgis02\projects\Worcester\PatchPond_Dam_Removal\MXD\Sediment_Sampling_Locations_11x17.mxd 6/16/2014

### 4.2.2 Equipment and Materials

The following equipment was used to obtain the sediment samples:

- Stainless steel AMS extendable bucket auger;
- Stainless steel AMS extendable core sampler (with 2" x 12" butyrate plastic liner with liner caps);
- Stainless steel bowls and spoons;
- Laboratory-supplies sample glassware containers;
- Nitrile gloves;
- Decontamination liquids (detergent and de-ionized water);
- Logbook;
- Trimble global positioning system (GPS) receiver;
- Chest waders;
- Disposable plastic spoons; and
- Cooler and ice.

### 4.2.3 Equipment Decontamination Procedures

The sampling equipment was decontaminated off-site prior to the sample collection. The field crews carried extra sampling equipment to prevent cross-contamination between samples and minimize the amount of field decontamination necessary.

When field decontamination was required the following procedure was used:

1. Rinse the equipment of sample (sediment/soil) with tap water brought into the site in plastic containers;
2. Wash and scrub equipment with laboratory grade non-phosphate detergent (Liquinox);
3. Rinse with tap water; rinse water was collected for offsite disposal when required.
4. Rinse with de-ionized water; and
5. Air dry.

### 4.2.4 Sediment Collection

Sediment samples were collected using the extendable bucket auger and the extendable core sampler. The volatile organic compounds samples were collected using the core sampler to avoid exposure to the air during the transfer from the sampler to the laboratory-provided vials. A separate butyrate plastic liner was used for each sample collected. An estimated thickness of sediment was reported by the on-site personnel at the time of sample collection. To estimate the thickness of sediment, the field personnel noted the depth where the sediment was encountered and the depth where the native materials were encountered. The thickness of the sediment was then calculated from these two measurements. The native materials below the accumulated sediment were also collected and analyzed for grain size analysis. Water depth and thickness of sediment, were recorded at each sample location (see **Table 4-1,** below). Sediment sampling glassware and vials (supplied by the laboratory) were immediately placed on ice in coolers.

**Table 4-1**
**Sediment Sample Depths**

| Sample ID | Description | Depth of Water (Feet) | Thickness of Sediment (Feet) |
|---|---|---|---|
| Patch-US-01-04-2014 | Upstream of Patch Pond (Tatnuck Brook near Ada Street) | Approximately. 0.5 | Approximately 0.3 |
| Patch-US-02-04-2014 | Upstream of Patch Pond (Mill Street Storm Drain/Unnamed Tributary) | Approximately 0.1 | 1.0 |
| Patch-1-04-2014 | Within Patch Pond (north) | 1.5 | 5.0 |
| Patch-2-04-2014 | Within Patch Pond (south) | 5.6 | 2.4 |
| Patch-DS-04-2014 | Downstream of Patch Pond (Tatnuck Brook near June Street bridge) | 1.0 | 0.1 |
| Williams-Comp-04-2014 | Williams Mill Pond (downstream of Patch Pond) | 1.5 to 2.8 | 2.0 to 3.3 |

### 4.2.5 Sediment Analyses

Samples were transported in laboratory-provided glass amber jars and vials with chain-in-custody documentation to Alpha Analytical Laboratory located at Eight Walkup Drive in Westborough, Massachusetts for chemical and physical analysis. In addition, samples were transported in zippered plastic bags to CDM Smith's Geotechnical Laboratory located at 153 South Street in Somerville, Massachusetts for grain size analysis in accordance with ASTM D422.

The remainder of this section presents the results of the chemical characterization of the sediments. The results from the grain size analyses were used in the sediment transport analysis/modeling, and are discussed in Section 6.

## 4.3 Sediment Characterization

Sediment samples were analyzed for general chemistry, total organic carbon (TOC), total metals, volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), polychlorinated biphenyl (PCB) congeners, total petroleum hydrocarbons (TPH), extractable petroleum hydrocarbon (EPH) ranges, Polycyclic aromatic hydrocarbons (PAH), herbicides, pesticides and hazardous waste characteristic parameters. All of the data were compared to several criteria as shown on Table 4-2.

# Table 4-2
# Patch Pond
# Sediment Sample Results
# Sample Date - April 2014

| LOCATION | | | | | | WILLIAMS-COMP-04-2014 | | PATCH-US-01-04-2014 | | PATCH-US-02-04-2014 | | PATCH-1-04-2014 | | PATCH-2-04-2014 | | PATCH-DS-04-2014 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SAMPLING DATE | | | | | | 24-APR-14 | | 24-APR-14 | | 24-APR-14 | | 24-APR-14 | | 24-APR-14 | | 24-APR-14 | |
| LAB SAMPLE ID | | | | | | L1408690-01 | | L1408690-02 | | L1408690-03 | | L1408690-04 | | L1408690-05 | | L1408690-06 | |
| | RCS-1 Criteria | RCS-2 Criteria | Stage I Screening Criteria | COMM-97 Unlined/Lined Criteria | Units | | Qual | | Qual | | Qual | | Qual | | Qual | | Qual |
| Specific Conductance | | | | | umhos/cm | 11 | | 10 | U | 20 | | 19 | | 21 | | 10 | U |
| Solids, Total | | | | | % | 82.7 | | 80.8 | | 47.5 | | 34.8 | | 58.8 | | 85.2 | |
| Solids, Total Volatile | | | | | % | 1.5 | | 1.1 | | 7.9 | | 14 | | 7.6 | | 1.2 | |
| pH (H) | | | | | SU | 6.6 | | 6.9 | | 6.8 | | 6.3 | | 6.4 | | 6.8 | |
| Total Organic Carbon (Rep1) | | | | | % | 1.1 | | 0.21 | | 0.919 | | 4.98 | | 3 | | 0.569 | |
| Total Organic Carbon (Rep2) | | | | | % | 0.662 | | 0.296 | | 1.02 | | 5.41 | | 3.26 | | 0.502 | |
| Cyanide, Reactive | | | | | mg/kg | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U |
| Sulfide, Reactive | | | | | mg/kg | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U | 10 | U |
| Oxidation/Reduction Potential | | | | | mv | 220 | | 210 | | 130 | | 160 | | 86 | | 180 | |
| Ignitability | | | | | - | NI | | NI | | NI | | NI | | NI | | NI | |
| **Metals** | | | | | | | | | | | | | | | | | |
| Antimony, Total | 20 | 30 | | | mg/kg | 32 | | 2.4 | U | 4 | U | 5.4 | U | 3.2 | U | 2.2 | U |
| Arsenic, Total | 20 | 20 | 33 | 40/40 | mg/kg | 15 | | 31 | | 100 | | 75 | | 52 | | 28 | |
| Beryllium, Total | 90 | 200 | | | mg/kg | 0.23 | U | 0.24 | U | 0.73 | | 0.96 | | 0.72 | | 0.22 | U |
| Cadmium, Total | 70 | 100 | 5 | 30/80 | mg/kg | 13 | | 0.48 | U | 0.81 | U | 1.1 | U | 0.64 | U | 0.44 | U |
| Chromium, Total | 100 | 200 | 110 | 1000/1000 | mg/kg | 11 | | 15 | | 38 | | 53 | | 29 | | 17 | |
| Chromium, Hexavalent | 30 | | | | mg/kg | 0.97 | U | 0.99 | U | 1.7 | U | 2.3 | U | 1.4 | U | 0.94 | U |
| Copper, Total | 1000 | 10000 | 150 | | mg/kg | 13 | | 9.5 | | 82 | | 100 | | 13 | | 4.3 | |
| Lead, Total | 200 | 600 | 130 | 1000/2000 | mg/kg | 21 | | 11 | | 54 | | 84 | | 14 | | 3.3 | |
| Mercury, Total | 20 | 30 | 0.18 | 10/10 | mg/kg | 0.087 | U | 0.081 | U | 0.158 | U | 0.366 | | 0.134 | U | 0.079 | U |
| Nickel, Total | 600 | 1000 | 49 | | mg/kg | 10 | | 17 | | 22 | | 34 | | 27 | | 13 | |
| Selenium, Total | 400 | 700 | | | mg/kg | 2.3 | U | 2.4 | U | 4 | U | 5.4 | U | 3.2 | U | 2.2 | U |
| Silver, Total | 100 | 200 | | | mg/kg | 0.46 | U | 0.48 | U | 0.81 | U | 1.1 | U | 0.64 | U | 0.44 | U |
| Thallium, Total | 8 | 60 | | | mg/kg | 2.3 | U | 2.4 | U | 4 | U | 5.4 | U | 3.2 | U | 2.2 | U |
| Zinc, Total | 1000 | 3000 | 460 | | mg/kg | 38 | | 48 | | 71 | | 160 | | 59 | | 28 | |
| **TCLP Metals** | | | | | | | | | | | | | | | | | |
| Lead, TCLP | | | | | mg/l | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U | 0.5 | U |
| Arsenic, TCLP | | | | | | | | | | 1 | U | | | | | | |
| **Chlorinated Herbicides** | | | | | | | | | | | | | | | | | |
| 2,4,5-T | 100 | | | | mg/kg | 0.04 | U | 0.041 | U | 0.069 | U | 0.095 | U | 0.055 | U | 0.038 | U |
| 2,4,5-TP (Silvex) | 100 | | | | mg/kg | 0.04 | U | 0.041 | U | 0.069 | U | 0.095 | U | 0.055 | U | 0.038 | U |
| 2,4-D | 100 | | | | mg/kg | 0.04 | U | 0.041 | U | 0.069 | U | 0.095 | U | 0.055 | U | 0.038 | U |
| 2,4-DB | 100 | | | | mg/kg | 0.04 | U | 0.041 | U | 0.069 | U | 0.095 | U | 0.055 | U | 0.038 | U |
| Dalapon | | | | | mg/kg | 0.04 | U | 0.041 | U | 0.069 | U | 0.095 | U | 0.055 | U | 0.038 | U |
| Dicamba | 500 | | | | mg/kg | 0.04 | U | 0.041 | U | 0.069 | U | 0.095 | U | 0.055 | U | 0.038 | U |
| Dichloroprop | | | | | mg/kg | 0.04 | U | 0.041 | U | 0.069 | U | 0.095 | U | 0.055 | U | 0.038 | U |
| Dinoseb | 500 | | | | mg/kg | 0.04 | U | 0.041 | U | 0.069 | U | 0.095 | U | 0.055 | U | 0.038 | U |
| MCPA | 100 | | | | mg/kg | 4 | U | 4.1 | U | 6.9 | U | 9.5 | U | 5.5 | U | 3.8 | U |
| MCPP | | | | | mg/kg | 4 | U | 4.1 | U | 6.9 | U | 9.5 | U | 5.5 | U | 3.8 | U |
| **VOC** | | | | | | | | | | | | | | | | | |
| 1,1,1,2-Tetrachloroethane | 0.1 | 0.1 | | | mg/kg | 0.0024 | U | 0.00087 | U | 0.0034 | U | 0.0045 | U | 0.005 | U | 0.0031 | U |
| 1,1,1-Trichloroethane | 30 | 600 | | | mg/kg | 0.0024 | U | 0.00087 | U | 0.0034 | U | 0.0045 | U | 0.005 | U | 0.0031 | U |
| 1,1,2,2-Tetrachloroethane | 0.005 | 0.02 | | | mg/kg | 0.0024 | U | 0.00087 | U | 0.0034 | U | 0.0045 | U | 0.005 | U | 0.0031 | U |
| 1,1,2-Trichloroethane | 0.1 | 2 | | | mg/kg | 0.0036 | U | 0.0013 | U | 0.0051 | U | 0.0067 | U | 0.0075 | U | 0.0046 | U |
| 1,1-Dichloroethane | 0.4 | 5 | | | mg/kg | 0.0036 | U | 0.0013 | U | 0.0051 | U | 0.0067 | U | 0.0075 | U | 0.0046 | U |
| 1,1-Dichloroethene | 3 | 40 | | | mg/kg | 0.0024 | U | 0.00087 | U | 0.0034 | U | 0.0045 | U | 0.005 | U | 0.0031 | U |
| 1,1-Dichloropropene | | | | | mg/kg | 0.0097 | U | 0.0035 | U | 0.014 | U | 0.018 | U | 0.02 | U | 0.012 | U |
| 1,2,3-Trichlorobenzene | | | | | mg/kg | 0.0097 | U | 0.0035 | U | 0.014 | U | 0.018 | U | 0.02 | U | 0.012 | U |
| 1,2,3-Trichloropropane | 100 | 1000 | | | mg/kg | 0.0097 | U | 0.0035 | U | 0.014 | U | 0.018 | U | 0.02 | U | 0.012 | U |
| 1,2,4-Trichlorobenzene | 2 | 6 | | | mg/kg | 0.0097 | U | 0.0035 | U | 0.014 | U | 0.018 | U | 0.02 | U | 0.012 | U |
| 1,2,4-Trimethylbenzene | 1000 | 10000 | | | mg/kg | 0.0097 | U | 0.0035 | U | 0.014 | U | 0.018 | U | 0.02 | U | 0.012 | U |
| 1,2-Dibromo-3-chloropropane | 10 | 100 | | | mg/kg | 0.0097 | U | 0.0035 | U | 0.014 | U | 0.018 | U | 0.02 | U | 0.012 | U |

# Table 4-2 (Cont'd)
# Patch Pond
# Sediment Sample Results
# Sample Date - April 2014

| LOCATION | | | | | | WILLIAMS-COMP-04-2014 | | PATCH-US-01-04-2014 | | PATCH-US-02-04-2014 | | PATCH-1-04-2014 | | PATCH-2-04-2014 | | PATCH-DS-04-2014 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SAMPLING DATE | | | | | | 24-APR-14 | | 24-APR-14 | | 24-APR-14 | | 24-APR-14 | | 24-APR-14 | | 24-APR-14 | |
| LAB SAMPLE ID | | | | | | L1408690-01 | | L1408690-02 | | L1408690-03 | | L1408690-04 | | L1408690-05 | | L1408690-06 | |
| | RCS-1 Criteria | RCS-2 Criteria | Stage I Screening Criteria | COMM-97 Unlined/Lined Criteria | Units | | Qual | | Qual | | Qual | | Qual | | Qual | | Qual |
| 1,2-Dibromoethane | 0.1 | 0.1 | | | mg/kg | 0.0097 | U | 0.0035 | U | 0.014 | U | 0.018 | U | 0.02 | U | 0.012 | U |
| 1,2-Dichlorobenzene | 9 | 100 | | | mg/kg | 0.0097 | U | 0.0035 | U | 0.014 | U | 0.018 | U | 0.02 | U | 0.012 | U |
| 1,2-Dichloroethane | 0.1 | 0.1 | | | mg/kg | 0.0024 | U | 0.00087 | U | 0.0034 | U | 0.0045 | U | 0.005 | U | 0.0031 | U |
| 1,2-Dichloropropane | 0.1 | 0.1 | | | mg/kg | 0.0085 | U | 0.003 | U | 0.012 | U | 0.016 | U | 0.018 | U | 0.011 | U |
| 1,3,5-Trimethylbenzene | 10 | 100 | | | mg/kg | 0.0097 | U | 0.0035 | U | 0.014 | U | 0.018 | U | 0.02 | U | 0.012 | U |
| 1,3-Dichlorobenzene | 3 | 200 | | | mg/kg | 0.0097 | U | 0.0035 | U | 0.014 | U | 0.018 | U | 0.02 | U | 0.012 | U |
| 1,3-Dichloropropane | 500 | 5000 | | | mg/kg | 0.0097 | U | 0.0035 | U | 0.014 | U | 0.018 | U | 0.02 | U | 0.012 | U |
| 1,4-Dichlorobenzene | 0.7 | 1 | | | mg/kg | 0.0097 | U | 0.0035 | U | 0.014 | U | 0.018 | U | 0.02 | U | 0.012 | U |
| 1,4-Dioxane | 0.2 | 6 | | | mg/kg | 0.097 | U | 0.035 | U | 0.14 | U | 0.18 | U | 0.2 | U | 0.12 | U |
| 2,2-Dichloropropane | | | | | mg/kg | 0.012 | U | 0.0044 | U | 0.017 | U | 0.022 | U | 0.025 | U | 0.015 | U |
| 2-Hexanone | 100 | 1000 | | | mg/kg | 0.024 | U | 0.0087 | U | 0.034 | U | 0.045 | U | 0.05 | U | 0.031 | U |
| Acetone | 6 | 50 | | | mg/kg | 0.087 | U | 0.031 | U | 0.31 | | 0.45 | | 0.28 | | 0.11 | U |
| Benzene | 2 | 200 | | | mg/kg | 0.0024 | U | 0.00087 | U | 0.0034 | U | 0.0045 | U | 0.005 | U | 0.0031 | U |
| Bromobenzene | 100 | 1000 | | | mg/kg | 0.012 | U | 0.0044 | U | 0.017 | U | 0.022 | U | 0.025 | U | 0.015 | U |
| Bromochloromethane | | | | | mg/kg | 0.0097 | U | 0.0035 | U | 0.014 | U | 0.018 | U | 0.02 | U | 0.012 | U |
| Bromodichloromethane | 0.1 | 0.1 | | | mg/kg | 0.0024 | U | 0.00087 | U | 0.0034 | U | 0.0045 | U | 0.005 | U | 0.0031 | U |
| Bromoform | 0.1 | 1 | | | mg/kg | 0.0097 | U | 0.0035 | U | 0.014 | U | 0.018 | U | 0.02 | U | 0.012 | U |
| Bromomethane | 0.5 | 0.5 | | | mg/kg | 0.0048 | U | 0.0017 | U | 0.0068 | U | 0.009 | U | 0.01 | U | 0.0062 | U |
| Carbon disulfide | 100 | 1000 | | | mg/kg | 0.0097 | U | 0.0035 | U | 0.014 | U | 0.018 | U | 0.02 | U | 0.012 | U |
| Carbon tetrachloride | 5 | 5 | | | mg/kg | 0.0024 | U | 0.00087 | U | 0.0034 | U | 0.0045 | U | 0.005 | U | 0.0031 | U |
| Chlorobenzene | 1 | 3 | | | mg/kg | 0.0024 | U | 0.00087 | U | 0.0034 | U | 0.0045 | U | 0.005 | U | 0.0031 | U |
| Chloroethane | 100 | 1000 | | | mg/kg | 0.0048 | U | 0.0017 | U | 0.0068 | U | 0.009 | U | 0.01 | U | 0.0062 | U |
| Chloroform | 0.2 | 0.2 | | | mg/kg | 0.0036 | U | 0.0013 | U | 0.0051 | U | 0.0067 | U | 0.0075 | U | 0.0046 | U |
| Chloromethane | 100 | 1000 | | | mg/kg | 0.0097 | U | 0.0035 | U | 0.014 | U | 0.018 | U | 0.02 | U | 0.012 | U |
| cis-1,2-Dichloroethene | 0.1 | 0.1 | | | mg/kg | 0.0024 | U | 0.00087 | U | 0.0034 | U | 0.0045 | U | 0.005 | U | 0.0031 | U |
| cis-1,3-Dichloropropene | 0.01 | 0.1 | | | mg/kg | 0.0024 | U | 0.00087 | U | 0.0034 | U | 0.0045 | U | 0.005 | U | 0.0031 | U |
| Dibromochloromethane | 0.005 | 0.03 | | | mg/kg | 0.0024 | U | 0.00087 | U | 0.0034 | U | 0.0045 | U | 0.005 | U | 0.0031 | U |
| Dibromomethane | 500 | 5000 | | | mg/kg | 0.0097 | U | 0.0035 | U | 0.014 | U | 0.018 | U | 0.02 | U | 0.012 | U |
| Dichlorodifluoromethane | 1000 | 10000 | | | mg/kg | 0.024 | U | 0.0087 | U | 0.034 | U | 0.045 | U | 0.05 | U | 0.031 | U |
| Diethyl ether | 100 | 1000 | | | mg/kg | 0.012 | U | 0.0044 | U | 0.017 | U | 0.022 | U | 0.025 | U | 0.015 | U |
| Diisopropyl Ether | | | | | mg/kg | 0.0097 | U | 0.0035 | U | 0.014 | U | 0.018 | U | 0.02 | U | 0.012 | U |
| Ethyl-Tert-Butyl-Ether | | | | | mg/kg | 0.0097 | U | 0.0035 | U | 0.014 | U | 0.018 | U | 0.02 | U | 0.012 | U |
| Ethylbenzene | 40 | 1000 | | | mg/kg | 0.0024 | U | 0.00087 | U | 0.0034 | U | 0.0045 | U | 0.005 | U | 0.0031 | U |
| Hexachlorobutadiene | 30 | 100 | | | mg/kg | 0.0097 | U | 0.0035 | U | 0.014 | U | 0.018 | U | 0.02 | U | 0.012 | U |
| Isopropylbenzene | 1000 | 10000 | | | mg/kg | 0.0024 | U | 0.00087 | U | 0.0034 | U | 0.0045 | U | 0.005 | U | 0.0031 | U |
| Methyl ethyl ketone | 4 | 50 | | | mg/kg | 0.024 | U | 0.0087 | U | 0.071 | | 0.091 | | 0.054 | | 0.031 | U |
| Methyl isobutyl ketone | 0.4 | 50 | | | mg/kg | 0.024 | U | 0.0087 | U | 0.034 | U | 0.045 | U | 0.05 | U | 0.031 | U |
| Methyl tert butyl ether | 0.1 | 100 | | | mg/kg | 0.0048 | U | 0.0017 | U | 0.0068 | U | 0.009 | U | 0.01 | U | 0.0062 | U |
| Methylene chloride | 0.1 | 20 | | | mg/kg | 0.024 | U | 0.0087 | U | 0.034 | U | 0.045 | U | 0.05 | U | 0.031 | U |
| n-Butylbenzene | | | | | mg/kg | 0.0024 | U | 0.00087 | U | 0.0034 | U | 0.0045 | U | 0.005 | U | 0.0031 | U |
| n-Propylbenzene | 100 | 1000 | | | mg/kg | 0.0024 | U | 0.00087 | U | 0.0034 | U | 0.0045 | U | 0.005 | U | 0.0031 | U |
| Naphthalene | 4 | 20 | | | mg/kg | 0.0097 | U | 0.0035 | U | 0.014 | U | 0.018 | U | 0.02 | U | 0.012 | U |
| o-Chlorotoluene | 100 | 1000 | | | mg/kg | 0.0097 | U | 0.0035 | U | 0.014 | U | 0.018 | U | 0.02 | U | 0.012 | U |
| o-Xylene | 100 | 100 | | | mg/kg | 0.0048 | U | 0.0017 | U | 0.0068 | U | 0.009 | U | 0.01 | U | 0.0062 | U |
| p-Chlorotoluene | | | | | mg/kg | 0.0097 | U | 0.0035 | U | 0.014 | U | 0.018 | U | 0.02 | U | 0.012 | U |
| p-Isopropyltoluene | | 1000 | | | mg/kg | 0.0024 | U | 0.00087 | U | 0.0034 | U | 0.0045 | U | 0.005 | U | 0.0031 | U |
| p/m-Xylene | 100 | 100 | | | mg/kg | 0.0048 | U | 0.0017 | U | 0.0068 | U | 0.009 | U | 0.01 | U | 0.0062 | U |
| sec-Butylbenzene | | | | | mg/kg | 0.0024 | U | 0.00087 | U | 0.0034 | U | 0.0045 | U | 0.005 | U | 0.0031 | U |
| Styrene | 3 | 4 | | | mg/kg | 0.0048 | U | 0.0017 | U | 0.0068 | U | 0.009 | U | 0.01 | U | 0.0062 | U |
| tert-Butylbenzene | 100 | 1000 | | | mg/kg | 0.0097 | U | 0.0035 | U | 0.014 | U | 0.018 | U | 0.02 | U | 0.012 | U |
| Tertiary-Amyl Methyl Ether | | | | | mg/kg | 0.0097 | U | 0.0035 | U | 0.014 | U | 0.018 | U | 0.02 | U | 0.012 | U |
| Tetrachloroethene | 1 | 10 | | | mg/kg | 0.0024 | U | 0.00087 | U | 0.0034 | U | 0.0045 | U | 0.005 | U | 0.0031 | U |
| Tetrahydrofuran | 500 | 5000 | | | mg/kg | 0.0097 | U | 0.0035 | U | 0.014 | U | 0.018 | U | 0.02 | U | 0.012 | U |
| Toluene | 30 | 1000 | | | mg/kg | 0.0036 | U | 0.0013 | U | 0.0051 | U | 0.0067 | U | 0.0075 | U | 0.0046 | U |

# Table 4-2 (Cont'd)
# Patch Pond
# Sediment Sample Results
# Sample Date - April 2014

| LOCATION | | | | | | WILLIAMS-COMP-04-2014 | | PATCH-US-01-04-2014 | | PATCH-US-02-04-2014 | | PATCH-1-04-2014 | | PATCH-2-04-2014 | | PATCH-DS-04-2014 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SAMPLING DATE | | | | | | 24-APR-14 | | 24-APR-14 | | 24-APR-14 | | 24-APR-14 | | 24-APR-14 | | 24-APR-14 | |
| LAB SAMPLE ID | | | | | | L1408690-01 | | L1408690-02 | | L1408690-03 | | L1408690-04 | | L1408690-05 | | L1408690-06 | |
| | RCS-1 Criteria | RCS-2 Criteria | Stage I Screening Criteria | COMM-97 Unlined/Lined Criteria | Units | | Qual | | Qual | | Qual | | Qual | | Qual | | Qual |
| trans-1,2-Dichloroethene | 1 | 1 | | | mg/kg | 0.0036 | U | 0.0013 | U | 0.0051 | U | 0.0067 | U | 0.0075 | U | 0.0046 | U |
| trans-1,3-Dichloropropene | 0.01 | 0.1 | | | mg/kg | 0.0024 | U | 0.00087 | U | 0.0034 | U | 0.0045 | U | 0.005 | U | 0.0031 | U |
| Trichloroethene | 0.3 | 0.3 | | | mg/kg | 0.0024 | U | 0.00087 | U | 0.0034 | U | 0.0045 | U | 0.005 | U | 0.0031 | U |
| Trichlorofluoromethane | 1000 | 10000 | | | mg/kg | 0.0097 | U | 0.0035 | U | 0.014 | U | 0.018 | U | 0.02 | U | 0.012 | U |
| Vinyl chloride | 0.6 | 0.7 | | | mg/kg | 0.0048 | U | 0.0017 | U | 0.0068 | U | 0.009 | U | 0.01 | U | 0.0062 | U |
| **PAHs** | | | | | | | | | | | | | | | | | |
| Acenaphthene | 4 | 3000 | | | mg/kg | 0.00902 | U | 0.00922 | U | 0.0263 | | 0.0196 | U | 0.0119 | U | 0.00812 | U |
| Acenaphthylene | 1 | 10 | | | mg/kg | 0.0616 | | 0.00922 | U | 0.168 | | 0.0368 | | 0.0196 | | 0.00812 | U |
| Anthracene | 1000 | 3000 | 0.057 | | mg/kg | 0.0402 | | 0.00922 | U | 0.146 | | 0.0354 | | 0.0127 | | 0.00812 | U |
| Benz(a)anthracene | 7 | | 0.11 | | mg/kg | 0.208 | | 0.019 | | 0.482 | | 0.112 | | 0.0302 | | 0.00812 | U |
| Benzo(a)pyrene | 2 | 7 | 0.15 | | mg/kg | 0.209 | | 0.0217 | | 0.496 | | 0.104 | | 0.0387 | | 0.00812 | U |
| Benzo(b)fluoranthene | 7 | 40 | | | mg/kg | 0.253 | | 0.0336 | | 0.585 | | 0.153 | | 0.0457 | | 0.00812 | U |
| Benzo(ghi)perylene | 1000 | 3000 | | | mg/kg | 0.158 | | 0.0206 | | 0.401 | | 0.101 | | 0.033 | | 0.00812 | U |
| Benzo(k)fluoranthene | 70 | 400 | | | mg/kg | 0.169 | | 0.0156 | | 0.401 | | 0.115 | | 0.0352 | | 0.00812 | U |
| Chrysene | 70 | 400 | 0.17 | | mg/kg | 0.261 | | 0.0262 | | 0.627 | | 0.204 | | 0.0574 | | 0.00812 | U |
| Dibenz(a,h)anthracene | 0.7 | 4 | 0.033 | | mg/kg | 0.0402 | | 0.00922 | U | 0.0984 | | 0.0276 | | 0.0119 | U | 0.00812 | U |
| Fluoranthene | 1000 | 3000 | 0.42 | | mg/kg | 0.456 | | 0.0419 | | 1.09 | | 0.228 | | 0.073 | | 0.00812 | U |
| Fluorene | 1000 | 3000 | 0.077 | | mg/kg | 0.0127 | | 0.00922 | U | 0.0636 | | 0.0206 | | 0.0119 | U | 0.00812 | U |
| Indeno(1,2,3-cd)Pyrene | 7 | 40 | | | mg/kg | 0.184 | | 0.0226 | | 0.455 | | 0.114 | | 0.0359 | | 0.00812 | U |
| Naphthalene | 4 | 20 | 0.18 | | mg/kg | 0.00922 | | 0.00922 | U | 0.039 | | 0.0196 | U | 0.0119 | U | 0.00812 | U |
| Phenanthrene | 10 | 1000 | 0.2 | | mg/kg | 0.24 | | 0.0148 | | 0.555 | | 0.152 | | 0.0434 | | 0.00812 | U |
| Pyrene | 1000 | 3000 | 0.2 | | mg/kg | 0.396 | | 0.035 | | 1.03 | | 0.216 | | 0.0851 | | 0.00812 | U |
| Total | | | | 100/100 | | 2.70 | | 0.25 | | 6.66 | | 1.62 | | 0.51 | | ND | |
| **PCB Congeners** | | | | | | | | | | | | | | | | | |
| Cl10-BZ#209 | | | | | mg/kg | 0.000902 | U | 0.000922 | U | 0.00148 | U | 0.00196 | U | 0.00119 | U | 0.000812 | U |
| Cl2-BZ#8 | | | | | mg/kg | 0.000902 | U | 0.000922 | U | 0.00148 | U | 0.00196 | U | 0.00119 | U | 0.000812 | U |
| Cl3-BZ#18 | | | | | mg/kg | 0.000902 | U | 0.000922 | U | 0.00148 | U | 0.00196 | U | 0.00119 | U | 0.000812 | U |
| Cl3-BZ#28 | | | | | mg/kg | 0.000902 | U | 0.000922 | U | 0.00148 | U | 0.00196 | U | 0.00119 | U | 0.000812 | U |
| Cl4-BZ#44 | | | | | mg/kg | 0.000902 | U | 0.000922 | U | 0.00148 | U | 0.00196 | U | 0.00119 | U | 0.000812 | U |
| Cl4-BZ#49 | | | | | mg/kg | 0.000902 | U | 0.000922 | U | 0.00148 | U | 0.00196 | U | 0.00119 | U | 0.000812 | U |
| Cl4-BZ#52 | | | | | mg/kg | 0.000902 | U | 0.000922 | U | 0.00148 | U | 0.00196 | U | 0.00119 | U | 0.000812 | U |
| Cl4-BZ#66 | | | | | mg/kg | 0.000902 | U | 0.000922 | U | 0.00148 | U | 0.00196 | U | 0.00119 | U | 0.000812 | U |
| Cl5-BZ#101 | | | | | mg/kg | 0.000902 | U | 0.000922 | U | 0.00148 | U | 0.00196 | U | 0.00119 | U | 0.000812 | U |
| Cl5-BZ#105 | | | | | mg/kg | 0.000902 | U | 0.000922 | U | 0.00148 | U | 0.00196 | U | 0.00119 | U | 0.000812 | U |
| Cl5-BZ#118 | | | | | mg/kg | 0.000902 | U | 0.000922 | U | 0.00148 | U | 0.00196 | U | 0.00119 | U | 0.000812 | U |
| Cl5-BZ#87 | | | | | mg/kg | 0.000902 | U | 0.000922 | U | 0.00148 | U | 0.00196 | U | 0.00119 | U | 0.000812 | U |
| Cl6-BZ#128 | | | | | mg/kg | 0.000902 | U | 0.000922 | U | 0.00148 | U | 0.00196 | U | 0.00119 | U | 0.000812 | U |
| Cl6-BZ#138 | | | | | mg/kg | 0.000902 | U | 0.000922 | U | 0.00625 | | 0.00196 | U | 0.00119 | U | 0.000812 | U |
| Cl6-BZ#153 | | | | | mg/kg | 0.000902 | U | 0.000922 | U | 0.0052 | | 0.00196 | U | 0.00119 | U | 0.000812 | U |
| Cl7-BZ#170 | | | | | mg/kg | 0.000902 | U | 0.000922 | U | 0.00617 | | 0.00196 | U | 0.00119 | U | 0.000812 | U |
| Cl7-BZ#180 | | | | | mg/kg | 0.000902 | U | 0.000922 | U | 0.00851 | | 0.00196 | U | 0.00119 | U | 0.000812 | U |
| Cl7-BZ#183 | | | | | mg/kg | 0.000902 | U | 0.000922 | U | 0.00183 | | 0.00196 | U | 0.00119 | U | 0.000812 | U |
| Cl7-BZ#184 | | | | | mg/kg | 0.000902 | U | 0.000922 | U | 0.00148 | U | 0.00196 | U | 0.00119 | U | 0.000812 | U |
| Cl7-BZ#187 | | | | | mg/kg | 0.000902 | U | 0.000922 | U | 0.00417 | | 0.00196 | U | 0.00119 | U | 0.000812 | U |
| Cl8-BZ#195 | | | | | mg/kg | 0.000902 | U | 0.000922 | U | 0.00148 | U | 0.00196 | U | 0.00119 | U | 0.000812 | U |
| Cl9-BZ#206 | | | | | mg/kg | 0.000902 | U | 0.000922 | U | 0.00148 | U | 0.00196 | U | 0.00119 | U | 0.000812 | U |
| Total PCBs | | | 0.06 | 2/2 | | ND | | ND | | 0.03213 | | ND | | ND | | ND | |
| **Organochlorine Pesticides** | | | | | | | | | | | | | | | | | |
| 4,4'-DDD | 4 | | 0.0049 | | mg/kg | 0.00941 | U | 0.00938 | U | 0.0167 | U | 0.0219 | U | 0.0134 | U | 0.00912 | U |
| 4,4'-DDE | 3 | | 0.0032 | | mg/kg | 0.00941 | U | 0.00938 | U | 0.0167 | U | 0.0219 | U | 0.0134 | U | 0.00912 | U |
| 4,4'-DDT | 3 | | 0.0042 | | mg/kg | 0.0176 | U | 0.0176 | U | 0.0312 | U | 0.041 | U | 0.0252 | U | 0.0171 | U |
| Aldrin | 0.04 | | | | mg/kg | 0.00941 | U | 0.00938 | U | 0.0167 | U | 0.0219 | U | 0.0134 | U | 0.00912 | U |
| Alpha-BHC | 50 | | | | mg/kg | 0.00392 | U | 0.00391 | U | 0.00694 | U | 0.00912 | U | 0.00559 | U | 0.0038 | U |

# Table 4-2 (Cont'd)
# Patch Pond
# Sediment Sample Results
# Sample Date - April 2014

| LOCATION | | | | | | WILLIAMS-COMP-04-2014 | | PATCH-US-01-04-2014 | | PATCH-US-02-04-2014 | | PATCH-1-04-2014 | | PATCH-2-04-2014 | | PATCH-DS-04-2014 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SAMPLING DATE | | | | | | 24-APR-14 | | 24-APR-14 | | 24-APR-14 | | 24-APR-14 | | 24-APR-14 | | 24-APR-14 | |
| LAB SAMPLE ID | | | | | | L1408690-01 | | L1408690-02 | | L1408690-03 | | L1408690-04 | | L1408690-05 | | L1408690-06 | |
| | RCS-1 Criteria | RCS-2 Criteria | Stage I Screening Criteria | COMM-97 Unlined/Lined Criteria | Units | | Qual | | Qual | | Qual | | Qual | | Qual | | Qual |
| **Beta-BHC** | 10 | | | | mg/kg | 0.00941 | U | 0.00938 | U | 0.0167 | U | 0.0219 | U | 0.0134 | U | 0.00912 | U |
| **Chlordane** | 0.7 | | 0.0032 | | mg/kg | 0.0764 | U | 0.0762 | U | 0.135 | U | 0.178 | U | 0.109 | U | 0.0741 | U |
| **cis-Chlordane** | 0.7 | | | | mg/kg | 0.0118 | U | 0.0117 | U | 0.0208 | U | | | | | | |
| **Delta-BHC** | 10 | | | | mg/kg | 0.00941 | U | 0.00938 | U | 0.0167 | U | 0.0219 | U | 0.0134 | U | 0.00912 | U |
| **Dieldrin** | 0.05 | | 0.0019 | | mg/kg | 0.00588 | U | 0.00586 | U | 0.0104 | U | 0.0137 | U | 0.00838 | U | 0.0057 | U |
| **Endosulfan I** | 0.5 | | | | mg/kg | 0.00941 | U | 0.00938 | U | 0.0167 | U | 0.0219 | U | 0.0134 | U | 0.00912 | U |
| **Endosulfan II** | 0.5 | | | | mg/kg | 0.00941 | U | 0.00938 | U | 0.0167 | U | 0.0219 | U | 0.0134 | U | 0.00912 | U |
| **Endosulfan sulfate** | | | | | mg/kg | 0.00392 | U | 0.00391 | U | 0.00694 | U | 0.00912 | U | 0.00559 | U | 0.0038 | U |
| **Endrin** | 8 | | 0.0022 | | mg/kg | 0.00392 | U | 0.00391 | U | 0.00694 | U | 0.00912 | U | 0.00559 | U | 0.0038 | U |
| **Endrin ketone** | | | | | mg/kg | 0.00941 | U | 0.00938 | U | 0.0167 | U | 0.0219 | U | 0.0134 | U | 0.00912 | U |
| **Heptachlor** | 0.2 | | | | mg/kg | 0.0047 | U | 0.00469 | U | 0.00833 | U | 0.0109 | U | 0.00671 | U | 0.00456 | U |
| **Heptachlor epoxide** | 0.09 | | 0.0025 | | mg/kg | 0.0176 | U | 0.0176 | U | 0.0312 | U | 0.041 | U | 0.0252 | U | 0.0171 | U |
| **Hexachlorobenzene** | 0.7 | | | | mg/kg | | | | | | | 0.0219 | U | 0.0134 | U | 0.00912 | U |
| **Lindane** | 0.003 | | 0.0024 | | mg/kg | 0.00314 | U | 0.00312 | U | 0.00555 | U | 0.0073 | U | 0.00447 | U | 0.00304 | U |
| **Methoxychlor** | 200 | | | | mg/kg | 0.0176 | U | 0.0176 | U | 0.0312 | U | 0.041 | U | 0.0252 | U | 0.0171 | U |
| **Toxaphene** | 10 | | | | mg/kg | 0.176 | U | 0.176 | U | 0.312 | U | | | | | | |
| **trans-Chlordane** | 0.7 | | | | mg/kg | 0.0118 | U | 0.0117 | U | 0.0208 | U | | | | | | |
| | | | | | | | | | | | | | | | | | |
| **TPH** | 1000 | 3000 | | | mg/kg | 90.7 | | 39.3 | U | 548 | | 197 | | 146 | | 38.6 | U |
| **Extractable Petroleum Hydrocarbons** | | | | | | | | | | | | | | | | | |
| **C11-C22 Aromatics** | | | | | mg/kg | 11.3 | | 7.74 | U | 23.4 | | 18.7 | U | 11.1 | U | 7.4 | U |
| **C11-C22 Aromatics, Adjusted** | 1000 | 3000 | | | mg/kg | 11.3 | | 7.74 | U | 23.4 | | 18.7 | U | 11.1 | U | 7.4 | U |
| **C19-C36 Aliphatics** | 3000 | 5000 | | | mg/kg | 10.4 | | 7.74 | U | 49.6 | | 18.7 | U | 11.1 | U | 7.4 | U |
| **C9-C18 Aliphatics** | 1000 | 3000 | | | mg/kg | 7.73 | U | 7.74 | U | 13.5 | U | 18.7 | U | 11.1 | U | 7.4 | U |

TEC = Threshold Effects Concentration

PEC = Probable Effects Concentration

Bold Outline concentration exceeds RCS-1 criteria.

Yellow Highlighted concentration exceeds Stage I ecological risk screening criteria.

Metals were detected in all the samples collected. VOCs, acetone and Methyl ethyl ketone, were detected at low concentrations in 3 out of the 6 samples. PAHs were detected in 5 out of 6 samples with total PAH concentrations ranging from 0.25 mg/kg to 7 mg/kg (highest being Patch-US-02-04-2014, upstream from Mill Street storm drain/stream). Herbicides and pesticides were not detected in any of the samples. PCBs were detected at low levels in only one sample (Patch-US-02-04-2014, upstream from Mill Street storm drain/stream). TPH was detected in 4 out of the 6 samples with concentrations ranging from 91 mg/kg to 548 mg/kg (highest being Patch-US-02-04-2014, upstream from Mill Street storm drain/stream). Low levels of EPH carbon ranges were detected in 2 out of 6 samples.

Sediment is not specifically regulated under the Massachusetts Contingency Plan (MCP) (unless part of a larger site of release); however, the data were compared to the reportable concentrations under the MCP as a point of reference. The Williams-Comp-04-2014 sample (downstream) exceeded the RCS-1 criteria for antimony with a concentration of 32 mg/kg (RCS-1 = 20 mg/kg). All of the other samples (two from within Patch Pond and the two upstream samples) exceeded the RCS-1 criteria for arsenic (20 mg/kg) with concentrations ranging from 28 mg/kg to 100 kg/kg. The highest arsenic concentration (100 mg/kg) was found in the sample upstream (Patch-US-02-04-2014, from Mill Street storm drain/stream).

In terms of ecological risks, the data were compared to the MA Stage I screening criteria. Table 4-2 shows the exceedances of these criteria. These exceedances indicate the potential for ecological effects downstream if the sediment is released when the dam is removed. Some of the samples exceeded the Stage I criteria for metals and PAHs. One of the 2 samples collected from within Patch Pond (Patch-1-04-2014) exceeded the criteria for mercury (0.18 mg/kg) with a concentration of 0.366 mg/kg. Both samples collected within Patch Pond (Patch-1-04-2014 and Patch-2-04-2014) exceeded the criteria for arsenic (33 mg/kg) with concentrations of 75 mg/kg and 52 mg/kg. The highest concentration of arsenic was found in Patch-US-02-04-2014, the upstream sample from Mill Street storm drain/stream. The two upstream arsenic samples (Patch-US-01-04-2014 at 31 mg/kg and Patch-US-02-04-2014 at 100 mg/kg) are higher than the 2 downstream samples that did not exceed the Stage 1 screening criteria for either arsenic or mercury.

PAHs exceeded the Stage I screening criteria in 1 of the 2 samples collected from within Patch Pond. The sample collected downstream from Williams Mill Pond also exceeded the criteria for the same PAHs at even higher concentrations. The sample collected upstream from Mill Street storm drain/stream showed the highest PAH concentrations.

The Patch-US-02-04-2014 Mill Street storm drain sample showed the highest concentrations of Arsenic and PAH's among all of the samples taken. These elevated concentrations are likely due to the fact that the drain receives runoff from Mill Street, which is a four lane road and a major thoroughfare. The 36-inch culvert is the low spot in the storm drainage network in the area, and therefore, collects rainwater and runoff characteristic of urban runoff.

## 4.4 Sediment Handling and Disposal

In terms of off-site disposal, based on the arsenic concentrations in Patch Pond, which exceeded the in-state landfill criteria (40 mg/kg), the sediment would require disposal out-of-state if this material is removed. Some out-of-state facilities (i.e., Waste Management (TREE) in New Hampshire) require a sampling frequency of 1 sample per 250 tons. This would likely be the most stringent sampling frequency that would be encountered; other facilities may offer a more relaxed sampling frequency such as 1 sample per 500 tons. Material would have to be dewatered prior to transporting. Material must pass a paint filter test in order to be transported to an off-site facility.

Discussion of alternatives that involve different sediment removal strategies is presented in Section 7.

## 4.5 Conclusions

Samples showed levels of metals and PAHs that exceeded some of the MCP RCS-1 criteria and Stage I ecological risk criteria. The primary metal of concern was arsenic. Arsenic levels in Patch Pond were 75 mg/kg and 52 mg/kg, which could be attributed to the naturally elevated arsenic levels in the Worcester area. These concentrations were higher than the downstream concentrations of 28 mg/kg and 15 mg/kg indicating a potential impact of the release of this material when the dam is removed.

Some PAHs exceeded the Stage I criteria in Patch Pond however the concentrations were not significantly higher and were actually lower than the downstream concentrations from the sample collected at Williams Mill Pond. Therefore, there is not likely to be an adverse impact due to PAHs from the removal of the dam.

The highest concentrations of arsenic and PAHs were found in the upstream sample collected from the storm drain/unnamed stream at Mill Street. This area should be investigated as a possible source of elevated concentrations of arsenic and PAHs, and may be a candidate for installation of stormwater Best Management Practices (BMPs).

## 4.6 Follow-up Investigations

The six sediment samples taken for this feasibility study are considered to be an appropriate sample size for an initial screening, but may not be fully representative of all of the sediments upstream, downstream and within the Patch Pond. Additional investigations and sediment samples will be needed during the design phase should the City elect to proceed with dam removal to finalize the sediment management strategy appropriate for removal, hauling and disposal.

The results of the sampling conducted under this feasibility study and recent discussions with MassDEP indicate that the sediments in Patch Pond can be either removed or stabilized in place (or a combination thereof). They should not be released to areas downstream of the dam unless subsequent sampling shows that the levels of arsenic in the pond sediments are at or below the levels seen in the downstream sediments. The results obtained from future sampling events will be used to refine the approach to sediment management and determine when and if disposal, release or in-place stabilization are appropriate.

MassDEP also provided guidance that the screening level analysis of sediment samples taken in this feasibility study can be used to focus the sample parameters for future samples. Based on the results of the six samples collected for this study, all future samples taken during final design should be analyzed for arsenic and mercury, while a smaller percentage of those samples (perhaps 25%) should be sampled for other parameters. Sampling for volatile organics can be minimized based on the feasibility study findings. This approach would be implemented as a cost savings measure since the overall chemical constituents within the sediments are generally understood.

# Section 5

# Hydrologic and Hydraulic Analysis

## 5.1 Background

To understand the impacts removing the Patch Pond Dam would have on the Tatnuck Brook and its surrounding areas, a hydrologic and hydraulic analysis was conducted for various recurrence intervals to develop flood profiles for existing and proposed conditions.

## 5.2 Model Approach

To evaluate the hydraulic impact of the proposed dam removal, a steady flow hydraulic model of the existing conditions and proposed removal of the Patch Pond Dam was constructed. Hydraulic modeling was performed using The Hydraulic Engineering Centers River Analysis System (HEC-RAS) version 4.1.0 published by the US Army Corps of Engineers (USACE) (2010). The HEC-RAS model was built in the HEC-GeoRAS environment, which integrates geospatial elevation data and facilitates the flood inundation mapping presented at the end of this section.

Peak flood flows for the hydraulic model were developed using a rainfall-runoff methodology. An existing runoff model was updated and run using the U.S. Army Corps of Engineers' Hydraulic Engineering Centers Hydraulic Modeling System (HEC-HMS). HEC-HMS is a computer-aided design program that combines meteorological data with standard hydrologic calculations to assess precipitation-runoff relationships. The meteorological data in this study was based on the extreme precipitation estimates from the Northeast Regional Climate Center (NRCC). The HEC-HMS model was also used to generate a historic 20-year long simulation and a short term storm simulation used in the sediment analysis presented in Section 6.

## 5.3 Model Development

From the best available data, a HEC-RAS model was built to simulate the hydraulic profiles of the existing conditions and the proposed removal conditions around the Patch Pond immediately upstream and downstream of the dam. A HEC-HMS model was developed for the hydrologic analysis and was based on an already existing model. Further detail such as updated basin characteristics was incorporated into the existing HEC-HMS model in the study area upstream and downstream of the Patch Pond Dam.

### 5.3.1 Data Sources

Data was provided from several sources to build the geometry and other parameters of the hydraulic model.

- Previous HEC-HMS and HEC-RAS models from the Emergency Action Plan (EAP) for the Coes Reservoir published by Weston & Sampson (2007) for the City of Worcester.

- LiDAR with 8-foot-square cells from the Blackstone River Valley (2005) coverage of the entire Patch Pond area including the downstream reach to Coes Reservoir and upstream reach to Cook Pond.
- Previous hydraulic investigation, including runoff model and hydraulic/hydrologic analysis, at Patch Pond conducted by Metcalf & Eddy (1990).
- Field survey of the project area conducted on May 2, 2014 by Surveying and Mapping Consultants (SMC) provided bathymetric elevations within the Patch Pond, elevations and dimensions of the Patch Pond Dam, and several cross sections upstream of the dam spillway in Patch Pond.
- Daily rainfall record at Worcester Regional Airport (COOP ID 72510, USW 94745) from 1948 to 2014.
- Field sediment samples taken by CDM Smith on April 24, 2014 at six locations provided grain size characteristics of the sediment in Patch Pond, and an estimate of depth to native soil at each location in the pond.
- FEMA's Flood Insurance Study in Worcester County, MA (2010).
- Aerial photography.

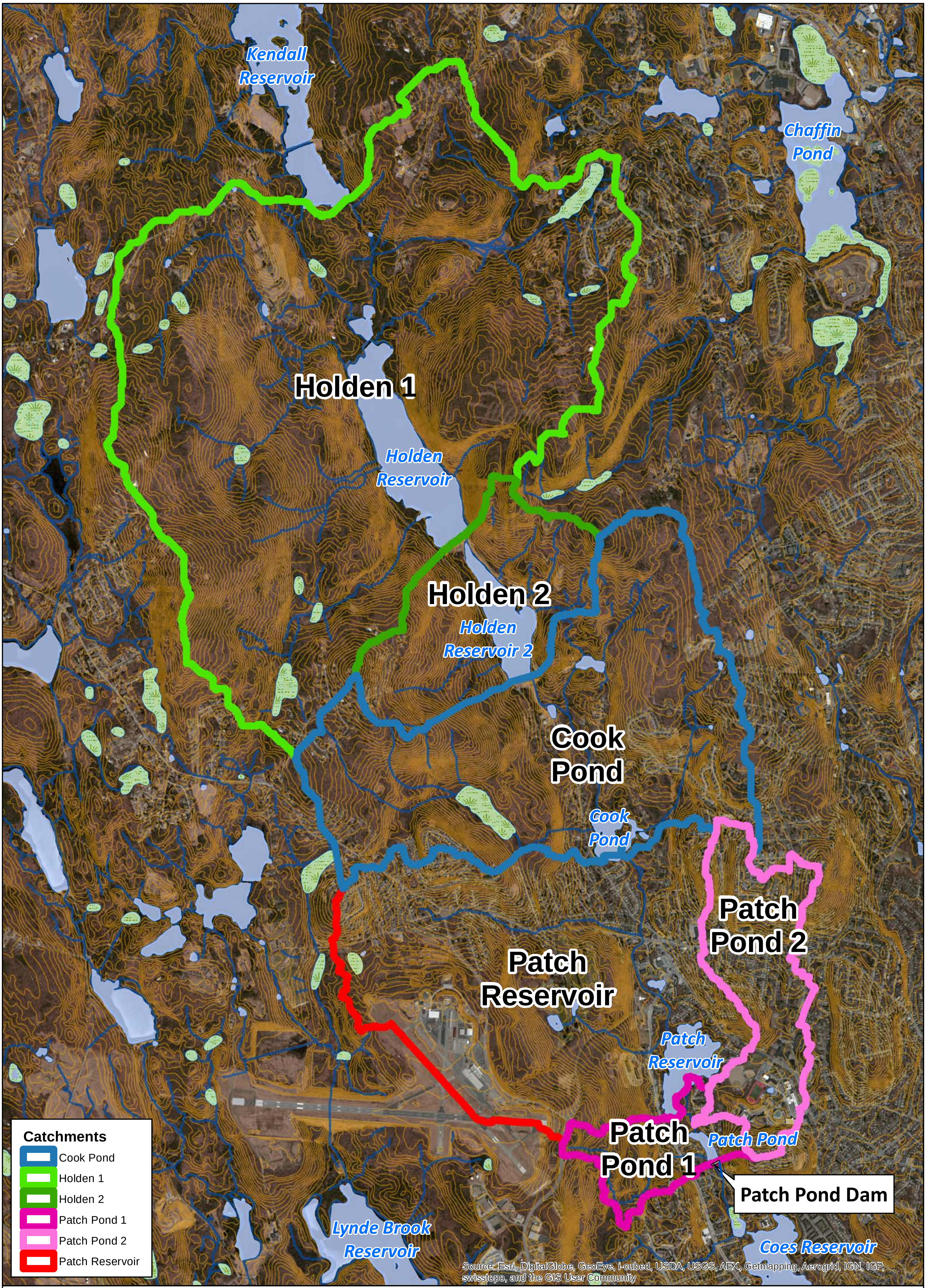
## 5.3.2 Hydrology and Peak Flow Rate

A hydrologic analysis was performed to determine: (1) the extreme flood flows at the Patch Pond Dam, (2) the median flows at Patch Pond, and (3) a 20-year flow time series of flows at Patch Pond representing the long-term basin statistics. The flows generated were used as input into the hydraulic model for determining flood profiles in Section 5.4.

### 5.3.2.1 Existing Model and Validation

In 2007, Weston & Sampson Engineers developed a HEC-HMS runoff model of the reservoir system upstream and downstream of the Patch Pond Dam in support of an emergency action plan for the Coes Reservoir, also owned and operated by the City of Worcester (Weston and Sampson, 2007). The existing model extends from the Holden Reservoirs, which are upstream of Patch Pond to the Coes Reservoir, which is downstream of the Patch Pond Dam. The Patch Pond Dam was not explicitly included in the Weston and Sampson model. In this study, CDM Smith used only the catchment properties for the Holden #1, Holden #2 and Cook Pond Reservoirs. Figure 5-1 shows the basins that were included in the final HMS model developed by CDM Smith, including the three from the existing model. CDM Smith also used the stage-storage and stage-discharge relationships from the existing model for the model reservoirs.

The basin delineations in the existing model were verified using another previous hydraulic investigative study, where the watershed characteristics were developed using the USGS Topographic Map for Worcester North. The total tributary drainage area consists of 9.9 square miles, comparable to the existing model which has a total area of 9.74 square miles (Metcalf & Eddy, 1990).




5/14/2014

Water
Contours
Dam
SURFACE WATER
WETLAND

CDM Smith

Worcester, Massachusetts
Patch Pond Dam Removal Feasibility Study

**Figure 5-1**
**Patch Pond Watershed**

N

0 750 1,500 3,000 Feet

SHEETSJA \\dacgis02\projects\Worcester\PatchPond_Dam_Removal\MXD\Derek\PatchPond_Watershed_11x17.mxd 5/14/2014

Metcalf & Eddy established Curve Number (CN) values using the methodology described in the National Engineer's Handbook (Mockus, 1972) and represent the area-weighted averages for each area of homogenous soil type and land use. These CN values were slightly higher but still similar to those of Weston & Sampson's. Basin lags were also verified by the 1990 Metcalf & Eddy study.

#### 5.3.2.2 Basin and Reservoir Characteristics

There are six sub-basins in the HEC-HMS runoff model developed for this study, including the three adapted from the existing model. The modeled basins are shown in Figure 5-1.

Additional detail was added to the existing model upstream of the Patch Pond Dam. The ArcHydro extension for ArcGIS 10.1 was used to delineate the catchments of the Patch Reservoir and two Patch Pond sub-basins using the Blackstone River Valley LiDAR terrain.

Rainfall losses for the three new sub-basins were calculated using the NRCS runoff curve number (CN) approach (USDA, 2004). The CN of an area is a function of the property of the soils and the land use. Geospatial soils data for the watershed was downloaded from the Web Soil Survey database maintained by NRCS (WSS, 2014). Land use data was classified to the cover type categories in the curve number tables in TR-55 (USDA, 1986).

The basin lag and time of concentration were calculated for each new sub-basin using the velocity method as described by the NRCS (USDA, 2010). The total Time of Concentration for each sub-basin is the sum of the travel times associated with sheet flow and shallow concentrated flow. The ArcHydro GIS extension was used to determine the longest path of flow for each catchment. The Lag Time used to define the unit hydrograph response for each sub-basin was assumed to be 60% of the Time of Concentration based on Equation 15-3 in the National Engineering Handbook (USDA, 2010). The Lag Time for each sub-basin was input to the HEC-HMS model. The runoff characteristics and rainfall losses used in the model are listed below in **Table 5-1**.

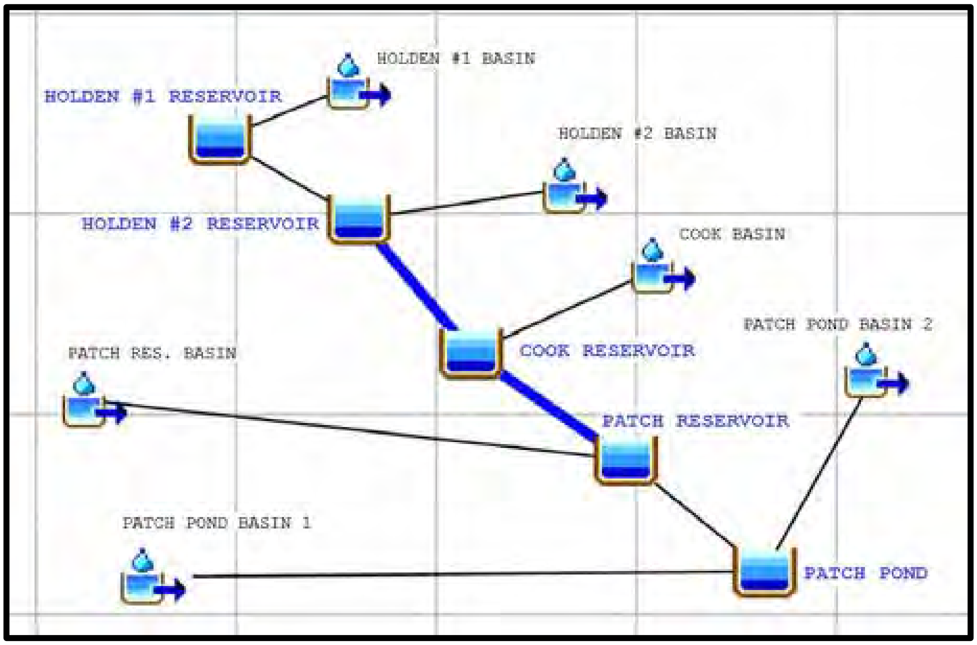
**Table 5-1**
**Basin Runoff Characteristics**

| Drainage Basin | Area ($mi^2$) | Runoff (CN) | Basin Lag (min) |
|---|---|---|---|
| Holden 1[1] | 4.52 | 64.0 | 68.1 |
| Holden 2[1] | 0.74 | 64.0 | 26.8 |
| Cook Pond[1] | 1.98 | 65.0 | 54.8 |
| Patch Reservoir[2] | 2.00 | 75.9 | 32.7 |
| Patch Pond 1[2] | 0.25 | 74.3 | 15.4 |
| Patch Pond 2[2] | 0.54 | 75.8 | 26.1 |

[1]Basin characteristics validated and used from existing model (2007)
[2]Basin characteristics developed by CDM Smith for the purpose of this analysis

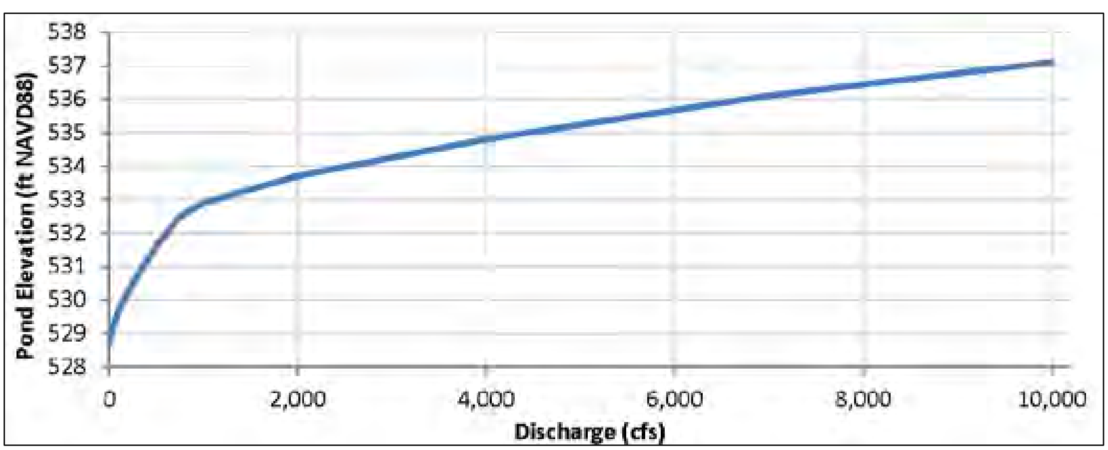
Figure 5-2 shows a schematic of the HEC-HMS model. There are five reservoirs and six defined watersheds tributary to those reservoirs in the HEC-HMS model, each representing a different pond in the Patch Pond watershed. The stage-storage and stage-discharge (rating curve) relationships for the Holden #1 Reservoir, Holden #2 Reservoir, Cook Reservoir and Patch Reservoir were taken directly from the existing Weston and Sampson model.

**Figure 5-2**
**Schematic of HEC-HMS Runoff Model**




The stage-storage curve for the Patch Pond was generated from the available LiDAR for the pond banks and the SMC 2014 bathymetric survey. The stage-discharge curve for the Patch Pond was generated with the HEC-RAS hydraulic model of the Patch Pond Dam based on the 2014 survey of the dam and embankments. The rating curve is shown in Figure 5-3.

**Figure 5-3**
**Rating Curve for Patch Pond Dam**



#### 5.3.2.3 Rainfall

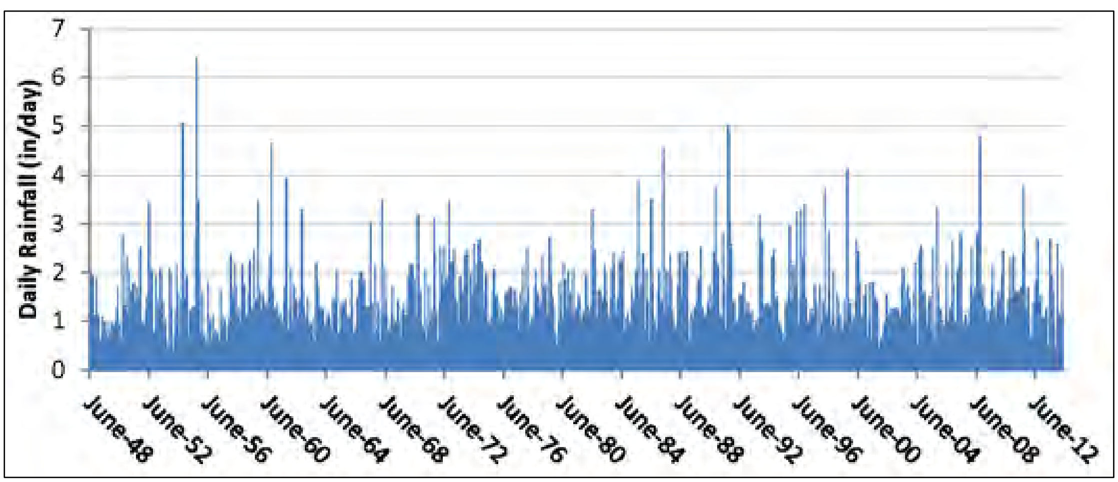
The NRCC at Cornell University maintains an online atlas that provides extreme precipitation estimates that include data from precipitation gages all over New England over the last fifty years (NRCC, 2014). Instead of the SCS storm events, the NRCC estimates are used in this model as they are the best and longest available representation of extreme precipitation statistics for the Northeast region. The 15-min, 30-min, 1-hr, and 24-hr rainfall depths of the 1-, 10-, 50-, 100-, 200-, and 500-year recurrence intervals are shown below in Table 5-2. Synthetic hyetographs of each recurrence event's 24-hour precipitation storm were generated in 15-min intervals as input to the runoff model. The 24-hour storm was selected because the time of concentration of the system including the attenuation from the Patch Reservoir upstream does not exceed 24-hours.

**Table 5-2**
**NRCC Extreme Precipitation Estimates**

| Recurrence Interval | 15 min depth (inches) | 30 min depth (inches) | 1 hr depth (inches) | 24 hr depth (inches) |
|---|---|---|---|---|
| 1-year | 0.52 | 0.69 | 0.74 | 2.6 |
| 10-year | 0.9 | 1.2 | 1.4 | 4.9 |
| 50-year | 1.2 | 1.7 | 2.0 | 7.4 |
| 100-year | 1.4 | 2.0 | 2.4 | 8.8 |
| 200-year | 1.6 | 2.3 | 2.8 | 10.5 |
| 500-year | 1.9 | 2.8 | 3.5 | 13.3 |

In order to generate a time series of flows through the Patch Pond, representing the long-term hydrologic condition, the full daily record of rainfall was obtained for the area from the Worcester Regional Airport (COOP ID 72510, USW 94745) from 1948 to 2014. Figure 5-4 shows the daily rainfall record.

**Figure 5-4**
**Daily Rainfall Record at Worcester Regional Airport**



#### 5.3.2.4 Peak Flood Flows

The first set of design flows used in the existing conditions model were simulated using the 1-, 10-, 50-, 100-, 200-, and 500-year recurrence interval precipitation estimates. The resulting recurrence interval peak discharge flows at the Patch Pond Dam are shown in Table 5-3.

**Table 5-3**
**Design Discharge at Patch Pond Dam**

| Design Condition | Discharge |
|---|---|
| Annual Median Daily Flow (P50) | 9.7 cfs |
| 1-year Peak Discharge | 385 cfs |
| 10-year Peak Discharge | 1,240 cfs |
| 50-year Peak Discharge | 2,460 cfs |
| 100-year Peak Discharge | 3,280 cfs |
| 500-year Peak Discharge | 7,279 cfs |

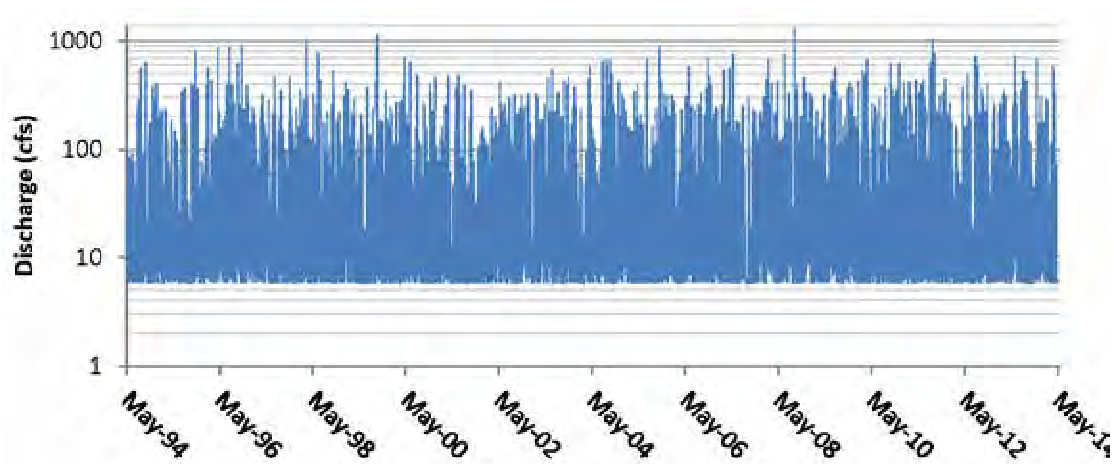
Note: the Annual Median Daily Flow (p50) is the Average Daily Flow

The mean daily flow (P50), which is equaled or exceeded 50-percent of the time, was also included in the simulation to mimic a low flow scenario. The P50 statistic was calculated based on regression equations developed for estimating low-flow statistics for Massachusetts streams (Ries and Friesz, 2007).

#### 5.3.2.5 Long Term Simulation

To represent the long-term hydrologic inflows to the Patch Pond, a 20-year simulation of the watershed was run using the HEC-HMS model with the rainfall record at the Worcester Regional Airport from May 1994 to May 2014. The model was run on a 3-hour time step. The simulated inflows to Patch Pond are shown in Figure 5-5.

**Figure 5-5**
**Patch Pond Inflows from Long Term Simulation**



## 5.3.3 Hydraulic Model

A steady-flow hydraulic model of the existing conditions and proposed dam removal was built in HEC-RAS version 4.1.0. This hydraulic model was adapted from the 2007 Emergency Action Plan (EAP) Dam Break Analysis Model (discussed earlier) developed by Weston & Sampson for the Coes Reservoir, which also includes the Patch Pond Reservoir.

The geometry was rebuilt and altered from the Weston & Sampson model in HEC-GeoRAS version 10 for ArcGIS 10. Details of the Patch Pond Dam physical geometry were incorporated into the model using the bathymetric data collected in May 2014 field survey by Surveying and Mapping Consultants (SMC). The model centerline extends from downstream of the Patch Reservoir Dam, through the Patch Pond Dam, over the Dam, and down to Coes Reservoir as shown in Figure 5-6. The total centerline length is 4,210 feet. The cross sections and river centerline objects are geo-referenced in the Massachusetts State Plan Coordinate System of NAD83 and vertically on NAVD88.

### 5.3.3.1 Model Cross Sections

The cross sections were replicated and altered from the existing model, which also included a bridge at the intersection of June Street. One additional cross-section was added upstream of the Patch Pond Dam within the pool, and another was moved further upstream to capture additional bathymetric detail.

The current HEC- RAS model includes 29 cross sections spaced an average of 150 feet apart with a maximum distance of 510 feet. All elevations were replaced using the Blackstone River Valley 8-foot cell LiDAR data (2005). Within the normal pool of the Patch Pond Dam, the eight cross sections upstream and one on the downstream face of the Patch Pond Dam have been further updated using the bathymetric field survey by SMC (May 2014). The channel bottom elevations have been further verified by field survey conducted by CDM Smith (April 2014).

### 5.3.3.2 Model Boundary Conditions

The downstream boundary condition of the hydraulic model is located at the Coes Reservoir. The normal depth is set at 0.008 given the gentle slope at this point. The model is run in a subcritical flow regime and does not have an upstream boundary condition.

### 5.3.3.3 Hydraulic Parameters

Manning’s roughness was used for energy loss calculations. In each cross section, roughness coefficients were assigned to the main channel defined by the bank stations selected from cross section geometry and the left and right banks. Manning’s roughness coefficient for the main channel is 0.065 based on the associated coefficients described FEMA’s Flood Insurance Study (FIS) of the area. The overbank Manning’s coefficients were set at n = 0.1.


6/16/2014

- HEC-RAS Model Centerline
- HEC-RAS Model Cross Sections
- Contours
- Dam
- SURFACE WATER
- WETLAND

CDM Smith

**Worcester, Massachusetts**
**Patch Pond Dam Removal Feasibility Study**

## Figure 5-6
## HEC-RAS Model Elements

0 125 250 500 Feet

N

SHEETSJA \\dacgis02\projects\Worcester\PatchPond_Dam_Removal\MXD\Derek\PatchPond_HEC-RAS_11x17.mxd 6/16/2014

#### 5.3.3.4 Proposed Removal

The proposed dam removal calls for the restoration of the natural streambed. The entire vertical extent of the dam will be completely removed in order to meet the criteria for a Streamflow restoration project under the proposed changes to the Wetlands Protection Act (see Section 8). The extent of the dam east of the centerline will also be removed, but the rubble will be piled up and left alone on the on the east bank of where the dam existed. This rubble field will extend downstream along the east bank of the dam and will help to ensure that the natural streambed (on the west side) is restored while channeling the water to its intended location. The removal of the stream on the east side created as a result of the breach on the east side of the dam will enhance the fishery resource by creating a single, deeper flow channel, which is beneficial to migrating fish during low flow periods. The impounded sediment upstream of the dam will either be physically removed or stabilized (further discussion of sediment management is presented in Section 7).

A second model geometry, (in addition to existing conditions) was built to represent these post-removal conditions with the assumption that all of the existing sediment is completely removed. This creates a worst case scenario (in terms of flooding) before dam removal and a best case scenario after dam removal.

For the post removal scenario, the dam was removed and rubble from the structure was piled on the east side of the streambed. The elevations of the native soils below the sediment were estimated from the six soil samples taken in the vicinity of the Patch Pond Dam in April 2014 by CDM Smith.

## 5.4 Hydraulic Impact of Dam Removal

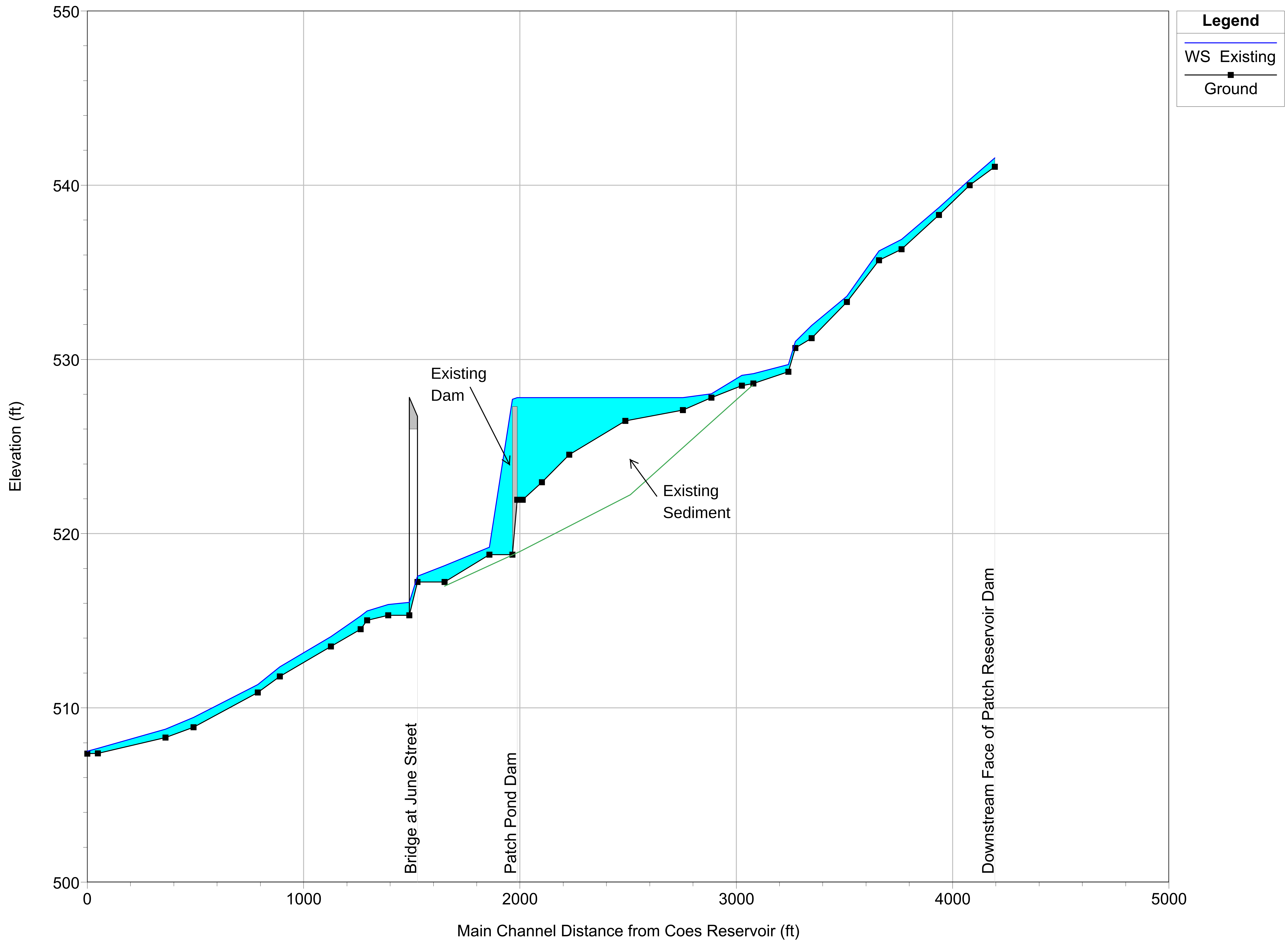
The HEC-RAS hydraulic model was run under two conditions representing the existing Patch Pond Dam geometry and the proposal removal of the dam. The design discharges listed in Table 5-3 were run as steady flow regimes in the HEC-RAS model to produce hydraulic profiles for each scenario.

### 5.4.1 Hydraulics of Existing Conditions

The hydraulic profiles of the existing conditions for the median daily flow (P50) and 100-year flood are shown in Figures 5-7 and 5-8 respectively. The existing conditions model includes the bottom elevation associated with the existing sediment that has collected behind the dam. Figures 5-7 and 5-8 show the bottom elevation of the native soils that were found during the April 2014 field investigation conducted by CDM Smith.

### 5.4.2 Hydraulics of Proposed Removal

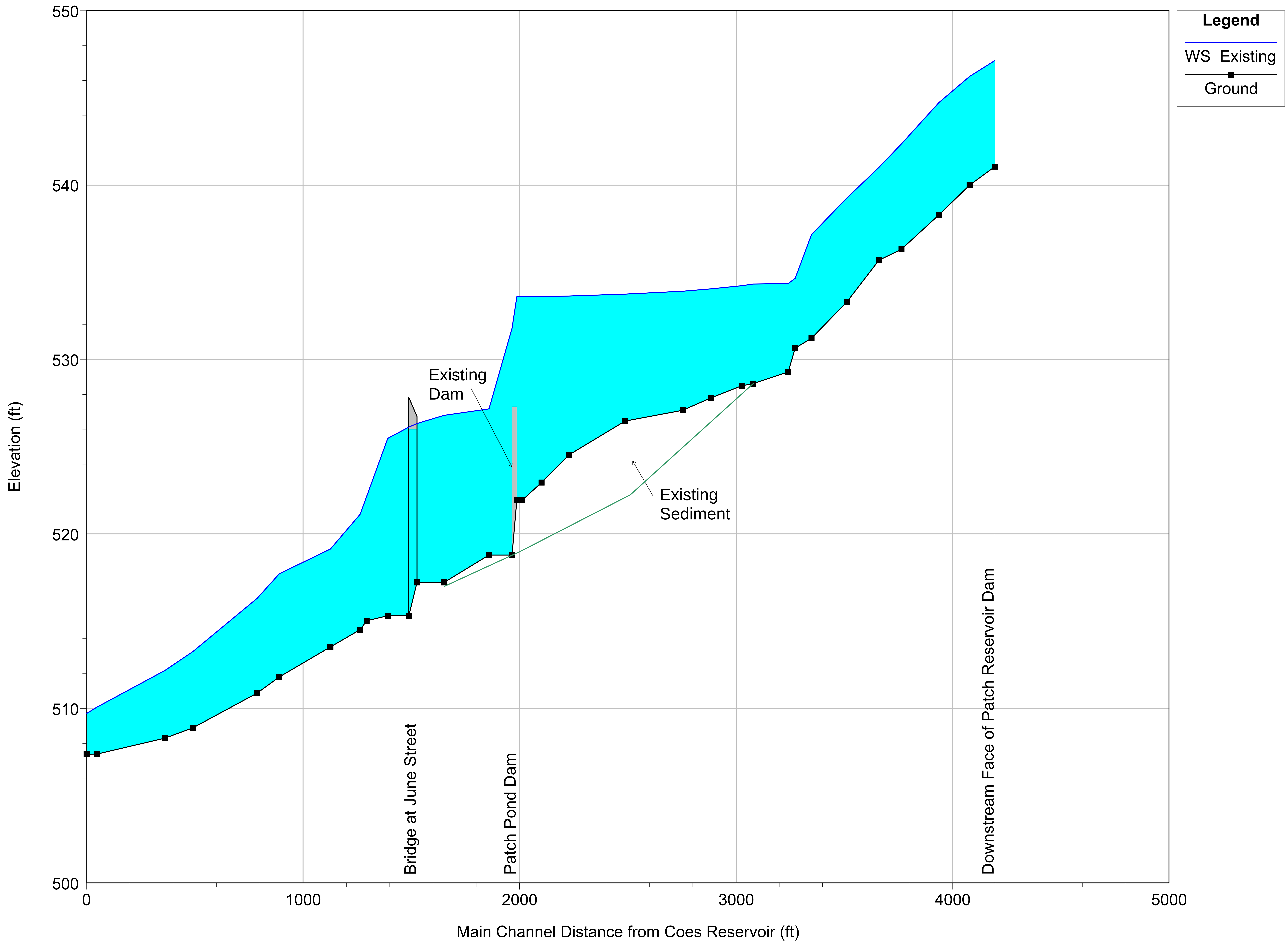
The hydraulic profiles of the Patch Pond area after removal of the Patch Pond Dam for the median daily flow and 100-year flood are shown in Figures 5-9 and 5-10, respectively. In each proposed conditions profile, the existing profile is also shown, in red, for comparison. The hydraulic profile is only affected in the immediate vicinity of the Patch Pond Dam. Based on Figures 5-9 and 5-10, the water surface elevations in the immediate upstream vicinity are lowered about 7 ft. after the removal of the Patch Pond Dam.




Date: May 2014

**Worcester, Massachusetts**
**Patch Pond Dam Removal Feasibility Study**

**Figure 5-7**
**Existing Conditions of Patch Pond Dam**
**Water Surface Profiles - Average Daily Flow**

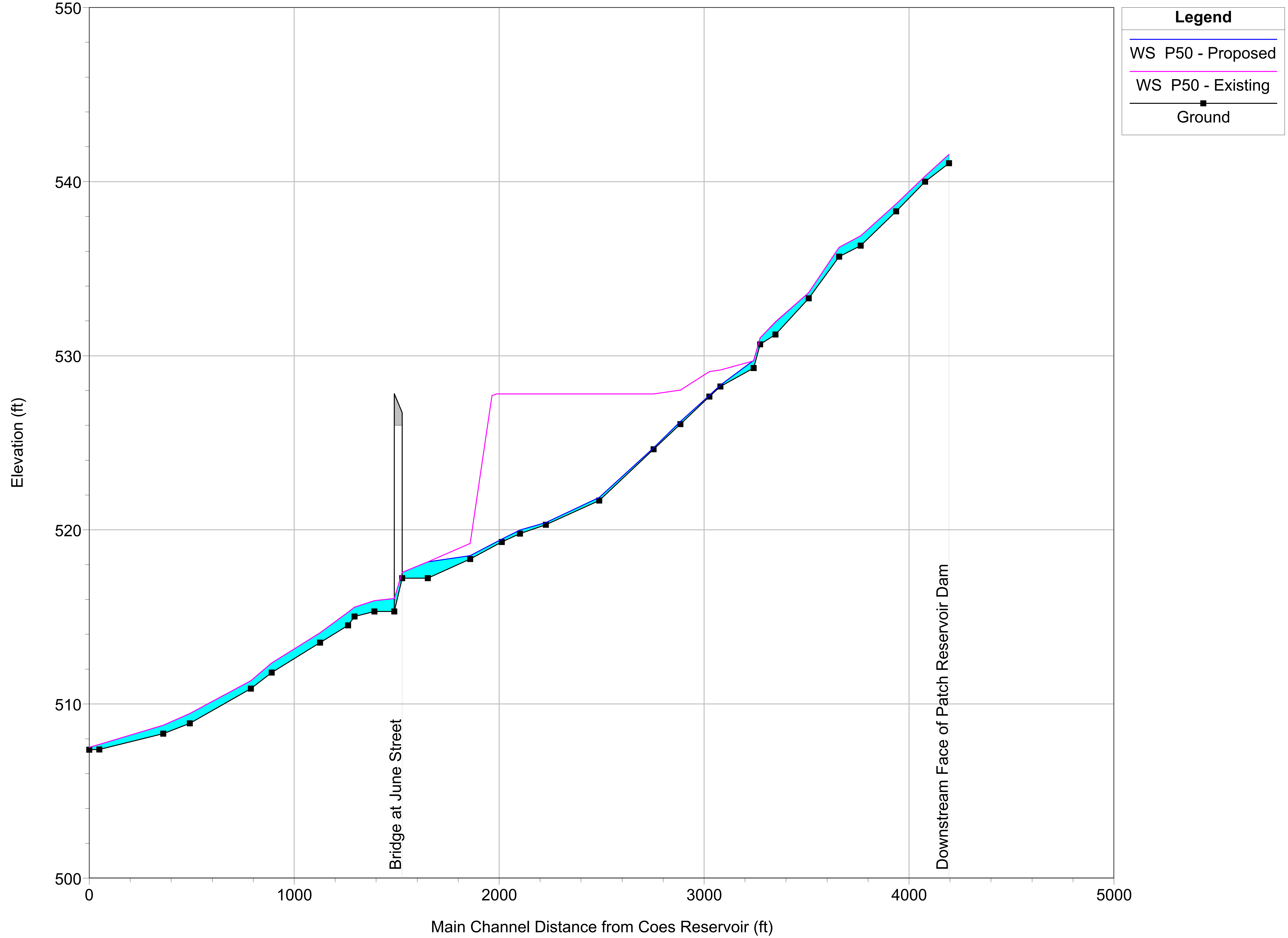



Date: May 2014

CDM Smith

**Worcester, Massachusetts**
**Patch Pond Dam Removal Feasibility Study**

**Figure 5-8**
**Existing Conditions of Patch Pond Dam**
**Water Surface Profiles - 100-year Flood**

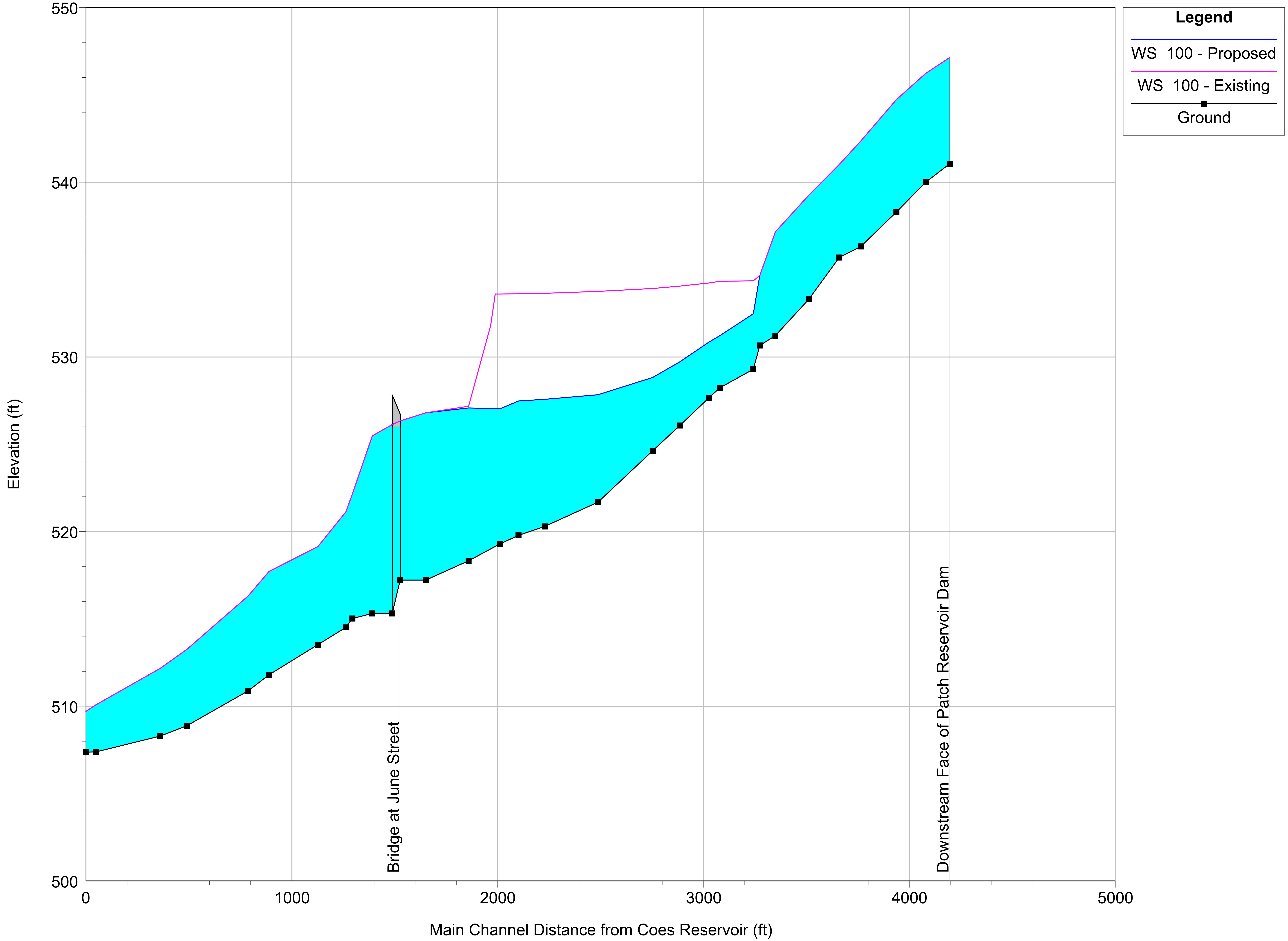



Date: May 2014

**Worcester, Massachusetts**
**Patch Pond Dam Removal Feasibility Study**

**Figure 5-9**
**Existing Conditions and Proposed Removal of Patch Pond Dam Water Surface Profiles - Average Daily Flow**

CDM Smith




Date: May 2014

## Worcester, Massachusetts
## Patch Pond Dam Removal Feasibility Study

**Figure 5-10**
**Existing Conditions and Proposed Removal of Patch Pond Dam Water Surface Profiles - 100-year Flood**

The removal of the dam decreases the peak flood stage in the immediate vicinity and 1,000 feet upstream of the Patch Pond Dam. The impact on downstream peak flood discharge is thought be minimal since available storage behind the existing dam is negligible when compared to the overall watershed.

In the Patch Pond area behind the existing dam, the velocities of the proposed dam removal model scenario are substantially greater after the removal of the dam. This because the flow will be directed to a flow channel similar to the existing Tatnuck Brook after the dam is removed. **Table 5-4** shows the change in velocities at the cross section 25 feet upstream of the existing dam.

**Table 5-4**
**Channel Velocity at RS. 2022.5 Upstream of Existing Dam**

| Model Scenario | Channel Velocity | |
|---|---|---|
| | Median Daily Flow (P50) | 100-yr Flood |
| Existing Conditions | 0.01 fps | 1.3 fps |
| Proposed Dam Removal | 1.3 fps | 4.8 fps |

### 5.4.3 Summary of Impact

The removal of the Patch Pond Dam will have little or no effect on the flood stage from the existing conditions outside the vicinity of the existing dam. In the area immediately upstream of the Patch Pond Dam, removal will increase the channel velocities and lower the peak flood stage as shown in Figure 5-11.

## 5.5 References


Federal Emergency Management Agency (2010) “Flood Insurance Study for Middlesex County Massachusetts” Study Number 25017CV001A – 25017CV008A. Effective: June, 4, 2010.

Metcalf & Eddy (1990). “Letter Report on Hydraulic Investigations at Patch Pond.” Department of Public Works. City of Worcester, MA.

Mockus, Victor (1972). “National Engineers Handbook Section 4: Hydrology”

Ries III, K.G., Atkins, J.B., Hummel, P.R., Gray, M., Dusenbury, R., Jennings, M.E., Kirby, W.H., Riggs, H.C., Sauer, V.B., Thomas, W.O. (2007) “The National Streamflow Statistics Program: A Computer Program for Estimating Streamflow Statistics at Ungaged Sites” Techniques and Methods 4-A6, U.S. Geological Survey, U.S. Department of Interior, Reston, VA, 2007.

Ries III, K.G., and Friesz, P.J. (2000) “Methods for Estimating Low-Flow Statistics for Massachusetts Streams” Water Resources Investigations Report 00-4135, U.S. Geological Survey, U.S. Department of Interior, 2000.

U.S. Army Corps of Engineers (2010) “HEC-RAS River Analysis System – Version 4.1.0”, Hydrologic Engineering Center, US Army Corps of Engineers, Davis CA.


7/1/2014

**Legend**

- Water
- Dam
- 100 Year Flood (Without Dam)
- 100 Year Flood

CDM Smith

# Worcester, Massachusetts
# Patch Pond Dam Removal Feasibility Study

**Figure 5-11**
**Patch Pond 100 Year Flood Analysis**

N

0 100 200 400 Feet

U.S. Department of Agriculture (1986) "Urban Hydrology for Small Watersheds" Technical Release 55, Soil Conservation Service, Washington DC, 1986.

U.S. Department of Agriculture (2004) "Estimation of Direct Runoff from Storm Rainfall" National Engineering Handbook, Part 630 Hydrology: Chapter 10, Natural Resources Conservation Service, Washington DC, 2004.

U.S. Department of Agriculture (2010) "Time of Concentration" National Engineering Handbook, Part 630 Hydrology: Chapter 15, Natural Resources Conservation Service, Washington DC, 2010.

U.S. Department of Agriculture (2007) "Hydrographs" National Engineering Handbook, Part 630 Hydrology: Chapter 16, Natural Resources Conservation Service, Washington DC, 2007.

Wandle, W.S. (1983) "Estimating peak discharges of small rural streams in Massachusetts" Water Supply Paper 2214, U.S. Geological Survey, U.S. Department of Interior, 1983.

Web Soil Survey (2014). "Custom Soil Resource Report for Worcester County, MA." Natural Resources Conservation Service. United States Department of Agriculture. http://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx

Weston & Sampson Engineers, Inc. (2007). "Emergency Action Plan (EAP) for Coes Reservoir Dam." City of Worcester. September 2007.