Project Number: PPM-1110

Edwards Pond Sediment Study

A Major Qualifying Project Report
Submitted to the Faculty
of the
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfillment of the requirements for the
Degree of Bachelor of Science

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Abstract

This project investigates possible actions for remediation of arsenic contaminated sediment if the Edwards Pond Dam in West Boylston, MA is removed. It focuses on the remediation options available and regulations governing plausible options. Background on arsenic contaminated sediments and removal and a review of applicable permitting for remediation work are included. Recommendations are provided for the appropriate steps that can be taken to minimize the impacts of contaminated sediments upon removal of the Edwards Pond Dam.

Acknowledgements

I would like to thank my liaison to the Department of Conservation Resources, Pat Austin, for her time and effort to help guide this project. I would also like to thank my adviser, Paul Mathisen, for his support and insight throughout the duration of this project.

Authorship

This Major Qualifying Project (MQP) is the second of two MQP reports addressing a proposal to remove Edwards Pond Dam in West Boylston, MA. The first of the two MQP reports, was completed by Kevin Curley and was entitled "Edwards Pond Dam Removal Study," (PPM-0905). That previous project concentrated on the hydrologic aspects of dam removal. The focus of this project report is on the considerations related to pond bottom sediments. This MQP report was primarily written by Ross Hudon with some content from the previous MQP submitted by Kevin Curley. The sections entitled "Geographic Description of Edwards Pond" and "Visual Inspection" were completed jointly by Ross Hudon and Kevin Curley in the early stages of the project, and were included as part of the previous MQP ("Edwards Pond Dam Removal Study"). The "Topography" section was completed by Kevin Curley as part of the previous dam removal MQP. Remaining sections of this report were completed solely by Ross Hudon for the "Edwards Pond Sediment Study."

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Capstone Design

This report summarizes the results of a Major Qualifying Project, a student project completed and submitted to the faculty of Worcester Polytechnic Institute as evidence of a degree requirement. The project includes a capstone design component which is the evaluation of alternatives and recommendation for a solution to a problem with realistic constraints. The capstone design for this project involved developing a plan for managing the contaminated sediments located in the pond behind the Edwards Pond Dam. This design included an evaluation of alternative options (including capping, disposal and other alternatives), recommendation of a preferred management alternative, and discussion of requirements regarding permitting and implementation. The work required research on the topography of the area, the health and safety effects of arsenic, the remediation methods for contaminated soils, and permitting and regulations regarding dredging and dredge material disposal.

The design involved consideration of environmental impacts, health and safety, economic constraints, social and political aspects, and sustainability. Safety risks to human health and to the environment were top concerns that required consideration and these issues provided opportunities to consider ethics as well. Economics is an important consideration since the remediation of the sediment and removal of the dam would have significant immediate costs. However the costs to repair and maintain the dam to contain the contaminated sediments would be greater over time. Therefore it was found that it would be more economically and environmentally sustainable to reduce arsenic levels below the MCL and return the area to its natural state. Analysis of various remediation methods was conducted and a recommendation provided based on effectiveness, feasibility, and cost. There are few social impacts of removing the dam and treating the contaminated sediments as the area is not used for recreation such as boating or fishing and the only public use for the area possibly includes some hiking. Since the area will be restored to its natural state, the benefit to public use will increase. Social aspects include consideration of policy related to sediment removal. Political concerns were not a major constraint as the site is owned solely by the Department of Conservation Resources.

1.0 Introduction

The effects of sediment transport and sediment quality are a primary concern when removing a dam. Years of sediment deposition often result in significant volumes of bottom sediment that accumulate behind the dam. If a dam is removed, this sediment could be eroded and lead to significant loads of sediment being moved downstream. This could be a problem if the sediment is contaminated. Sediment samples must be analyzed to determine the presence and extent of any contamination. If sediment is found to contain a contaminant in concentrations exceeding acceptable limits, a remediation plan must be devised and enacted before the dam is removed or contaminated, possibly hazardous, material may be transported downstream.

This project focuses on the sediment in the Edwards Pond Dam in West Boylston, Massachusetts. Edwards Pond is believed to be an old farming pond dammed to supply water for irrigation and for livestock. The farms of the area are long gone and this dam now serves no practical or recreational purpose. The pond and land surrounding it is now the property of the Department of Conservation and Resources (DCR) and the responsibility falls to them to confront the problem. As the pond and the dam no longer serve any purpose, DCR is exploring the option of removing the small, earthen dam.

Analyses of core samples of the sediment behind the dam have revealed that high concentrations of arsenic exist. These concentrations are not currently impacting areas downstream of the pond. Nevertheless, a plan to address the contaminated sediment must be developed before the removal of the dam can proceed. The pond eventually empties into Wachusett reservoir, a major supply of drinking water, about a mile downstream. The proposed alternatives are to treat the sediment to reduce arsenic concentrations to a safe level that meets regulations or dredge and dispose of the sediments.

The approach followed in this study included background research on arsenic and regulations, characterization of the sediments and conditions within the pond, identification and evaluations of alternatives, development of a recommendation, and review of procedures necessary for permitting. The background and research on these topics is presented in Chapter 2, the methodology is discussed in Chapter 3, the results are included in Chapter 4, and recommendations are presented in Chapter 5.

2.0 Background

This chapter provides general background information related to the requirements for dam removal, with specific focus on sediments. A general review of the concerns and requirements regarding the fate of arsenic contaminated sediments upon removal of the dam are outlined in this chapter. A geographic overview of Edwards Pond and the surrounding area and specific information on the sediment at Edward's Pond are also reviewed. In addition, general background of the effects of arsenic on human health, the processes in which sediments can become contaminated with arsenic, and methods of remediation that have been developed are discussed. Furthermore, an investigation and description of the permitting process concerning dredging and the disposal of dredged material are presented.

2.1 Sediment Contamination at Edwards Pond

The Edwards Pond Dam has been found to be in need of repair and the Department of Conservation and Resources (DCR) is investigating options to address the problem. Breaching the dam and restoring the stream is one of the primary options being explored. Before the dam can be removed however, the impacts of sediment transport downstream must be considered. Analysis provided by DCR estimates that about 200 cubic yards of sediment may be transported downstream if the dam is breached and that the majority of this sediment would settle within a tenth of a mile downstream.

In addition to sediment transport, the quality of the sediment must be determined before it could be released downstream. Four sediment samples were taken for analysis in the fall of 2010. Two samples were taken in the pond, behind the dam, and one sample taken upstream and one downstream. Table 1 (provided by DCR) lists the concentrations in PPM of several contaminants found in the sediment. Nickel concentrations in the sediment behind the dam are above the standard set by Massachusetts Contingency Plan for category 1 Soils and Ground Water (MCP S1 & GW1). The presence of nickel in waterways and sediments is not a major concern as there are no serious health risks. The few instances of adverse health effects were due to a nickel allergy or consumption of extreme doses. Of primary concern is the high concentration of arsenic. The arsenic levels upstream and downstream are slightly above the benchmark of 20PPM. The sediment samples from behind the dam are nearly four times the acceptable concentration.

Table 1 - Sediment Contaminant Concentrations (PPM)

Compound	Impoundment 1	Impoundment 2	Impoundment Average	Downstream	Upstream	MCP S1& GW1
Arsenic	71.8	79.4	75.6	24.3	21.6	20.0
Cadmium	0.742	0.839	0.7905	0.037	0.052	2.0
Chromium	24.3	26	25.15	9.77	26.15	30
Copper	14.5	17	15.75	3.19	2.49	NC
Lead	48.6	49	48.8	3.95	4.67	300
Mercury	0.148	0.177	0.1625	0.015	0.015	20.0
Nickel	22.4	26.4	24.4	9.46	7.66	20.0

Upon reviewing the sediment analysis results, it became apparent that remediation steps are required to prevent the contamination from spreading if the dam is to be removed.

2.2 Geographic Description of Edwards Pond

Edwards Pond is located at 44°22’19”N and 71°47’59” about one mile west of the Route 12 bridge that crosses the Thomas Basin, a long narrow arm of the Wachusett Reservoir that reaches northwest from the southern end of the Reservoir. It can be found on Malden Street in West Boylston, MA, shown below in Figures 1 & 2 taken from Google Earth.

Figure 1 – Aerial View of Edwards Pond and Thomas Basin

Figure 2 – Aerial View of Wachusett Reservoir

The Wachusett Reservoir watershed is approximately 117 square miles and includes land in 12 different municipalities, all within Worcester County. These include Boylston, Clinton, Holden, Hubbardston, Paxton, Princeton, Rutland, Sterling, West Boylston, Westminster, Leominster and Worcester. The Reservoir was created in 1898 by damming the southern branch of the Nashua River just north of Clinton to flood the Nashua River Valley.

The majority of the Reservoir's waters come from the watershed and are supplied by the Quinapoxet and Stillwater Basins. However, almost 260 million gallons per day is sent about 30 miles by the MDC/DCR from the Quabbin Reservoir east to the Wachusett Reservoir. The Reservoir has approximately 6.2 square miles of surface area with a mean depth of 49', for a holding capacity of about 65 billion gallons. Wachusett Reservoir serves as the final resting place for the water before it is sent to 46 different communities around Boston by the Massachusetts Water Resource Authority (MWRA). Because Malden Brook empties into the Reservoir, the quality of the sediment in Edwards Pond is a very serious concern.

Figures 3, 4 & 5 show Malden Brook as it approaches the culvert that crosses Thomas Street and leads into the Wachusett Reservoir.

Figure 3 – Malden Brook at Wachusett Reservoir Entrance

Figure 4 – Malden Brook culvert entering Wachusett Reservoir

Figure 5 – Malden Brook culvert entering Wachusett Reservoir

2.3 Extent and Health Effects

It is helpful to understand the health and safety risks associated with arsenic exposure to justify the need to spend resources to remediate the area of concern. The discussion in this background section provides a general review of the concerns regarding arsenic. Arsenic in surface and ground water is an increasing concern around the globe. Direct contact with contaminated sediment is less of a concern than arsenic polluted water however the two are closely linked. Polluted surface and ground water is a common means of arsenic consumption. While exposure to or consumption of arsenic by means of contaminated soil is far less likely, it is still a concern especially in recreational areas or places where children may encounter the polluted sediments. In addition to direct exposure, contaminated sediments can play a role transporting arsenic between surface waters or may be a source of groundwater contamination if conditions allow it to dissolve and leach underground.

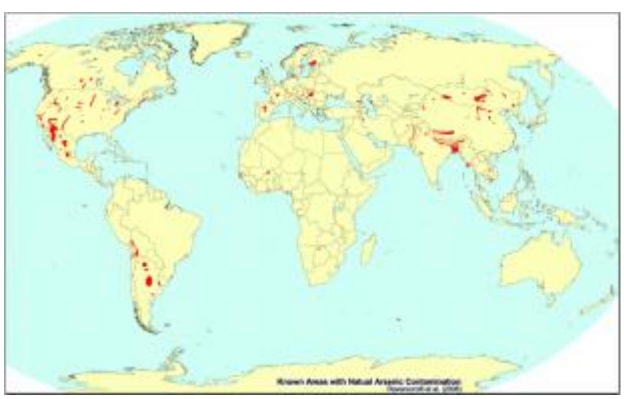

Figure 6 – Naturally occurring arsenic around the world

(**http://www.ucl.ac.uk/lag/**)

Arsenic contaminated water sources are especially abundant in the Indian subcontinent and the south west United States (Figure 1). Arsenic is the third most toxic substance, after lead and mercury, on the US Toxic Substances and Disease Registry (Naidu, 2006). It can be extremely toxic to humans if breathed or consumed. Consumption of water from a contaminated source can cause a wide range of severe symptoms and conditions. Acute exposure to arsenic causes vomiting and diarrhea and can often lead to death. Chronic intake of arsenic can lead to skin pigmentation, circulatory ailments, diabetes, respiratory conditions, cardiovascular and neurological conditions, and several types of cancer. Arsenic is mostly absorbed through the gastrointestinal tract and can spread, via blood, throughout the body for which it has a four day half-life (National Research Council, 1999). The type or specie of arsenic greatly affects the toxicity and therefore the severity of health effects. Acceptable concentrations in soils and water can widely vary as some are based on total arsenic levels while others are based on the concentration and toxicity of individual species. Inorganic species of arsenic are generally considered more toxic than organic forms. (National Research Council, 1999)

Arsenic has long been known to cause serious health risks but there was no set acceptable concentration threshold until fairly recently. As part of the Safe Drinking Water Act (SDWA) of 1976, the EPA set maximum contaminant level (MCL) standards of arsenic and other toxic substances for drinking water to protect public health. The exact effects of consuming arsenic and at what doses were not well understood at the time. Therefore, an interim MCL of 50 micro grams of arsenic per liter was set until further studies and more information became available. (National Research Council, 1999) When revisited in 2001 the MCL for arsenic was lowered to 10 micrograms/L or 10mg/kg in soil (Naidu, 2006).

2.4 Sources of Contamination

A remediated area can soon become polluted again if the source of the contamination is not identified and addressed. Therefore it is crucial to understand and investigate potential sources of pollution. Unlike many other contaminants, the source of arsenic contamination is more often from naturally occurring processes and sources than anthropogenic. Manmade sources of arsenic contamination include mining, smelting, metal refining, pesticides, herbicides, wastewater sludge, and the burning of fossil fuels (most notable coal). Furthermore, some growth promoter foods for poultry and pigs can contain arsenic witch can be concentrated in animal waste. Also, ash from the burning of pressure treated wood can contain a high concentration of arsenic. Especially concerning in some areas is the risk of using contaminated ground water for crop irrigation (Naidu, 2006).

Arsenic is often present in the environment due to naturally occurring sources and processes. The weathering of a parent material (pedogenic processes) containing high concentrations of arsenic is a main source of naturally occurring arsenic. Watersheds that encompass geological strata that are rich in arsenic can accumulate it in bodies of water and sediments in high concentrations. Sedimentary rock, metal ores, coal, and shale can contain arsenic in especially high concentrations as well as igneous rock to a lesser extent. Arsenic can also enter the environment by volcanic emissions. Figure 2 shows the concentrations of naturally occurring arsenic across the U.S. (Naidu, 2006).

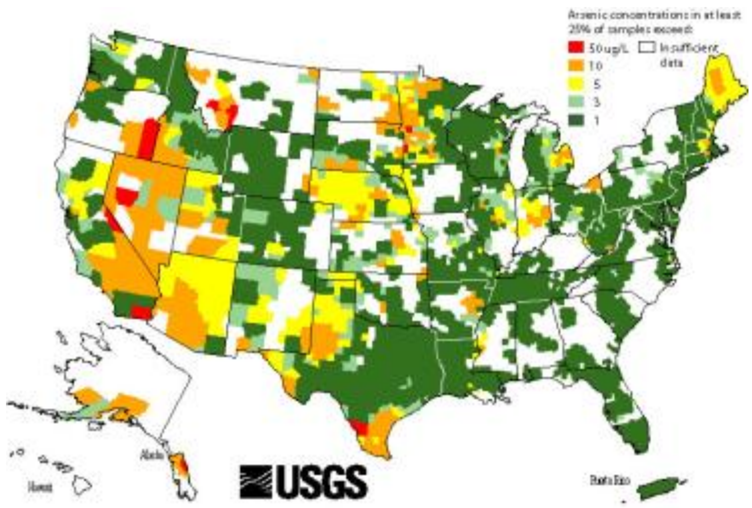

Figure 7 – Naturally occurring arsenic in the U.S.

(**http://arsenicproblem.blogspot.com/**)

Typical arsenic concentrations in water can range from 0.1-80 micrograms/L mostly as inorganic As^3. While average concentrations in soil can be in the range of 5-10 mg/kg mostly as As^5 in water logged soil (Naidu, 2006). The specie of arsenic, its oxidation state, determines its toxicity and other properties such as mobility and bioavailability. As such, there are many proponents of setting individual MCLs for each specie instead of a single MCL of total arsenic as currently defined by the EPA. This would more accurately represent the risk of a contaminated site to human and environmental health and allow more flexibility in remediation options. Higher concentrations of less toxic species could be exempt from high cost, low benefit remediation endeavors while lower concentrations of higher toxicity could be deemed a hazard and require remediation. Opponents of the change insist that the increased complexities that would undoubtedly arise by setting different MCLs and risk levels for each specie would be prohibitive. One such complexity could be the necessity and means of determining what species are present in contaminated water or soil and what percentage are they of the total arsenic load. This could increase the cost and time of remediation projects. While speciation and concentration can be determined through several means such as liquid chromatography, the associated costs and time may make such efforts impractical (Naidu, 2006).

2.5 Remediation Options

Arsenic in groundwater is usually of greater concern than arsenic contaminated soil as the groundwater maybe a drinking source or used for irrigation of crops directly affecting human health. However, contaminated soil can transport or leach into groundwater resulting in the same concerns. Arsenic that does not leach out can be taken up by plants, volatilized by biological processes, or be retained in the soil. As with any remediation, the economic, social, and environmental impacts of any actions taken need to be addressed. The species and related properties of the pollutant, its toxicity, and the source need to be considered when exploring remediation options for arsenic contamination. The feasibility and cost effectiveness of each option are important considerations as well. There are several general strategies of remediation, each with multiple methods:

- destabilize the pollutant to make it soluble and remove it in situ
- stabilize the pollutant in the soil to reduce mobility and bioavailability
- dredge the soil, remove the pollutant, and return the soil
- cap the exposed contaminated soil
- dredge the soil and dispose of it offsite

The effectiveness of individual methods is governed in large part by the sorption potential of the species of concern. Sorption can vary greatly based on PH, redox potential, and ionic strength of the individual species. There are several methods for the removal of arsenic from ground water. It can be removed by the use of adsorbents, such as activated alumina and cerium oxide, and the traditional water treatment processes of coagulation, flocculation, clarification, and filtration. Ion exchange and precipitation using iron treated sand, gel beads, or activated carbon is also used for the removal of arsenic from water sources. If an especially low arsenic concentration needs to be obtained further oxidation can be achieved through the use ultraviolet light (Naidu, 2006).

The remediation of arsenic contaminated soil however can be more complicated. Bioremediation of contaminated soil can be achieved through the use of microbial fauna that transform or degrade the pollutant. Arsenic can be transformed through methylation; a process that makes the pollutant volatile. It can also be degraded by bio oxidation, changing arsenite to arsenate which is less toxic. Chemical fixation with the use of ion-exchange resins such as silica gel, gypsum, clay minerals, green sand, and most commonly ferrous compounds, lowers bioavailability and mobility of arsenic. By increasing the sorption of arsenic to the soil, it is less likely that it will be transported or leach into groundwater and therefore reduce its bioavailability. Arsenic can bioaccumulate in plants as they uptake it from water and soil. Phytoremediation uses certain plants that readily absorb the contaminant in relatively high concentrations. Ferns, for example, can bio accumulate particularly high concentrations of arsenic removing it from the soil and bringing it to the surface. The plants can then be harvested and disposed of. Chemical remediation, or soil washing, removes arsenic by lowering the pH with the use of phosphoric or sulfuric acid, which makes arsenic more soluble. Chelating agents are chemicals that react to form soluble molecules with metal ions, rendering heavy metals inert so they will not react with the soil. Chelating or sequestrating agents can be very expensive however (Naidu, 2006).

Electroremediation is another removal method being explored that applies a direct current through the soil by use of electrodes in the ground. The electric current draws the contaminant ions toward one electrode and therefore concentrates the pollutant so that there is less volume of soil to dredge or treat. Electroremediation works especially well for fine grain, moist soils such as sediment (Naidu, 2006).

Another method of addressing contaminated sediments is to cap the affected soils. This is usually done by applying a thick layer of sand or clay to the area of concern. Capping was mainly used in ocean applications but has become a strategy for restoring river systems recently. Caps are “designed to isolate contaminated sediments from bottom-dwelling organisms and other aquatic organisms and prevent the transport of contaminated sediments in the water body" (USEPA, 2008). The site must be monitored to ensure that the contaminant does not spread over time; this usually includes groundwater monitoring wells. Another concern is the cap material eroding and no longer containing the pollutant. Furthermore, the effects of capping on river fauna and the long term effectiveness to contain a pollutant are still uncertain. (USEPA, 2008) The use of a cap is most beneficial for an area of low velocity flows and where the contaminants will remain stable and undisturbed after capping. Another potential drawback is that the cap material itself could become contaminated through the same process that contaminated the sediment and there would be a greater volume of soil contamination to address. Some caps, known as active caps, have added compounds, such as activated carbon or phosphate additives, to reduce permeability and reduce contaminant migration through sorption and reaction (Schuck, 2010).

Depending on the design and maintenance, caps can last 20 to 100 years or more. A multilayer cap is preferred to a single layer. Multilayer caps have a layer of vegetation, a layer for drainage, and a water-resistant layer above the contaminated soil. Capping is usually only an option when the treatment or removal of contaminated sediment is not feasible. Capping "is used when the underground contamination is so extensive that it prohibits excavation and removal…" or "if the removal of wastes from the site would pose a greater threat to human health then simply leaving them in place" (USEPA, 1994).

2.6 Permitting

As with any project the relevant regulations and required permits must be well understood and followed through the duration of the work. Regardless of what remediation solution is pursued, some dredging will most likely be required. In order to comply with the regulations and standards governing the proposed work, the correct regulatory document must be referenced based on the jurisdiction for the area. In the case of Edwards Pond, the governing document is 310 CMR 9.00 “The Massachusetts Waterways Regulations.” This document implements regulations in chapter 91 of the Public Waterfront Act and has jurisdiction as described in the excerpt below (MDEP, 2012):

> *9.04 Geographic Areas Subject to Jurisdiction*
>
> *The following geographic areas, generally considered "trust lands", are subject to licensing and permitting by the Department under 310 CMR 9.00:*
>
> > *(1) all waterways, including all flowed tidelands and all submerged lands lying below the high water mark of:*
> >
> > > *…*
> > >
> > > *(e) any non-tidal river or stream on which public funds have been expended for stream clearance, channel improvement, or any form of flood control or prevention work, either upstream or downstream within the river basin, except for any portion of any such river or stream which is not normally navigable during any season, by any vessel including canoe, kayak, raft, or rowboat; the Department may publish, after opportunity for public review and comment, a list of navigable streams and rivers; and…*

With the relevant regulatory document identified, it must then be determined if a license or permit is required for the intended remediation actions. A permit is required as described in section 9.05 Activities Requiring a Permit Application (MDEP, 2012):

> *…an application for a permit or permit amendment shall be submitted to the Department for the following activities unless the applicant includes such activities in a license application: (a) any beach nourishment; (b) any dredging;…*

This states that any dredging in Massachusetts requires written authorization through either a permit or a license. In general, permits are faster, less expensive, and less complicated than licenses. If a license is obtained for work beyond dredging, authorization for dredging may be included and no further permit required. If a full license for reasons other than dredging is not required, a permit will cover the work and a license application is not needed. However, licensing is required for projects that involve a Great Pond (a pond having a surface area of 10 acres or more), projects that involve the construction or alteration of a structure, or projects that may interfere with navigation, or infringe on public rights as described in section 9.05 Activities Requiring a License Application. If a license is obtained, a Certificate of Compliance (BRP WW 05) as described in section 9.19 must be requested within 60 days of completion of the project. A professional engineer must confirm in writing that the project was completed according to the specifications and conditions of the license. The DEP may conduct an inspection to confirm the claim and may revoke the license if it is determined that the certificate cannot be issued. A permit, however, does not require a Certificate of Compliance; another benefit of acquiring a permit over a license (MDEP, 2012).

The regulations and permitting for a water-dependent project can be complicated and it may not be obvious as to whether the project and area under consideration requires a license or permit. If a project does require authorization and the responsible party does not obtain the appropriate license or permit, they could face penalties and the project may be stopped. A party can submit a form, with an $85 application fee, to the DEP inquiring whether 310 CMR 9.00 applies to the area and project under consideration. The form would convey the specifications of the area and the details of the proposed work so that the DEP can accurately assess the level of authorization necessary. While the form is not required, it is recommended as it could save time and money if it is determined that the project only requires a permit instead of a license or no authorization at all. The requirements and procedure for such an inquiry is described in section 9.06 Requests for Determination of Applicability (MDEP, 2012). (See the complete BRP WW 04 application form at http://www.mass.gov/dep/water/approvals/ww04.pdf):

> *9.06: Requests for Determination of Applicability*
> *(1) Any person who desires a determination whether 310 CMR 9.00 presently apply to any area of land or water, or any activity thereon, may submit to the Department a request for a determination of applicability. Said request shall:*
> *(a) use the appropriate determination of applicability forms provided by the Department;*
> *(b) provide a detailed description of the proposed project, if any, which identifies all existing and proposed fill and structures and uses thereof; and*
> *(c) include a plan or plans showing:*
> *1. an appropriately-scaled site location map;*
> *2. references to any previous licenses, permits, or other authorizations for existing structures, fill, or dredging at the site, including the license number(s) and the date the license was recorded at the Registry of Deeds or Land Court;*
> *3. appropriately-scaled principal dimensions and elevations of proposed and existing fill, structures, or dredging in waterways;*
> *4. any historic dredging, filling, or impoundment at the site; and*
> *5. a delineation of the present high and low water marks, and the historic high and low water marks, as relevant.*

Some parties may be eligible for certain monetary exemptions for obtaining a permit. As described in section 9.16 Exemption from Fees for Certain Projects, the standard permitting fee may be waived if the party is a public agency or if the project is beneficial to the public (MDEP, 2012).

9.16: (4) Exemption from Fees for Certain Projects.
(a) Public Agencies. The fees described herein at 310 CMR 9.16(2) and 9.16(3) shall not be applicable to a municipality or other public agency undertaking a public service project, provided that said project does not deny access to its services and facilities to any citizen of the Commonwealth in a discriminatory manner.

Chapter 91 of the Public Waterfront Act, Waterways Permit, covers the applicability and terms of the general water-dependent permit, Bureau of Resource Protection Waterways 01 (BRP WW 01). The permit does not cover projects for which construction of or modifications to structures or fill is expected. The permit term is 5-10 years and has an application fee of $270 for non-residential or $175 for a residential area of four or less units. The BRP WW 01 license has a 30 year term and has an application review period of 276 days compared to 105 days for the permit. The appropriate permits and forms should be submitted to the regional MassDEP office (MDEP, 2012).

In addition to the act of dredging, there are regulations and permits for the disposal of dredged material. Section 9.40 of 310 CMR Standards For Dredging and Dredged Material Disposal describes the standard practices and regulations governing dredging and disposal. In areas of critical environmental concern (ACEC) no dredging or disposal of dredged material is permitted. The channel cannot be dredged to an average low water depth over 20 feet or deeper than the main channel it is connected to. Dredging must follow resource protection requirements and be designed and timed as to not interfere with fish runs. The dredging and disposal needs to be supervised and hydraulic dredging is preferred over mechanical dredging. According to this regulation, the responsible party must notify the DEP at least 3 days prior to dredging or disposing of dredged material. A dredging inspector is also required to escort the material while in transit if it is deemed hazardous. The responsible party is also required to submit a report containing information on the dredging activities and disposal that is certified by the inspector (MDEP, 2012). (See 310 CMR 9.40 in its entirety at http://www.mass.gov/dep/service/regulations/310cmr09.pdf)

After completion of the project, if additional dredging is required in the future application for a new permit may not be required as described in section 9.22 Maintenance Dredging (MDEP, 2012):

> *9.22: (2) Maintenance Dredging. Maintenance dredging may occur for five years from the date of issuance of the license or permit or for such other term, not exceeding ten years, specified therein, provided that the written notice required pursuant to the Wetlands Protection Act (M.G.L. c. 131, § 40 and 310 CMR 10.00) has been filed with the Conservation Commission and a copy has been sent to the Department.*

The disposal of dredged materials is closely regulated as it can be a hazardous waste and source of pollution. The sediments that accumulate in river beds and behind dams can raise concentrations of natural or anthropogenic pollutants to hazardous levels. The army corps of engineers oversees dredge material disposal. Disposal methods include open ocean disposal at designated locations, landfill disposal, and beach nourishment. The regulations governing the disposal of dredged material are outlined in 310 CMR 40.00 (Massachusetts Contingency Plan). Samples of the sediment from a dredge site must be collected and tested for Water Quality Certification and the Bureau of Waste Prevention (BWP). The samples are tested for pollutants such as polychlorinated biphenyl (PCBs), volatile organic compounds (VOCs), and metals, including chromium, cadmium, lead, and mercury (MDEP, 2012).

Core sample depths are determined by and should match the dredge depth. There should be one core sample for every 1000 cubic yards with a minimum of two samples. A site plan illustrating the sampling locations is required. Half of each core is used for compositing (combining representative portions of a core) and the other half should be saved in the event that further analysis is required beyond the initial composites. Up to three composites can be submitted for analysis.

Sediments are dewatered before transport to the extent that there are no free draining liquids. The dredged material needs to be covered during transport; this may be by means of an enclosed trailer or simply a tarp. The dredged material for disposal should be free of solid waste such as construction debris. A DEP Material Shipping Record is required and needs to be completed by the environmental professional accompanying the material during transit.

Disposal of sediments at landfills is a last resort. The preferred options for disposal involve the reuse or recycling of the material such as beach nourishment to control erosion or as cover layers in a landfill. If the material is determined to be unsuitable for reuse or recycling through core sample testing, another option is destruction or detoxification of the sediments. If none of these alternatives are feasible, the dredge material is then considered for landfill disposal. If a dredge material exceeds any of the maximum concentration levels for tested pollutants it cannot be used for daily cover, intermediate cover, or used as a pre-cap material at landfills. The maximum contamination concentration for arsenic in sediment is 40ppm to be considered for reuse. If the dredge material exceeds maximum contamination concentration, a Special Waste Determination, through further analysis, is needed by the BWP before granting approval for landfill disposal (MDEP, 2012).

3.0 Methodology

The goal of this project is to provide DCR with information on the requirements for addressing arsenic contaminated sediments and explore different options for remediation as required to meet regulations. This chapter summarizes the approach used to achieve this goal. A preliminary inspection and analysis of Edwards Pond and the potential impacts of the transport of arsenic contaminated soils downstream upon the removal of the dam were investigated.

To determine what course of action DCR should take several objectives and related tasks were completed:

1. Gather information on Edwards Pond Dam such as water and sediment quantities, watershed data, dam dimensions, pond bathymetry, ecosystem characteristics, and any other relevant data on the area.
2. Research the characteristics and properties of arsenic contamination and what effects the sediments may have.
3. Research the remediation methods available and how they would apply to the case of Edwards Pond.
4. Research the permitting process and regulations as applicable to remediation work that may be done to restore the sediments.
5. Outline and elaborate on the different options available and recommend which option would be the safest, most economically viable and feasible, and most environmentally responsible.

3.1 Collect Data on Edwards Pond Dam

Information on Edwards Pond Dam and the accumulated sediments was collected to make informed decisions of how to proceed. A visual inspection of the pond, dam, and surrounding area was conducted to gather any pertinent information. Boundaries of the watershed emptying into Edwards Pond were determined through the use of GIS and USGS maps so the area of concern can be defined. The measurements of the dam itself were taken for use in analysis as well as hydraulic measurements such as the bathymetry of the pond. Furthermore, information provided by DCR including already completed analysis of sediment samples and further site characteristics are utilized.

3.2 Research Impacts of Arsenic Contamination and Remediation Methods

Research was conducted on the impacts and effects that sediments contaminated with arsenic may have of the environment and human health as well as what remediation methods are available. The impacts and effects on human health provide insight as to why arsenic contamination is a concern and why the environmental regulations are in place. The various methods of soil remediation to remove arsenic, how they work, and their effectiveness was researched so that all of the options may be considered and the solution with the highest benefit to cost ratio may be determined.

3.3 Research Regulations and Permitting Process

Research was conducted on the regulations and permitting process as they relate to the situation at Edwards Pond. Regardless of which remediation method is pursued some dredging will most likely be required; therefore the focus of the research was on permitting related to dredging and the disposal of dredged material. An overview of the permitting process is provided so that the most appropriate course for DCR can be recommended.

3.4 Analyze Remediation Options

Once research had been completed on the scenario at Edwards Pond, the permitting process, the remediation methods, and analysis of the options was completed to determine which is the most appropriate and beneficial for DCR. The best remediation method must be effective enough to reduce arsenic concentrations in the sediments below the standards set by state and federal regulations. It must be feasible based on the resources available to DCR and economically realistic. The analysis of the remediation methods took into account the state regulations and some options may not meet the environmental laws governing contaminated soils and waterways. Some methods are relatively new and expensive and have not been proven to succeed in river or pond sediment applications and therefore are not attractive options. Methods that include the addition of agents or chemicals to react with arsenic could have impacts on the drinking water downstream. The cost of implementing remediation actions and the required resources is a top concern and some methods are too expensive or impractical for the scale of this project. The preferred remediation method will provide the highest benefit to cost ratio so that DCR's resources are used in the most efficient manner.

Possible actions that can be taken to limit any negative impacts of the contaminated sediment and to meet regulations and pollutant concentration standards were explored. Based on research and the information specific to the scenario at Edwards Pond, recommendations are provided as to which option is most feasible for DCR and will accomplish their goals of making the sediment safe and comply with the concentration standards. The options initially being considered include:

1) treat the sediment for arsenic contamination in situ,
2) dredge the contaminated sediments, treat, and dispose of on site or at another DCR owned site
3) combination of dredging and capping contaminated soils
4) dredge the contaminated sediments and dispose of off site

In addition, for each of these options, the extent of remediation that is required must be determined. It may be necessary to dredge or cap a large section of the pond or only dredging of the stream bed may be required. The option that is ultimately chosen must fulfill the requirement of reducing arsenic levels in the sediment below the acceptable limits and make the sediment safe so that any transport downstream upon the removal of the dam will have minimal risk of negative consequences on the environment and human health. In addition to meeting environmental regulations, the proposed option must be feasible for DCR resources. The results of this analysis are presented in the following section.

4.0 Results and Discussion

This chapter presents the results of the field visits used to descript the general nature of Edwards Pond, the topography of the pond and general area, and the quantification of sediment volumes. It also includes the identification and evaluation of remediation options.

4.1. Visual Inspection and general nature of Edwards Pond

In order to understand the area around Edwards Pond, it was necessary to acquire data on the immediate and surrounding area. Numerous site visits were made to visually inspect the area, collect survey data, and depths of the pond. On September 24, 2009 during the first of the site inspections, pictures, observations, and measurements were obtained of the road, culvert, stream, spillway and dam. Edwards Pond lies approximately 200 feet south of Malden Road by the Crescent Street intersection. The pond discharges into Malden Brook and crosses Malden Street through a stone culvert on its way to its eventual end in Wachusett Reservoir. Malden Street, shown Figure 6, is a small road, approximately 20’ wide, located in a rural area of West Boylston.

Figure 8 – Malden Street at Malden Brook Culvert

The culvert that takes the brook under the road is a large concern for the dam removal process. The size of the culvert places a restraint on how much discharge can be allowed to pass through without causing a flood post-removal. The culvert was measured with a tape measure and found to be 10 feet wide at the mouth, narrows to 4’ as it passes under the road, widens to 6 feet and eventually back to 10 feet wide at the end. Pictured below in Figure 9 is the culvert from the upstream side. On the day of this visit, from the roof of the upstream side of the culvert to the surface of the water measured 4’6” and the depth of the stream was 6 inches.

Figure 9 – Malden Brook Culvert view from upstream

Seen below in Figure 10, the area is marked as property of the Massachusetts DCR with a sign on a tree directly visible upon driving into the turnaround that serves as a parking lot located between the dam and the road.

Figure 10 – Signage at Edwards Pond

The stream itself comes over the spillway and travels about 250’ before reaching the road. Directly under the spillway, the stream is moderately sloped, about 4-5’ feet wide with medium sized rocks and tree roots along the streambed.

Figure 11 – Malden Brook flowing past spillway

After about 50' the stream takes an abrupt turn, almost 90 degrees and runs parallel to Malden Road for about 125 feet. When the stream turns, it flattens significantly and widens out to about 10 feet. During a site visit in early January after heavy rains on top of an existing snow cover, it was observed that this portion of the stream widened to about 20' to serve as a detention area for high-flow events. Because of this flooding that occurs, the area around that portion of the stream has a thicker vegetative cover without the presence of the larger trees that can be seen along the upper rockier portion of the stream. As well as being informed by the DCR that beavers have caused problems in the area by creating their own dams in the past, it was also evident that beavers inhabited the area by the amount of drift wood along the banks of the stream as well as felled trees around the perimeter of the pond.

Figure 12 – Malden Brook between spillway and culvert

Again the stream then takes a sharp turn, this time traveling about 75’ back towards Malden Road and the culvert. As the stream approaches the culvert it narrows down slightly, remaining at about 10’ wide. During the same January wet weather event mentioned before, this last portion of the stream was observed to widen only slightly, but its depth increased significantly from the 6” measured on the day pictured to approximately 24”. Figure 13 below shows the stream as it approaches the culvert from where it turns back toward the road. On the left side of the picture there looks to be a small area of water joining the stream. This is because during the second portion of the stream, when it widens significantly, the stream has started to make a new path that cuts more directly toward the culvert. This portion is only about 2 feet at its widest, though it looks to be getting wider as the stream continues to carve a new path for itself.

Figure 13 – Malden Brook approaching Malden Street

The spillway in Figure 14 consists of a sharp crested weir, made of what looks to be iron, at the end of the earthen embankment with cement structures on either side. The spillway (including cement structures) is about 15’ wide. The weir itself consists of two 4’wide 12” high iron plates side by side held together with a pin structure on top of an 18” cement foundation.

Figure 14 – Edwards Pond Dam spillway

The dam itself, shown in Figure 15 is an earthen embankment about 130' long, 6' high and 6'wide along the top. Although it cannot be known what the dam is actually made of without actually coring into it, the old age of the dam and the local area suggest that the embankment was possibly created with large boulders at the base and smaller rocks, sediment and vegetation providing support for the upper portion of the embankment. The validity of this assumption has an impact on the ultimate decision made regarding the removal of the dam. If possible, a core will likely be necessary to ascertain the true makeup of the dam. Also, there are numerous large trees growing out of the side of the dam, the largest of which with a diameter of about 3' at shoulder height can be seen on the left side of the picture showing the top of the earthen dam below. The existence of these larger trees will increase the cost of removal as well as impose design considerations during the decision making process.

Figure 15 – Edwards Pond Dam

4.2 Field Work to Characterize Bottom Sediments

On October 20th with the assistance of Environmental Engineer Dave Getman of the DCR, we obtained numerous depths of the pond using a small rowboat, a weight on a string, a tape measure and a handheld GPS device provided by the DCR. The boat was launched and measurements were taken intermittently across the pond, lowering the weighted string to the top of the sediment, measuring its length, and marking the location using the GPS device. Eleven depths and their locations were recorded using this method. Mr. Getman then sent along a GIS file containing an approximate outline of the pond with the depth locations marked on the pond.

As well as the depths acquired from the center of the pond, measurements were also taken along the edge of the pond at the spillway, both ends of the earthen dam, and the center of the earthen dam. These depths did not need to be located using the GPS as they can be accurately placed by their relation to the dam. At the points along the edge of the pond, both the depth from the surface of the water to the top of the sediment build up as well as the distance from the surface of the water to the bottom of the sediment build up were measured. The depth to the bottom of the sediment was acquired using a long piece of iron rebar and a tape measure after the water depth was acquired using the weight on a string method from above. Unfortunately, because the process of measuring down to the bottom of the sediment stirred up so much dirt making the water too murky to see through, sediment depths were not able to be measured at the depth locations in the center of the pond.

Figure 16 shows a hand drawn sketch of Edward Pond created by using coordinates from the AutoCAD drawing discussed further in Section 4.3. The depths were used to create estimated contour lines describing the bottom of the pond.

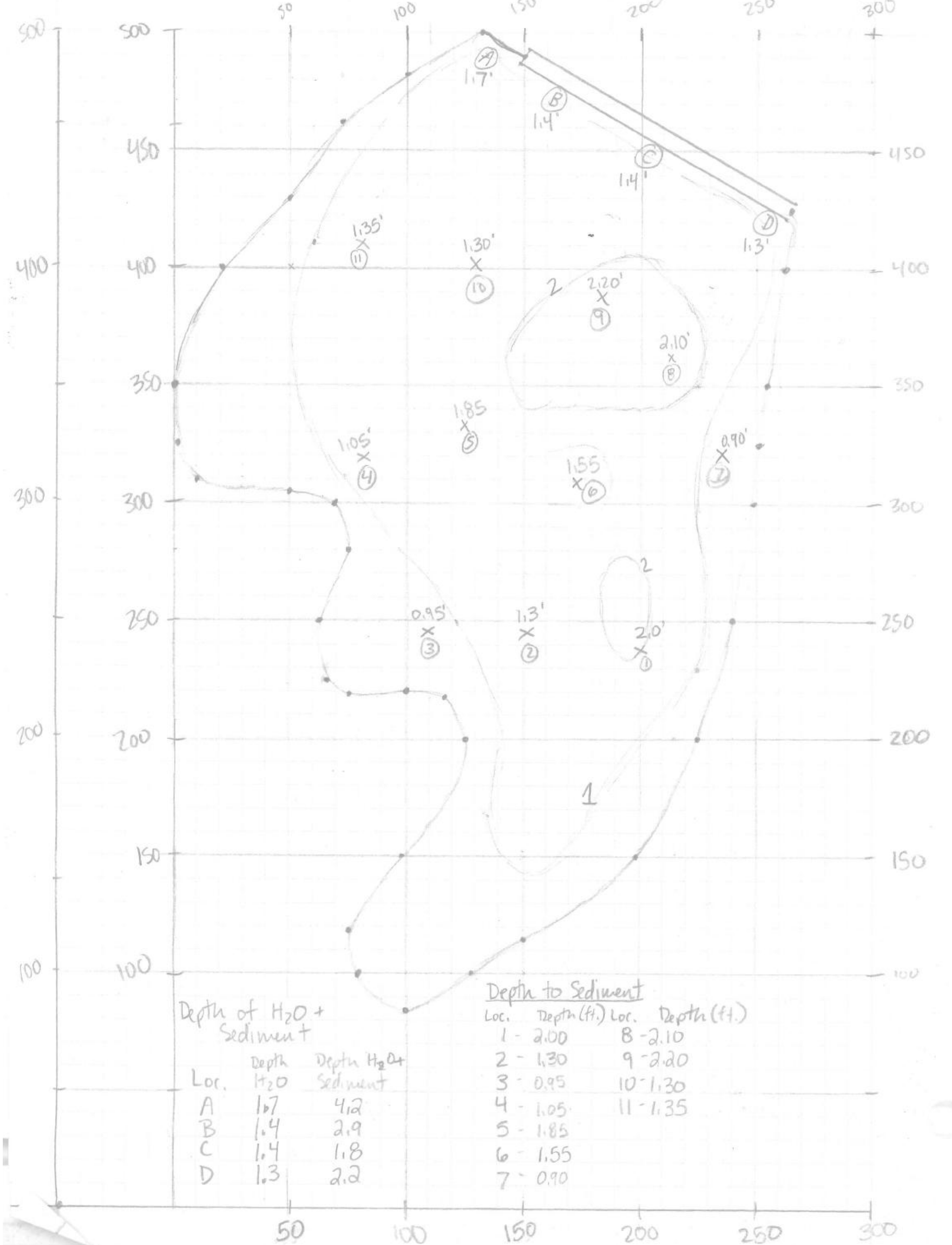

Figure 16 – Sketch of Edwards Pond with pond depths

4.3 Topography of area

The topography of the area needs to be taken into consideration both on a small scale, focusing directly at the site, and on a larger scale that looks at the area further up and downstream of the dam in order to predict what will happen when the dam is removed. Maps of the area on both scales were used in addition to an on-site survey to determine more precise elevation changes in the area from the dam to the culvert.

The DCR provided a survey of the property showing accurate property lines and an approximation of the Malden Brook and Edwards Pond. This was scanned and the image was used to create an AutoCAD drawing that enabled measurements to be determined much easier.

Next, a topographic map was imported to the same AutoCAD drawing, scaled and centered on top of the survey map. This was used to create a profile of the stream by measuring the distance between the 3-meter contour lines on the map shown in Figure 17 (Curley, 2010).

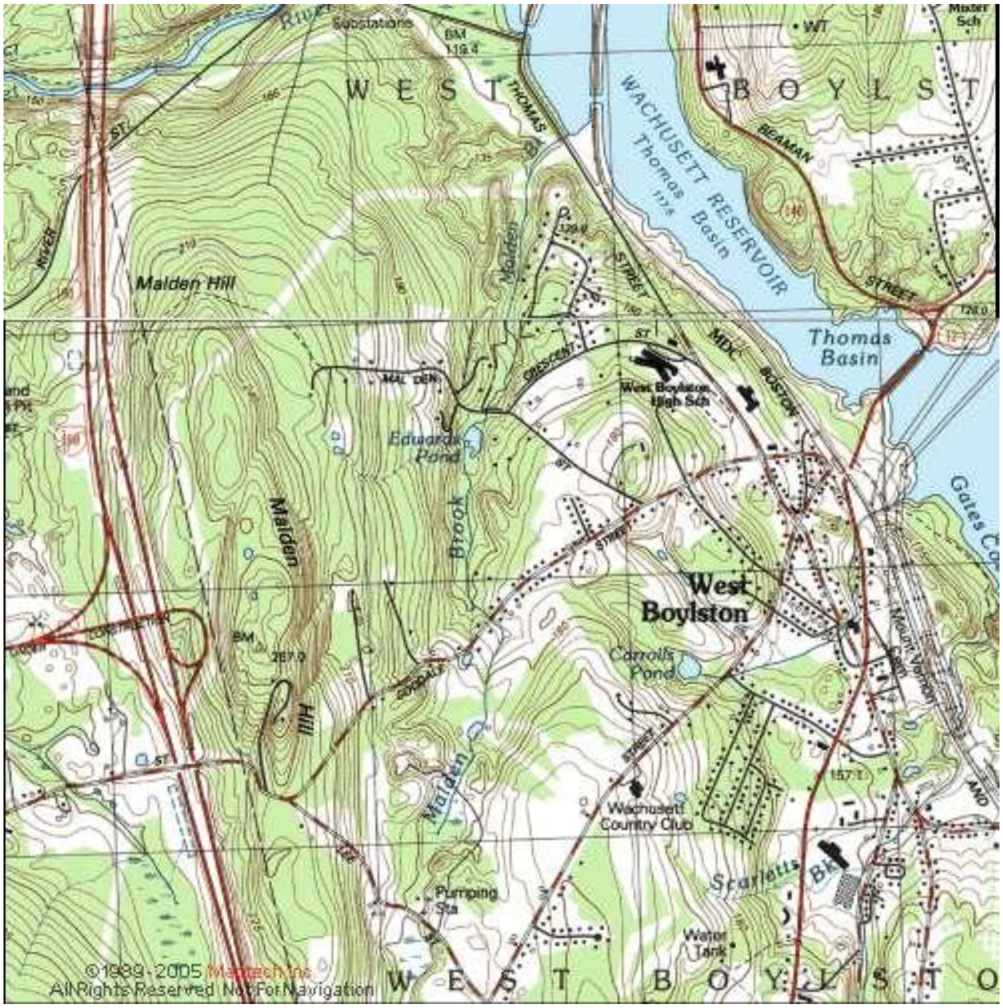

Figure 17 – Topographic Map of Edwards Pond and surrounding area (USGS)

These measurements allow for a profile of the stream to be drawn from the dam as it flows from Wachusett Reservoir to the culvert at Malden Street. This provides the total length of the stream of 3,900 feet as well as the slope of the stream as it flows toward the Reservoir, as shown below in Figure 18. The maximum slope is 9.29% with an overall average slope of 2.74%. Because the topographic map had contours that were 3-meter (or 10-foot) intervals in elevation, and there was considerable difficulty in discerning the contour lines (especially in the area closest to the dam), the profile is limited accuracy.

This is most evident from the 3,000 foot reach located between the reservoir and the road. From visual inspection of the area downstream of the culvert, the stream is not likely as flat as it is shown in the profile. The profile shows a 400’ stretch with a 0.00% slope, then a 176’ section with 5.59% slope, followed by 119’ more of no elevation change, and finally a 156’ long portion with a slope of 6.31%. This is more accurately represented by a more consistent slope. When the 852’ foot long section described is taken as a whole, the average slope across that area comes to be 2.34%, a much more representative number of the overall slope (Curley, 2010).

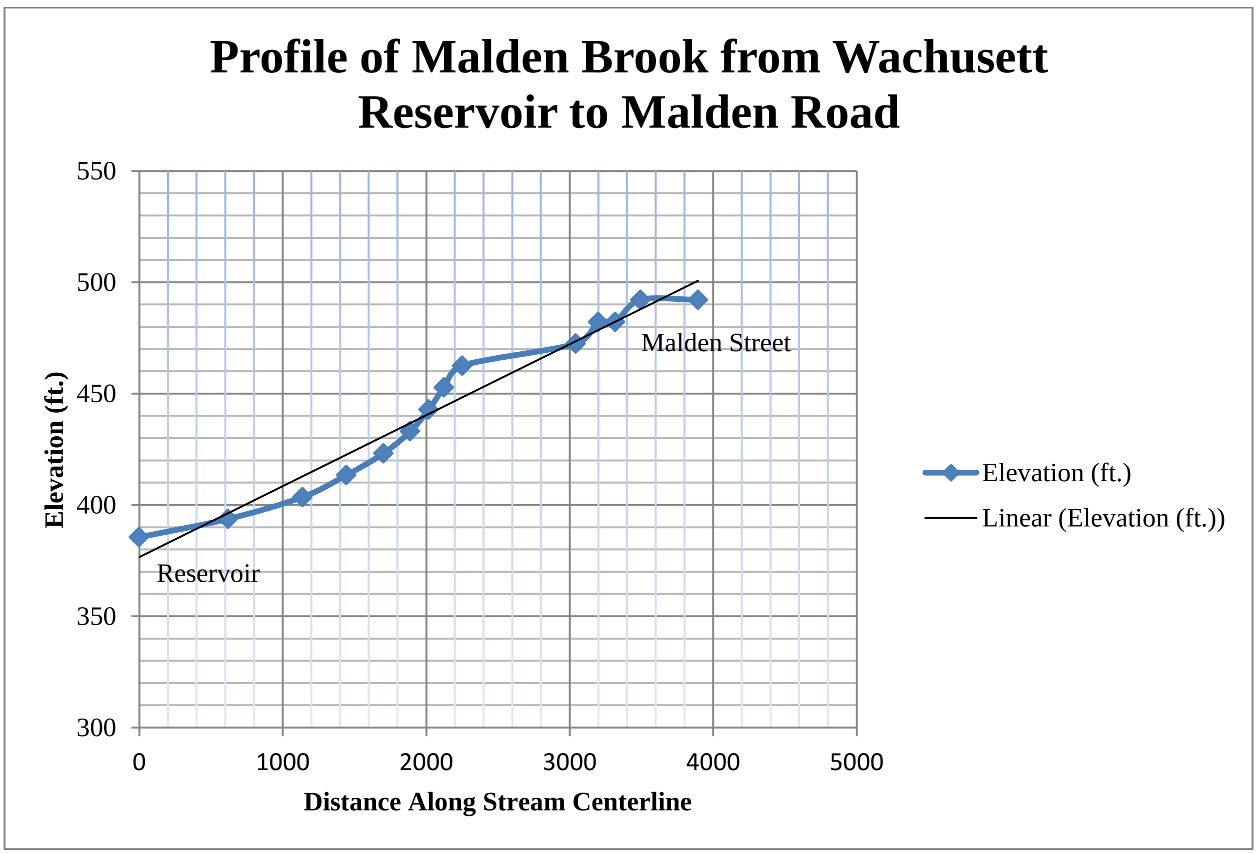

Figure 18 – Profile of Malden Brook from Wachusett Reservoir to Malden Road

A profile was also created from a simple elevation survey performed on the site. This elevation survey used a station and a leveling rod to measure the difference in elevations at numerous points along the stream and the dam. It was determined that the streambed at the mouth of the culvert is approximately 16’ lower in elevation than the top of the earthen dam, and about 15’ lower than the spillway. This drop in elevation occurs over a stream length of about 250’. This number was acquired from the AutoCAD drawing prepared because an accurate length of the stream from spillway to culvert was not able to be obtained in the field due to the short length of the tape measure as well as the challenges posed by the vegetation and deadwood along the sides of the stream.

In addition, it was determined that the streambed immediately downstream of the culvert is about 1 foot lower than the mouth of the culvert. Although the other measurements were obtained using the station and leveling rod, this had to be determined with the tape measure because the leveling rod was barely too short to obtain a reading, so the accuracy of the measurement is questionable. A few of the readings were unable to be taken from the stream bed itself due to visual obstruction by trees and leaves, and instead these values were taken from the streambed as close to the stream as possible and then adjusted to approximate the bottom of the stream. The points that were taken from the side of the stream were observed to be consistently about 2’ higher than the stream bed. Using the point downstream of the culvert as the zero elevation point, the profile in Figure 19 was created (Curley, 2010).

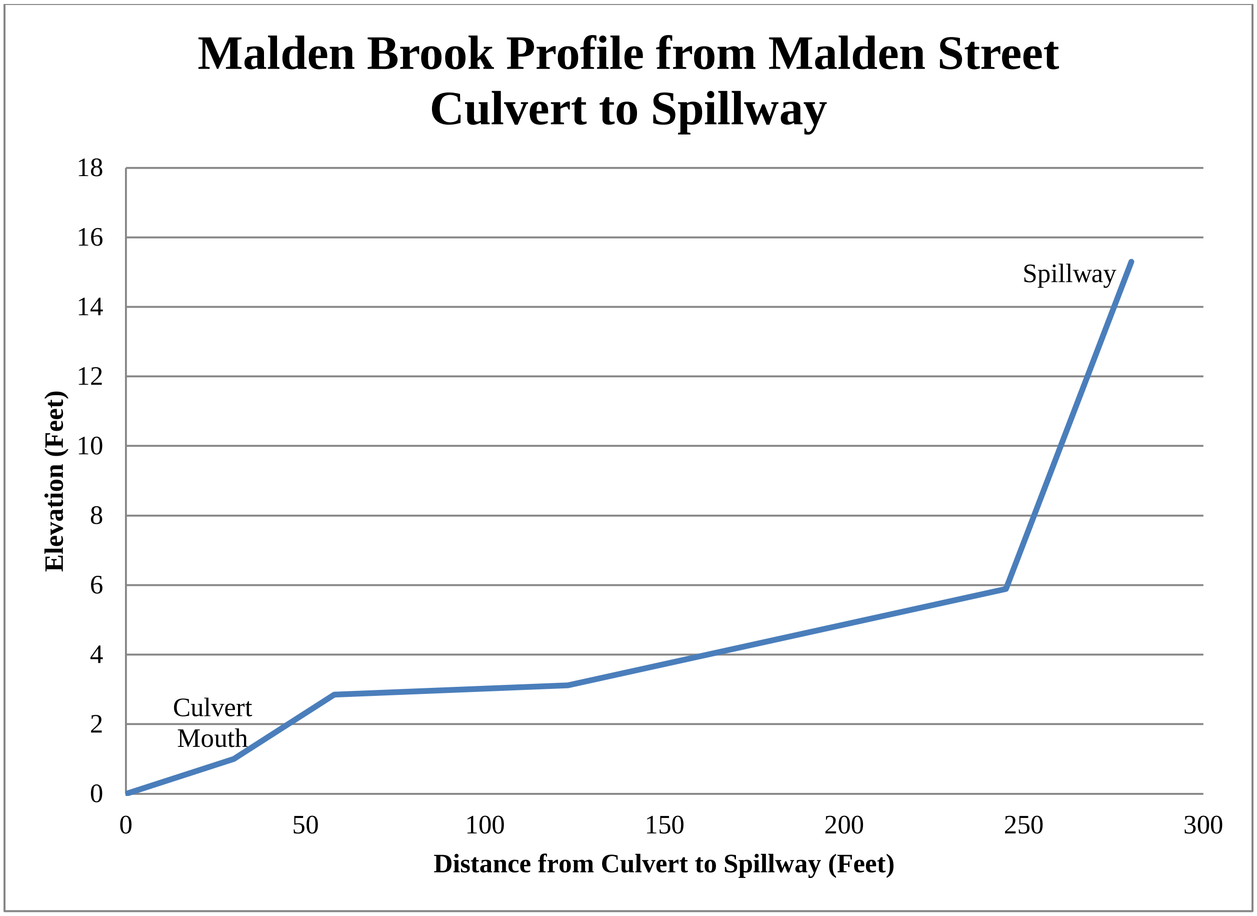

Figure 19 – Malden Brook Profile from Malden Street Culvert to Spillway

4.4 Sediment Volume

The visual inspection and topography study provided measurements and data that can be used to determine the estimated volume of contaminated sediment. The core samples provided by DCR were taken at depths of 6 to 12 inches and DCR estimated that there may be 200 to 400 cubic yards of sediment behind the dam. As some of the measurements are not exact or may not be very accurate, all estimates or averages of measurements are made conservatively so that the sediment volume may be overestimated rather than underestimated. The profile (scale is approximate) of the dam, pond, and sediment is shown in figure 20.

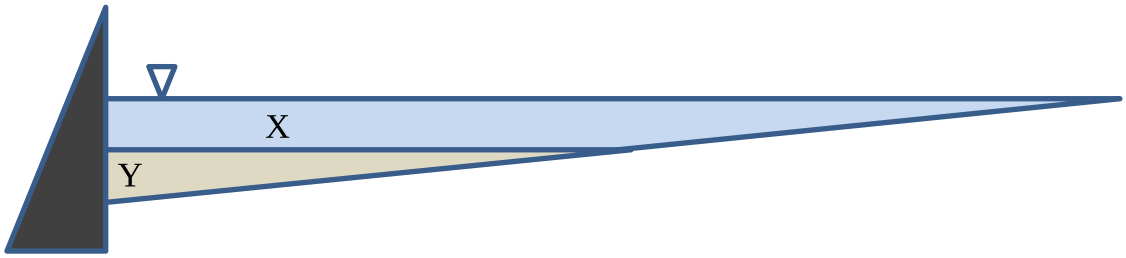

Figure 20 - Sediment Profile

The average depth of the sediment is represented by Y and the distance behind the dam that sediment has deposited is represented by X. From the water and sediment depth measurements taken at several locations behind the dam, the average water depth and average sediment depth are each estimated to be 2ft. Dividing the sediment depth of 2 ft. by the average slope of 2.74% (as described in section 4.3) provides X as 72.7ft. The area of the sediment is found by: (72.7ft)(2ft)(0.5) = 72.7ft^2. It is assumed that the width of the pond behind the dam remains approximately the same as the length of the dam (150ft) for the distance being considered (72.7ft). The volume is then determined by multiplying this area by the length of the dam: (72.7ft^2)(150ft) = 10905ft^3 or 404yds^3. This is consistent with the high end of the range of sediment volume estimated by DCR. The actual sediment volume could vary to some extent depending on the requirements of the specific dredging approach.

4.5 Discussion of Remediation Options

Several remediation options have been proposed to address the contaminated sediments if the Edwards Pond Dam is to be removed. This section provides a description of these options and also includes an assessment of their applicability for Edwards Pond. If the Edwards Pond Dam is to be removed, the remediation method must meet the regulations put forth by the Massachusetts Contingency Plan (310 CMR 40), by reducing the current arsenic concentration of 75PPM to a value below 20PPM or it must at least substantially reduce its mobility and bioavailability to ensure that it is not a hazard to the environment or human health. The recommended method must be feasible and must be financially acceptable. The chosen remediation action should provide the greatest benefit to cost ratio to ensure that Edwards Pond is remediated to the fullest extent with the resources available.

4.5.1 Description of Methods

A set of four alternative options are considered. Each remediation method takes a different approach to making the sediments behind Edwards Pond Dam safe. The methods being considered include in situ treatment, capping of exposed contaminated soils, dredging and treatment of the sediment followed by on-site replacement or replacement at another DCR owned site, and dredging the contaminated sediments and off-site disposal.

4.5.1.1 In situ Treatment

Treating the arsenic contaminated sediments in situ is one option being explored. One in situ method is to destabilize the arsenic from the soil, concentrate it, and remove a much smaller volume of contaminated sediment. Arsenic could be destabilized from water logged soils with the use of an adsorbent such as activated alumina. Once the arsenic is destabilized from the sediment, electroremmediation could be used to concentrate it. Electroremmediation would apply a direct current through the soils with the use of electrodes that would draw the arsenic ions toward the electrode greatly concentrating the arsenic. The substantially reduced volume of sediment with high concentrations of arsenic could then be dredged and disposed of. Another approach to in situ treatment is to stabilize the contaminant in the soil so that it does not spread. Chemical fixation with the use of ion-exchange resins such as ferrous compounds, green sand, and clay minerals, can reduce the mobility and bioavailability of arsenic by increasing sorption to the soil so that it is stable and less likely to spread. Chemical remediation is a method in which chelating agents are used to react with heavy metals and render them inert. Bioremediation is another in situ option that would use microbial fauna or certain plants to utilize natural processes to aid in the cleanup. Bioaccumulation of arsenic occurs naturally in some plants such as ferns. The plant would be cultivated over the contaminated area, arsenic would be drawn up from the soil and stored in the plant which is then harvested and disposed of. Some microbes are able to degrade harmful forms of arsenic such as arsenite to less toxic species including arsenate through a process known as bio oxidation (Naidu, 2006).

4.5.1.2 Capping Sediments

Capping the contaminated soils that would be exposed after the Edwards Pond Dam is breached is another remediation method being considered. A thick single layer cap of sand and clay could be applied to the area; however multilayer caps have been more successful and are the preferred capping method. A multilayer cap would be used to contain and isolate the arsenic pollution from spreading in the environment and protect human health. This would include a water resistant layer just above the contaminated soil to prevent the arsenic from leaching. A middle layer of sand or gravel would allow for drainage to divert water flow over and away from the capped sediments. The top layer would consist of low maintenance vegetation to guard against erosion. Well maintained caps can last up to 100 years or more. The success of caps is supervised with the use of groundwater monitoring wells to ensure that there are no leaks in the cap and that the contaminant does not spread (USEPA, 2008). Recently, compounds such as activated carbon or phosphate additives, have been applied to caps. These “activated caps” reduce permeability and migration through sorption and reaction with the contaminant (Schuck, 2010).

4.5.1.3 Dredging and On-site Disposal

Another remediation option is to dredge the contaminated sediment and return it to the Edwards Pond site or another DCR location. The expected path of the stream once the dam has been removed would be dredged so that the contaminant is removed from the water body. The dredged material could then be deposited on top of the contaminated soil exposed after the water level has dropped. While the contaminant would still be on-site, it would be out of the flow of the stream and less likely to be transported downstream. In the case of Edwards Pond, the dredged sediment would need to be treated before being re-deposited at the same site or at another DCR owned property because of the high concentration of arsenic. Once the material is dredged, it may be treated by adding adsorbents, such as activated alumina and cerium oxide. Then the arsenic could be removed by water treatment processes of coagulation, flocculation, clarification, and filtration. Iron treated sand, gel beads, or activated carbon can be added to promote ion exchange and precipitation of arsenic from the sediment slurry. Ultraviolet light could also be used to oxidize arsenic (Naidu, 2006). Once the sediment has been treated and the concentration of arsenic reduced to a safe level, it could be re-deposited on site.

4.5.1.4 Dredge and Off-site Disposal

Dredging and disposing the dredged material off site is the most commonly implemented remediation method for contaminated sediments. All of the contaminated sediment would be dredged, transported, and disposed of at a landfill. Mechanical dredging with common construction machinery is one option however; hydraulic dredging has become the preferred method as it has less of an impact on the environment. Hydraulic dredging would pump the sediments to a drying area or into a transport vehicle. A floating portable hydraulic dredger or land based dredger would essentially act as a vacuum to remove the contaminated sediment from the pond bottom (Dredge America, 2010). The sediment would then need to be dewatered to the extent that there is no free flowing water, loaded into a transport vehicle, and covered. Due to the high concentration of arsenic, the dredged sediment would be considered hazardous waste and would require an environmental professional to accompany the transported sediments and require a DEP Material Shipping Record to be completed. Since the sediment was found to contain 75PPM of arsenic, the only disposal option for the dredged material would be landfill disposal (MDEP, 2012).

4.5.2 Evaluation of Methods

After researching the available remediation options, the processes by which they work, and their applications, the advantages and drawbacks of each method were considered. The following sections evaluate each method as they would be utilized for the remediation of Edwards Pond. The effectiveness, feasibility, costs, and potential complications and obstacles to each method are discussed.

4.5.2.1 In situ Treatment

In situ treatment options have some merit but may not be a practical remediation method at Edwards Pond. In situ treatment would reduce the need to cap, dredge, or dispose of polluted sediments. As the accessibility of Edwards Pond is limited, the lack of major equipment associated with this option would be one advantage. Most in situ remediation options are relatively new and have not been extensively studied. The effectiveness of many in situ treatments is not well known. The success of many in situ treatments based on adding reacting compounds depends heavily on the sorption potential of the contaminant. Sorption can vary greatly based on PH, redox potential, and ionic strength of the individual species. Additional testing would be required to determine the species of arsenic in the sediment. While in situ options may be an attractive alternative to dredging, the agents and compounds required can be expensive and their effectiveness is not certain. The effectiveness of phytoremediation is also still being studied but shows some potential. Due to the very high concentration of arsenic in the sediments at Edwards Pond and the uncertainty of in situ treatments, this may not be the best option to pursue.

4.5.2.2 Capping Sediments

Applying a single layer cap over the contaminated soil is an inexpensive and simple containment method. However, there is a trend toward multilayer caps as they have proven to be more reliable with greater lifetimes. Sand and clay are common and inexpensive for use in caps but the multilayer caps can increase costs. Accessing the pond with construction machinery to deposit the cap material could prove problematic as it is set back from Malden Street. Malden brook has low velocity flows and the cap would be unlikely to be disturbed making the area a good candidate for a cap. However, the cap material eroding and no longer containing the pollutant remains a concern. While caps can last over a hundred years they must be maintained and the long term effectiveness to contain a pollutant are still uncertain. In addition to maintenance, groundwater monitoring wells may be required to reveal any leaching or breaches in the cap adding to the cost. Another possible drawback to consider is arsenic depositing on and contaminating the cap material. However, the dam will be removed and the potential of arsenic sediments building up in the free flowing stream that would exist is unlikely. The use of a cap may be feasible for DCR, however the cost is a variable and the use of a cap is usually a secondary option if treatment or removal of the contaminated sediment is not practical. As the volume of contaminated sediment at Edwards Pond is relatively small and accessible to dredging, it may be difficult to justify capping as the primary method of remediation.

4.5.2.3 Dredging and On-site Disposal

Dredging and on site disposal would involve placement of material in a location on the property where the dam is located. This approach is likely not a viable option for the contaminated sediments at this site. It is unlikely that the sediment can be simply dredged and placed somewhere else on-site or another DCR location. Space limitations would present one concern. In addition, the high concentration of arsenic would require that the sediment be treated before it could be re-deposited. This would combine the costs and difficulties of dredging and treatment options. Accessing Edwards Pond with dredging machinery may be difficult and the compounds required for treatment can be expensive. The specific form of arsenic is unknown and therefore the success of sorption based treatments is uncertain. In addition to these concerns, it is likely that on-site disposal may not even be allowed since the concentration of arsenic must be below 20ppm by law to deposit the sediment in the environment.

4.5.2.4 Dredging and Off-site Disposal

Dredging and off-site disposal is a common method of remediating polluted sediments. The process of dredging, transportation, and disposal while straightforward can be expensive. However, there are many examples for which this approach has been found to be simple and effective. Obtaining the required equipment and accessing the area to be dredged may pose some challenge. Hiring a dredging company can be expensive and difficult due to the small scale of this project. Transporting the dredged material would add some cost and complexity as it would be considered a hazardous material. In spite of the costs it may be the best option to guarantee adequate remediation as the contaminant is physically removed from the area and does not depend on other factors. Furthermore, dredging and landfill disposal may be one of few options available to DCR due to state and federal regulations.

4.6 Recommended Remediation Method

The advantages and disadvantages of each option were considered and compared in order to recommend the best remediation method to address the arsenic contaminated sediments at Edwards Pond. The following table summarizes pros and cons determined after evaluating each method.

Table 2 - Summary of Remediation Methods Evaluation

Remediation Method	Advantages	Disadvantages
In situ Treatment	• Limited or no dredging, transportation, and disposal of sediments	• Unproven for pond sediment applications • Effectiveness uncertain • Agents may be expensive • Additional testing may be required
Capping Sediment	• No dredging and disposal of sediments • Materials are common and not expensive • Common and proven remediation method • Low risk of erosion or leaching	• May not be allowed as a primary solution by environmental regulations • Must be monitored • Long term but not a permanent solution • Limited access for equipment • Cost may vary due to design and maintenance / monitoring
Dredge and On-site Disposal	• Certain to remove contaminated sediments from waterway • No transportation of sediments	• May not be allowed to dispose of on-site due to high concentration of arsenic • Both treatment expenses and dredging expenses • Treatment may not reduce arsenic concentrations enough for on-site disposal • Limited access for equipment
Dredge and Off-site Disposal	• Certain to remove contaminated sediments from area • Permitted by environmental regulations • Common, simple, and proven remediation	• May be expensive to dredge and dispose of sediment • Must transport sediment as hazardous waste • Limited access for equipment

After considering the advantages and drawbacks of the discussed remediation methods as they apply to the arsenic contaminated sediment at Edwards Pond, the method of dredging and off-site disposal is recommended. While the expense of dredging, transporting, and disposing of the sediments would not be inconsequential, the benefits of successful remediation outweigh the costs. Dredging is a commonly used, simple, and proven remediation method. Dredging the contaminated sediments would guarantee that the arsenic would be removed from the area such that the release of sediments would not be a concern in the case of dam removal. There would be no concern as to what species of arsenic is present or the effectiveness of the treatment. Dredging is a one-time, permanent solution that would not require any maintenance or monitoring. This option has the fewest risks and potential for complications. Most importantly, this may be the only remediation method that would be allowed by and adhere to all state and federal regulations and reduce arsenic concentration below the maximum concentration level of 20PPM.

5.0 Conclusions and Recommendations

The following section provides a recommendation for the approach that could be followed to implement a dredging plan to resolve the concern of arsenic concentration in the sediments at Edwards Pond. The recommended remediation method is presented and discussed as it applies to this situation and the permitting process is explained as well.

5.1 Recommended Remediation Action

The recommended remediation plan for this project involves dredging and off-site disposal of the contaminated sediments at Edwards Pond is pursued. While this may be one of the more expensive options, dredging would guarantee successful remediation of the area.

This approach would require renting equipment or hiring of a dredging company to remove the arsenic contaminated sediment behind Edwards Pond Dam. This can be accomplished with the use of a portable hydraulic dredger to remove the fine sediment and deposit it in trucks for transport off site. If a land based hydraulic dredger cannot be found that has sufficient length to reach the sediment, a small water based dredger may be required. The dredged material needs to be covered for transportation but can be as simple as using a tarp covering. A dredging inspector would be required as well as a qualified environmental professional to escort the dredged material in transit. As the arsenic concentrations are nearly four times the MCL, additional testing may be required prior to disposal at a landfill. Once the contaminated sediment has been removed the

Edwards Pond Dam can be breached without concern of arsenic pollution spreading downstream. The regulations and permitting that DCR would need to follow for enacting this remediation method is discussed in the following section.

5.2 Permitting Process

It is important to be aware of and adhere to all state and federal regulations and permitting as described above before starting the project and through the duration of the remediation. The dredging that this recommendation involves would be categorized as improvement dredging. This term applies to any dredging with a license or a permit in an area that was not previously dredged and dredging that alters the boundaries of an area that was previously dredged. In addition, it may be necessary to perform maintenance dredging in the future which is dredging in accordance with a license or permit previously authorized that does not alter the boundaries of the initial dredging.

The regulation designated as 310 CMR 9.00 ("The Massachusetts Waterways Regulations") has jurisdiction over the Edwards Pond area according to section 9.04. If a license for the removal or alteration of the dam at Edwards Pond is required, authorization for dredging may be included. If a full license for reasons other than dredging is not required, a license application may not be needed as Edwards Pond is not a Great Pond defined as "any pond or lake that contained more than 10 acres in its natural state" (MDEP, 2012). Furthermore, dredging at Edwards Pond will not interfere with navigation or infringe on public rights. It would be appropriate to pursue a permit over a license if possible as permits are generally less expensive and faster than a license and do not require a Certificate of Compliance upon completion of the project. As described in section 9.16 Exemption from Fees for Certain Projects, it may not be necessary for an organization such as DCR to pay the standard permitting fee because it is a public agency and the project is beneficial to the public.

The permit that applies to the water-dependent actions that would be required to remediate Edwards Pond, namely dredging is BRP WW 01 (see http://www.mass.gov/dep/water/approvals/ww10_11.pdf for the complete application). As stated earlier, the permit would cover the expected work that would be undertaken and the license may not be necessary. It may be appropriate to submit a BRP WW 04 (Request for Determination of Applicability) to confirm the jurisdiction and level of authorization required for the work to be done. Edwards Pond falls under the jurisdiction of the central office and forms and applications should be sent to:

MassDEP Central Regional Office
627 Main Street
Worcester, Massachusetts 01608
Main Phone: 508-792-7650
Service Center: 508-792-7683
Permit Assistance:508-767-2734

The application fee (if applicable) and copy of the *Transmittal Form for Permit Application and Payment*1 (See http://www.mass.gov/dep/service/online/tr-formw.pdf) should be sent to:

Department of Environmental Protection
P.O. Box 4062
Boston, MA 02211

After acquiring the permit, the DEP must be notified at least 3 days prior to commencing dredging. It is also necessary to hire a dredging inspector to escort the material while in transit since it is potentially hazardous due to the concentration of arsenic. It would also be required to submit a report containing information on the dredging activities and disposal certified by the inspector. The sediment samples from Edwards Pond indicate that the dredge material may not be classified as reusable or recyclable. Because the dredge material exceeds 40 ppm of arsenic, a Special Waste Determination, through further analysis, is needed by the BWP before granting approval for landfill disposal.

5.3 Recommendations for Additional Work

This project represents a first step in addressing the concerns regarding contaminated sediments associated with the removal of Edwards Pond Dam. This is meant as a preliminary investigation into the options available to address this issue and additional investigation and analysis should be completed before committing to a course of action.

Firstly, it should be determined with certainty which remediation options specific to the scenario at Edwards Pond are allowed by state and federal regulations. For example, if it is confirmed that on-site disposal or capping would not comply with regulations; those options could be abandoned as there would be little purpose in investigating costs and other aspects. The remaining compliant options should then be investigated further.

Additional data and information on the sediments at Edwards Pond may be required to select the best option of the remaining remediation methods. More accurate measurements and estimation of the volume of contaminated sediments should be determined. Also, more sediment core samples and analysis may be required to determine the depth of the contaminated sediments in multiple locations and the species of arsenic that are present.

Once the required measurements and data are gathered and the compliance of the remediation methods is confirmed, an in depth comparison of the remaining options should be completed. This should include a detailed cost analysis for dredging, transport, and disposal of the revised sediment volume estimation as well as a cost analysis for in situ and capping methods if they are still viable options. Furthermore, potential obstacles such as access to the pond and final disposal location should be investigated.

6.0 References

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