Drinking Water Contamination in Charlton: Education and Solutions

An Interactive Qualifying Project Report
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ABSTRACT

Private well water is used throughout many rural communities in the United States. Because private wells are not monitored as rigorously as public water supplies, it is imperative residents understand the need to test and treat their water regularly. Working with the Town of Charlton, our project goal was to understand and inform residents of the contamination risks in Charlton’s groundwater. Our recommendations include methods for informing residents about testing and cleaning their wells, and the benefits of public water, as well as ideas for future projects to aid the town.

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EXECUTIVE SUMMARY

Clean drinking water is an essential resource for human survival. Humans depend on clean water for consumption, cleaning, and sanitation. Between the 1980s and 1990s two Exxon gas leaks contaminated the groundwater in the Town of Charlton, Massachusetts with the gasoline additive methyl tertiary butyl ether (MtBE). Another chemical, 1,4-Dioxane, has been found in Charlton residents' wells near the Charlton-Southbridge border, where the Southbridge landfill is located. Contaminants like MtBE and 1,4-Dioxane are introduced into the environment while other contaminants, like arsenic, are naturally occurring. A large arsenic vein runs through Charlton, like many other communities in New England (Romero et al. 2008).

Many residents in Charlton rely on private wells for their drinking water, leaving them potentially subject to the contamination. Residents living in affected areas have received bottled water, municipal water from the neighboring Town of Southbridge, or have installed point of entry treatment (POET) systems on their private wells. There are sufficient POET systems for both arsenic and MtBE, but there are no proven well treatment systems for 1,4-Dioxane.

Public water systems must comply with drinking water regulations to provide water to homes. The most important drinking water law is the federal Safe Drinking Water Act (SDWA). The SDWA mandates water has clean taste, smell, and appearance while meeting the required maximum contaminant levels (United States, 2004). The SDWA grants the United States Environmental Protection Agency authority to regulate water systems in the United States.

Charlton officials are concerned for residents' safety because many Charlton residents who live in areas affected by contamination have private wells. Robin Craver, Charlton's Town Administrator, and James Philbrook, Charlton's Health Director, sought assistance from

Worcester Polytechnic Institute's (WPI) Massachusetts Water Resource Outreach Center (WROC) to inform residents about public water lines, well water testing, and POET systems.

Methodology

Our goal was to inform Charlton residents of Charlton's groundwater contamination, the importance of independent water testing, the benefits of connecting to town water, and approaches for Charlton residents to decontaminate their private wells. To accomplish this goal, we developed five objectives:

1. Assess Charlton's drinking water sources, methods of well testing, and treatment.
2. Gauge public awareness of Charlton's drinking water contamination.
3. Research strategies to identify and mitigate contamination in private wells.
4. Develop a list of recommendations for Charlton residents and officials.
5. Produce two informational videos for Charlton residents.

To accomplish these objectives, we scheduled in-person interviews with experts, and state and town officials. We conducted an online and in-person survey with Charlton residents to gauge public awareness of the contamination in Charlton, to learn where residents get their water, and to see if they are willing to connect to public water. We researched POET systems to evaluate their effectiveness at mitigating the contamination in Charlton's drinking water. This led to a list of recommendations for Charlton residents to follow, as well as recommendations for future projects. Finally, we produced informational videos identifying the implications of drinking water contamination, how to conduct well water testing, and the benefits of public versus private water supplies.

Findings

Throughout our research we discovered potential solutions for Charlton residents, as well as shortcomings in current law, resident knowledge, and science. We grouped our 8 primary findings into three subcategories to portray our findings as we understand them: issues the town faces, Charlton residents' awareness, and potential solutions for Charlton residents. We believe by researching and discovering issues, solutions, and public awareness, we will help inform officials of ways they may aid residents.

During our research we discovered issues we did not foresee. For example, **although some means of removing 1,4-Dioxane exist, there is no proven method for treating the chemical to achieve safe levels.** Carbon bed filters remove 1,4-Dioxane, but experts in water treatment are not sure how the filters are working, and they are concerned because the carbon filters barely remove enough 1,4-Dioxane to meet standards, which are subject to change (Gary Magnuson, Mark Baldi, personal communication, 2017). Another issue we found is **there is competing information regarding drinking water safety in Charlton.** Residents are concerned 1,4-Dioxane is not taken as seriously by experts as known carcinogens, while experts are concerned arsenic is overlooked by many residents. Additionally, **some Charlton residents have a misperception about the quality of public water.** Residents are hesitant to connect to public water imported from neighboring Southbridge, believing the water to be dirty city water. Local experts argue the water from Southbridge is pristine, and a tour of the Southbridge treatment facility highlighted the multitude of processes the water goes through for treatment. One of the biggest dilemmas Charlton faces is **property and contamination clean-up laws need stricter standards and enforcement.** In Charlton, home sellers are not required to test for contamination or prove their private wells are safe, so many residents may assume they are buying a safe water supply (James Philbrook, personal communication, 2017). Experts are also worried contaminant levels for 1,4-Dioxane and MtBE are set too high, arguing these levels should be lowered (Gary Magnuson, personal communication, 2017). On top of high allowable contaminant levels, these levels are only guidelines meaning the Massachusetts Department of Environmental Protection (MassDEP) may or may not act depending on the severity of the contamination (Marielle Stone, Mark Baldi, personal communication, 2017). Another concern regarding laws and enforcement is when contamination occurs: contaminators need only clean their sites, not external sites where contamination has spread (Robin Craver, personal communication, 2017).

We found a gap in residents' knowledge of Charlton's contamination, but also ways to inform residents. From our survey we found **at least one in four Charlton residents are unaware of local contamination.** Moreover, a majority of residents surveyed live by contaminated areas, but only 29% of residents surveyed believe they have been affected by water contamination. Additionally, over a quarter of residents never heard of MtBE, and a third of residents have never heard of 1,4-Dioxane. The survey results confirmed the need to combat this resident knowledge gap. **We discovered multiple methods for informing residents.** When we conducted our survey in-person we provided brochures including details about MtBE and 1,4-Dioxane, as well as Charlton's Board of Health contact information in case residents wanted to learn more. For the online format of the survey, we included links to pdf files with information on MtBE and 1,4-Dioxane. We also went on Richard "Dick" Vaughan's talk show on Charlton Community Television Channel 12 because town officials and residents stated many residents watch his show.

Although we discovered issues related to Charlton's groundwater contamination, we also found some solutions for residents. After receiving input from experts and officials, we found **certified labs are the most reliable means of testing drinking water.** Do-it-yourself kits are cheaper and more convenient, but typically do not test for MtBE and 1,4-Dioxane. Labs can test for every contaminant found in Charlton, often providing recommendations for specific filters and further steps for residents (Mark Baldi, personal communication, 2017). We also found **public drinking water is more advantageous for Charlton residents than private wells.** Residents who connect to public water would not have to pay betterment fees or connection fees if they connected to the new waterline within one year of the beginning of its operation (James Philbrook, personal communication, 2017). Residents connected to public water would only pay a quarterly fee for clean water monitored and treated by professionals, while residents with private wells have to pay for annual testing, and maintenance which may not guarantee the level of quality public water systems provide (Chris McClure, personal communication, 2017). Because public water is not available to all residents, we researched private well treatment and found **point of entry treatment (POET) systems are the most effective treatment option available for residents** with private wells who cannot connect to public water. Available POET systems meet Charlton's needs, removing MtBE, arsenic, and 1,4-Dioxane to a degree. While POET systems are less effective at treating water than public water systems, POET systems are still more effective at removing contaminants than simple filters residents may put on their taps (Gary Magnuson, personal communication, 2017).

Recommendations

We developed recommendations specifically for Charlton officials and residents to inform residents of the steps they should take to secure clean drinking water. For Charlton officials, **we recommend playing the videos we produced on local television stations, radio stations, websites, social media pages, and in schools.** The videos we produced contain information regarding Charlton's groundwater contamination, and ways residents may ensure clean water supplies. For residents with private wells **we recommend testing well water annually through professional labs certified for the contaminants present in Charlton's groundwater.** Certified labs conduct thorough testing while do-it-yourself testing kits usually do not test for MtBE and 1,4-Dioxane. For residents living along new and proposed water lines **we recommend connecting to public water.** Some water lines are shown in Figure 1 on the following page. Connecting to public water would be cheaper for residents and a better investment, as betterment and connection fees are waived, residents' property values increase, they have a clean water supply, and quarterly fees are cheaper than paying for well testing and maintenance. For residents who do not have the option of connecting to public water **we recommend installing POET systems.** POET systems are able to remove the contaminants present in Charlton's groundwater such as MtBE, arsenic, and 1,4-Dioxane. These systems are relatively expensive costing upwards of $1000 to install, but they help protect residents from contamination more effectively than typical water filters.

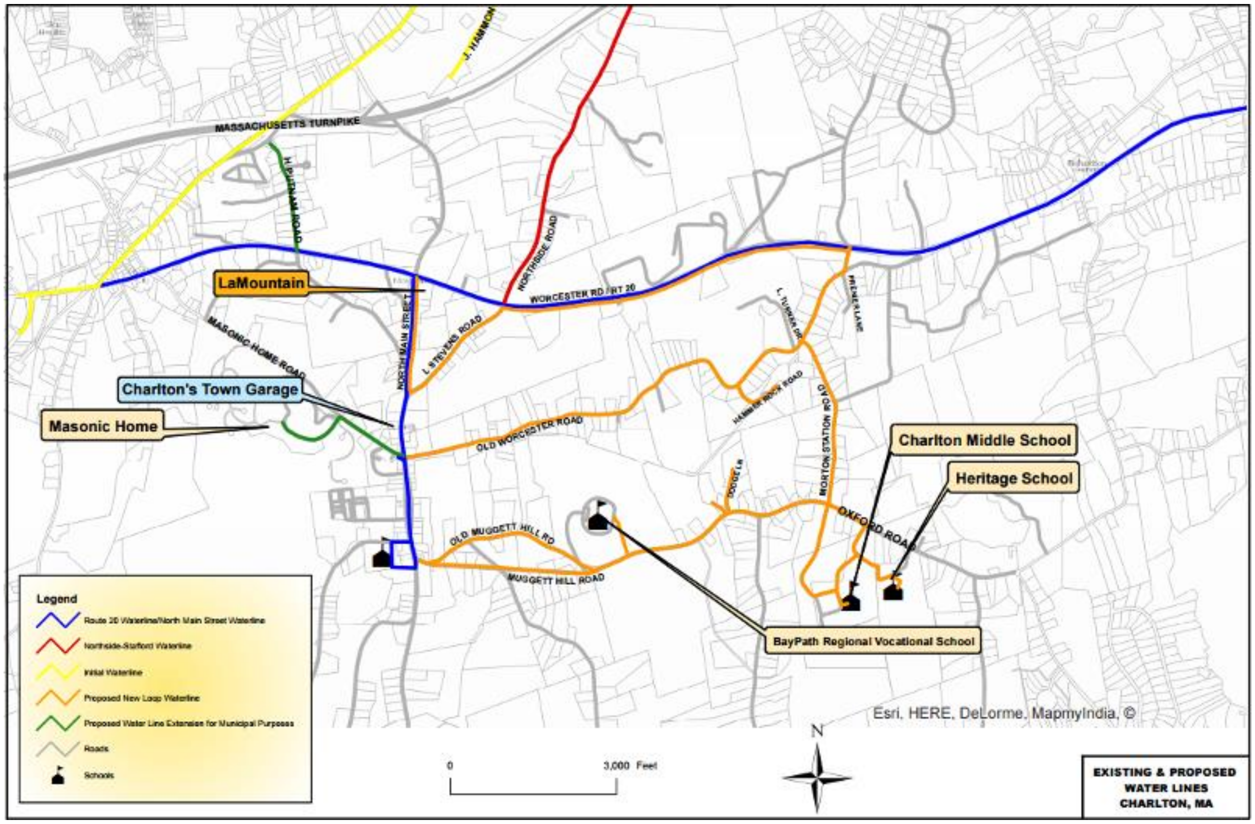

Figure 1: Existing & Proposed Water Lines Charlton, MA (ExxonMobil, 2016)

We also developed recommendations for future projects and research to help the Town of Charlton. **We recommend a future project aimed at reducing the cost of well water testing.** Town officials could survey residents to get an idea of the price residents are willing to pay for testing, and interview various labs to find price ranges for testing different contaminants. Officials would try to negotiate a lowered price with local companies to help more Charlton residents test their wells. **We recommend a future project dealing with various methods of municipal groundwater decontamination.** Researchers could focus on areas where bedrock hinders contamination removal, applying what they learn to Charlton. Tests could be run in various softwares to analyze the best methods of decontamination for Charlton. **We recommend a future project analyzing existing POET systems.** Researchers could gather information from various suppliers to compare cost, efficiency, energy consumption, contaminants removed, and other criterion to determine the best POET systems for Charlton residents. Finally, **we recommend the Town of Charlton collaborate with WPI to develop a project dealing with 1,4-Dioxane filtration.** Students could analyze carbon filters to understand how they work at removing 1,4-Dioxane, focusing on any chemical reactions taking place, analyzing system efficiency, and using what they learn to create a new system more effective at removing 1,4-Dioxane.

Conclusion

Overall, we believe our project achieved all of our goals and objectives. All of our findings are supported by both our background research and field research we conducted. Our educational component may help to inform any interested Charlton residents of the implications of the groundwater contamination in Charlton and steps they can follow to ensure clean drinking water in their homes. However, to ensure clean drinking water for all residents, more work must be done for the Town of Charlton.

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2. Importance of Clean Water	**James Gadoury**	**Edited by All**
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Objective 3: Researched strategies to identify and mitigate contamination in private wells.	**James Gadoury**	**Edited by All**
Objective 4: Developed a list of recommendations for Charlton residents and officials.	**Tristam Winship**	**Edited by All**
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3. Conclusion	**James Gadoury**	**Edited by All**

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ACRONYMS

ATC: Academic Technology Center

CSMP: Community Septic Management Program

EIR: Environmental Impact Report

HAL: Health Advisory Level

ITA: Massachusetts Interbasin Transfer Act

MassDEP: Massachusetts Department of Environmental Protection

MCL: Maximum Contaminant Levels

MtBE: Methyl tertiary-Butyl Ether

MWMA: Massachusetts Water Management Act

MWRC: Massachusetts Water Resources Commission

POET: Point of Entry Treatment

ppb: Parts per billion

SDWA: Safe Drinking Water Act

SWOT: Strengths, Weaknesses, Opportunities, and Threats

USEPA: United States Environmental Protection Agency

USGS: United States Geological Survey

VOC: Volatile Organic Compound

WPI: Worcester Polytechnic Institute

WROC: Massachusetts Water Resource Outreach Center

CHAPTER 1: INTRODUCTION

Access to clean drinking water is a basic human necessity, fundamental to our survival. Many people depend on municipalities to provide potable water to fulfill many of their hygiene and hydration needs. Typical sources of drinkable water are surface and groundwater, which can become contaminated by pollution. If this water contamination is not handled appropriately, there could be disastrous consequences for those who rely on these sources of drinking water. For example, due to a change in water sources, the drinking water of Flint, Michigan was heavily contaminated with lead in 2014. Many residents complained and reached out to their local and state governments for help, but their pleas were unanswered. As a result, an estimated 8,657 children in Flint, Michigan have been affected by the lead contamination; potentially impacting brain development (Durando, 2016). Water contamination must be taken seriously, as contaminated water causes 3.1% of all deaths worldwide (World Health Organization, 2002).

Communities typically get their water from surface and groundwater sources. Surface water is precipitation collecting in natural or manmade barriers such as dams, reservoirs, rivers, and lakes. Groundwater is found in soil and in fractures of rock formations and can be retrieved for use through a well system. Pollution threatens these resources as chemicals and pathogens can travel through soil and contaminate local water (United States Department of Health, 2010).

Contaminants can pose potential health risks for those who use ground and surface water. According to the Centers for Disease Control and Prevention (2014), contaminants in water can cause detrimental health effects such as gastrointestinal illness, reproductive problems, and neurological disorders. Outbreaks in public water systems can cause diseases such as Giardia, Legionella, Norovirus, Salmonella, and E. coli (Centers for Disease Control and Prevention, 2014). Water contamination has potentially long lasting effects on not only human health, but also on the infrastructure of the water system. Many contaminants can adhere to corroded pipes or form biofilms on pipe walls and contaminate the clean water flowing through pipes to household faucets for many years (Szabo & Minamyer, 2014). Therefore, pipes left untreated within the water system could reintroduce contaminants into decontaminated surface and groundwater.

One community currently struggling with water contamination is the Town of Charlton, Massachusetts. Due to contamination from various sources, many residents have no access to potable water from within Charlton's borders. As a result, some residents have to purchase water from the nearby Town of Southbridge (Craver, 2017). In 2017, about 8.6 percent of Massachusetts experienced extreme drought, 59 percent experienced severe drought, and 30.5 percent experienced moderate drought (Rosen, 2017). According to Chris McClure of McClure Engineering, it is not a feasible or permanent solution for one town to supply water to its own residents as well as the residents of an additional town during a drought. It is imperative to inform Charlton residents of any steps they may follow to secure potable water within their homes.

In the following chapter, we describe background information on water contamination issues and the factors affecting Charlton's specific situation. In chapter 3, we explain the methodology we used to accomplish our project goal and objectives. We discuss our research findings in chapter 4. In the final chapter, chapter 5, we provide recommendations and strategies to the town of Charlton and our closing thoughts.

CHAPTER 2: BACKGROUND

The availability of potable water, water safe for human consumption without negative health effects, is something many United States residents take for granted. Drinking water contamination is a serious issue in the U.S., despite the many laws protecting drinking water, and existing water treatment systems. This chapter introduces the situation in Charlton, Massachusetts, highlights the importance of clean water, provides examples of drinking water contamination, discusses important drinking water laws, and describes the basics of water treatment systems.

2.1 - Charlton

Charlton is a town in Massachusetts spanning 43.8 square miles, 42.5 square miles of which is land and 1.2 square miles is water. While it contains a large amount of land relative to other towns in Massachusetts, it has a small population of 13,306 (US Census, 2015). According to the town administrator, Robin Craver, Charlton has been experiencing problems with its groundwater for a long time. Some residents in Charlton receive their water from the nearby Town of Southbridge because of contamination in their local groundwater. Some issues are more serious than others, but they are all negatively affecting the community (Robin Craver, personal communication, 2017).

In 1990 an ExxonMobil gas station leak caused the release of the gasoline additive MtBE into Charlton's groundwater. According to Mark Baldi, Deputy Regional Director for the Bureau of Waste Site Cleanup in Massachusetts Department of Environmental Protection's (MassDEP) Central Regional Office, the company Casella, which owns two landfills in Southbridge, may be responsible for the release of another chemical, 1,4-Dioxane, into the environment. This led the

MassDEP to pressure Casella into providing bottled water for a number of families affected by the contamination (Southbridge Landfill, 2017). Additionally, there lies an arsenic vein beneath the town creating difficulties when homeowners attempt to dig wells and construct water lines. Lastly, there is an exposed salt shed off of Route 20 where runoff from rainwater is causing nearby pipes to become corroded from the chlorine in the salt. These multiple sources of contamination hinder the town's ability to deliver potable water within its borders. (Robin Craver, personal communication, 2017).

2.2 - Importance of Clean Water

Potable water is consumed by members of communities and towns to not only hydrate, but also to cook, clean, and shower with (United States Department of Health, 2010). In 2014 the USEPA stated individuals in the United States used an average of 75 gallons of water daily for showering, plumbing, drinking, laundry, and cleaning. Water is also vital for livestock and the production of crops. According to the United States Department of Agriculture Economic Research Service (2016), agriculture accounts for roughly 80% of surface and groundwater used in the United States. Its everyday uses make clean water a resource we must secure for current and future needs.

2.3 - Drinking Water Contamination

There are 330 million cubic miles of water on Earth, and only 2 million cubic miles of water are fresh, clean, and accessible, meaning only 0.6% of all the water on Earth can be used. Despite the limited amount we can use, many watersheds in the U.S. are being contaminated (United States Geological Survey, 2012). A watershed is defined by the United States Geological Survey (USGS) as an area of land draining "all the streams and rainfall to a common outlet such as the outflow of a reservoir, mouth of a bay, or any point along a stream channel" (USGS, 2016). Since water flows, it can pick up and carry contaminants along its path. In Kanawha County, West Virginia, total household damage costs reached $17 million in 2014 after water contamination from a nearby industrial accident (Schade et al., 2015). More medical bills, higher taxes (to fix public water issues), and increased personal costs combined, yield an economic strain on the individuals affected by water contamination (Abdalla et al., 1992). Road salt over-chlorinates surrounding watersheds, damaging wildlife habitats and potentially increasing the rate at which pipes rust. Some sources of contamination are natural; arsenic veins run through areas of New England, often directly contaminating water sources. Arsenic veins are difficult to deal with because of their size and accessibility, and arsenic is a known carcinogen (Romero et al. 2008). Oil spills and gas leaks spread potentially dangerous chemicals such as methyl tertiary-butyl ether (MtBE). Industrial sites and landfills can leak chemicals such as 1,4-Dioxane, a chemical difficult to separate from water, making filtration an issue for both towns and individuals.

2.3.1 - Road Salt

Road Salt is common in areas where snowfall occurs, such as Massachusetts, as it is frequently used to melt snow and ice on the road, allowing for safer driving conditions. The chemical name of salt is sodium chloride (NaCl). During the 1940s the average annual road salt sales in the U.S. were about 0.28 million metric tons, increasing to 16 million metric tons in 2008 (Corsi et al. 2010). This staggering jump in sales resulted in an increase in salt contamination. According to Michael Dietz, a Water Resources Professor at the University of Connecticut, salt is transported off the roads through water runoff, usually during melting periods or rainstorms, causing high levels of chlorine in soil and groundwater (Dietz et al. 2016).

Salt contamination has serious consequences on the environment. Fish kills, where localized fish populations die off, serve as indicators of water quality issues (Burton & Pitt, 2001). The presence of certain oxygen-sensitive species of fish (such as trout and bass) shows a body of water has enough food and oxygen to support large species of aquatic life. Salt at high levels can be toxic to freshwater fish (Burton & Pitt, 2001). When fish die off due to contamination, it is an indicator the contamination is reaching dangerous levels. Salt also increases the spread of rust on metal, potentially causing issues within water distribution systems by causing holes in pipes and rust contamination (Xi & Xie, 2002).

2.3.2 - Arsenic

Millions of people are exposed to arsenic through contaminated water (Naujokas et al., 2013). Arsenic enters groundwater from natural veins in the earth (Smith et al. 2000). Since arsenic is found naturally underground, the easiest way to avoid arsenic contamination is to drill wells and pipelines away from arsenic veins when possible.

Human health is severely affected by arsenic, as it is a known human carcinogen capable of causing cancer of the skin, bladder and lungs. Arsenic bioaccumulates, meaning it does not get filtered through consumers' bodies during digestion, accumulating in their bodies (Romero et al. 2008). Because of health concerns, the USEPA, pursuant to its federal Safe Drinking Water Act authority, passed regulations limiting the amount of arsenic allowable in drinking water.

2.3.3 - Methyl Tertiary-Butyl Ether

Gasoline leaks are common occurrences in the U.S. due to the abundance of automobiles and gas stations. In 2013 alone there were over 7,662 gas and oil leaks in only 15 states (Soraghan, 2014). Most gas stations use large underground tanks, thousands of gallons in volume, to store their gasoline. Since tanks are located underground, maintenance, monitoring, and clean-up are difficult compared to aboveground storage. Once a tank ruptures or leaks, the gasoline is free to flow as far as it can, often contaminating the surrounding watershed. While the gasoline alone may be simple to track and clean, its additives, especially methyl tertiary-butyl ether (MtBE), are not (Jacobs et al. 2001).

MtBE is a commonly known chemical due to its past usage as a gasoline additive with the intent of helping the fuel burn cleaner, reducing the air emissions (Jacobs et al. 2001). MtBE is 75 times more soluble in water than most other chemicals and compounds found in gasoline (Jacobs et al. 2001). For example, MtBE has a solubility of 42 g/L which is over 80 times greater than the solubility of the gasoline additive toluene, which has a solubility of 0.52 g/L (DECHEMA, 2017). This means MtBE dissolves well in water, making in-home filtration ineffective at removal as most in-home filters cannot separate highly dissolvable substances. While the U.S. does not yet recognize MtBE as a carcinogen, International Agency for Research on Cancer studies involving rats conclude otherwise, and MtBE is still known to induce nausea, dizziness, and headaches (Froines et al., 1998). Because of these health concerns, some states, such as California, have developed their own limitations on allowable levels of MtBE in drinking water (California, 2010).

2.3.4 - 1,4-Dioxane

Manufacturing companies and companies using trichloroethane during industrial processes are dumping their contaminated waste, effluent, directly into water sources. The USEPA's criminal enforcement program opened 346 new environmental crime cases in fiscal year 2010 alone (USEPA, 2010). Roughly 100 million people in the United States suffered from acute gastrointestinal illnesses in 1980, resulting in billions of dollars in medical costs and losses in worker productivity, with an estimated 6-40% of the cases due to poorly treated water (Gaffield et al., 2003).

1,4-Dioxane is a chemical created as a by-product from industrial activities, and landfills. 1,4-Dioxane is difficult to remove from water, even with high quality filtration systems. The USEPA initially set goals for 1,4-Dioxane in drinking water at relatively high levels (6.1 μg/L) because 1,4-Dioxane is not a significant toxin to aquatic organisms, and it is costly to remove (Mohr et al., 2010). However, these goals only applied to USEPA Regions 3, 6, and 9 (USEPA, 2006). The USEPA has classified 1,4-Dioxane as a possible carcinogen for people (Woodard et al. 2014). Consumption of 1,4-Dioxane causes vertigo, drowsiness, headache, anorexia and irritation of the eyes, nose, throat, skin and lungs in humans (USEPA, 1992). 1,4-Dioxane has not been proven to cause cancer because most of the industries producing 1,4-Dioxane produce other chemicals, some of which are known carcinogens (USEPA, 2014). Studies conducted in 2012 by the USEPA revealing high contamination and heightened health concerns associated with 1,4-Dioxane, resulted in the agency setting a 0.3 micrograms per liter (μg/L) Health Advisory Level (HAL) for 1,4-Dioxane (USEPA, 2012). HALs are guidelines for the maximum levels of individual contaminants deemed safe for human consumption. Putting 0.3 micrograms into perspective, one gram is 1,000,000 times bigger than a microgram, and one gram is approximately equivalent to a quarter teaspoon of sugar.

2.4 - Drinking Water Laws and Regulations

Public drinking water management systems in the United States must comply with the federal Safe Drinking Water Act (SDWA). Additionally, systems in Massachusetts must comply with the Massachusetts Water Management Act (MWMA), and the Interbasin Transfer Act (ITA). The SDWA, passed by Congress in 1973 and signed into law in 1974, ensures clean taste, appearance, and smell, and sets limits to the amount of contaminants allowed in drinking water (United States, 2004). The MWMA strives to maintain water supplies for present and future generations through limits to the amount of water to be withdrawn from a water source, as well as water lost through leaks during distribution (Massachusetts, 2013). The ITA limits the amount of water allowed to be transferred from one river basin to another, and allows the MassDEP to implement safety regulations regarding how transfers are conducted (Massachusetts, 2003). Government agencies such as the United States Environmental Protection Agency (USEPA) and the Massachusetts Department of Environmental Protection (MassDEP) pass and enforce regulations to ensure the requirements of these laws are met. Although the USEPA has jurisdiction over all U.S. drinking water, pursuant to the SDWA, the USEPA can grant states, such as Massachusetts, primacy authority if they maintain regulations and procedures no less stringent than the USEPA's (United States, 2017).

2.4.1 - Safe Drinking Water Act

The Safe Drinking Water Act and accompanying regulations establish standards for public drinking water quality. Water departments are legally required to publish an annual water quality report and send it to their consumers, allowing the public to stay informed on their water supplies. Annual reports contain information such as contaminant concentrations, water source(s), possible health effects, and any changes made to the departments' water systems (United States, 2004). The SDWA allows the USEPA to set water quality standards and monitor water suppliers implementing those standards in their management systems (Drinking Water Distribution Systems, 2006). Under the SDWA, public drinking water must meet standards, called maximum contaminant levels (MCLs), for about 80 contaminants. If public drinking water exceeds just one of these MCLs, there are consequences to ensure consumer health. The goal of the standards is to monitor public drinking water systems and determine if water, provided from these systems, is safe for public consumption (93^{rd} United States Congress, 1974).

2.4.2 - Massachusetts Water Management Act (1986)

Enacted in 1986, the Massachusetts Water Management Act (MWMA) gave the Massachusetts Department of Environmental Protection the power to regulate the amount of water (in gallons) withdrawn from surface and groundwater sources (Massachusetts, 2013). The MWMA ensures sufficient water supplies for now and for the future by setting the allowed standard for water volume to be withdrawn from an individual source at 100,000 gallons per day. This law is intended to sustain/reserve water by preventing too much water from being withdrawn at any one time, thereby attempting to preserve both aquatic ecosystems and drinking water supplies (Massachusetts, 2015b). The program may issue permits to groups drawing more than 100,000 gallons of water per day or nine million gallons in three months (Massachusetts, 2015b). Annual reports are required by those holding permits of their average monthly withdrawal information. Any violation of the permits, or any failure to comply with orders results in a civil fine. Fine values vary based on MassDEP's determinations of "the willfulness of the violation, damage or injury to the water resources and other water users, [and] the cost of restoration of the water resources" (Massachusetts, 2015a).

The MWMA also holds public water suppliers accountable for water losses during distribution. Suppliers must develop a water conservation program before applying for their permit (Massachusetts, 1996). Water suppliers must focus on meter installation and maintenance, leak detection, and reduction of water usage (Massachusetts, 1996). The MWMA is supplemented by the Interbasin Transfer Act and the Offsets Policy Regarding Proposed Interbasin Transfers.

2.4.3 - Interbasin Transfer Act and Offsets Policy

Enacted in 1984, the goal of the Massachusetts Interbasin Transfer Act (ITA) is to ensure water resources are conserved during interbasin transfers (Massachusetts, 2003). Interbasin transfers are transfers of surface water, groundwater, or wastewater outside of the water's basin of origin (Massachusetts, 2003). The Massachusetts Water Resources Commission (MWRC) approves or denies interbasin transfer applications. Interbasin transfers within the same municipality are exempt from the ITA (Massachusetts, 2003). Similar to how the MWMA is implemented, the MWRC makes sure plans to conserve water and to minimize impacts to the watershed's wildlife habitat are in place, protecting the environment as well (Massachusetts, 2003).

MWRC's Offsets Policy Regarding Proposed Interbasin Transfers (Offsets Policy for short) has the goal of minimizing the amount of interbasin transfers to prevent effects of transfers such as soil erosion, reduced stream flow, and decreased water quality (Massachusetts, 2007; Cosens, 2010). Some offsets, the actions taken to counteract an issue, include preventing contamination and water loss by repairing pipes to prevent leaks in the distribution systems and reducing demand for water through conservation efforts (Massachusetts, 2007). Environmental Impact Reports (EIR) can help determine offsets and are required, under the ITA, for any interbasin transfers greater than one million gallons per day (Massachusetts, 2003). EIRs are created by water suppliers, and contain information such as laws suppliers must follow, practices and equipment suppliers utilize, organisms and habitats suppliers may affect, and recommendations the suppliers have for future operation. The ITA and corresponding Offsets Policy are important for water utilities distributing water across river basins. Combined with the

MWMA and SDWA, these laws help protect Massachusetts drinking water. See Appendix A for a comparative chart of each law, the reason for its passage, and what it regulates.

2.5 - Water Systems

When water resources and infrastructure are insufficient, residents may fall victim to illness, buy water bottles for drinking and cleaning, and even have their homes condemned (James Philbrook, personal communication, 2017). To create and maintain sufficient water systems, municipalities must understand basic water treatment, while considering funding, size and scope of systems (i.e. regionalization), and what types of management exist.

2.5.1- Water Treatment Process

The water treatment process makes water usable for everyday uses including drinking, cleaning, washing, and irrigation. All public water systems follow the standard process for water treatment and distribution including steps such as pretreatment, pre-filtration, filtration, and chemical treatment and disinfection (Crittenden, 2012). Pretreatment uses screen filters to remove debris before the water undergoes further stages of purification (Sullivan, 2005). Prefiltration is the procedure of adding and mixing chemicals into the water, allowing for easy removal of remaining debris and particles during the pretreatment stage (Crittenden, 2012; Logsdon, 2008). Filtration uses sand belts to collect colloidal material left behind in the prefiltration stage. Depending on filtration parameters, sand type, flow velocity, filter size, the water can receive maximum or a minimum purification (Baruth, 2005). In the last stage, the removal of vestige chemicals from previous stages and the sanitization of the water takes place (Agardy, 2005). Disinfection can be brought about in the form of ultraviolet radiation care or chemical affixing. The water treatment process helps ensure safe drinking water for human consumption.

2.5.2 - Funding Water Systems

Monitoring, protecting, and disinfecting water distribution systems is expensive, so running a water treatment system requires ample funding. Sound financial practices are key in providing sufficient funding for keeping a water system functioning. Some basic financial considerations include setting reserve levels, and balancing rate affordability with pricing to encourage judicious water use (USEPA, 2016). Capital costs and operating costs of water systems are paid for by government agencies, private companies, and residents.

Funding Capital Costs

Capital costs are initial costs on an investment, similar to a down payment made on a new house. Communities without significant funding invariably turn to the federal government or their state government for capital funds for water infrastructure (Lachman et al., 2016). Within Massachusetts, the Massachusetts Clean Water Trust, Massachusetts State Revolving Fund, and Massachusetts Water Management Act help provide such assistance. An estimated 97% of Massachusetts residents have benefited from these projects. In fiscal year 2016, the Trust provided binding commitments for 36 clean water projects, including the Community Septic Management Program (CSMP) totaling $191 million, and 14 drinking water projects totaling $49 million (Trust, 2016). In one specific instance, the Town of Plymouth during the winter of 2015/2016, experienced sewer infrastructure failure in several locations causing health emergencies. Thanks to the Clean Water State Revolving Fund, the town was authorized $48.2 million to provide construction of a new sewer system (Trust, 2016). Residential property taxes may be increased for months to years to pay off capital costs. After capital costs are paid off, taxes may decrease to simply meet operating costs, or be appropriated to another section of the water system budget (Lachman et al., 2016).

Funding Operating Costs

After water systems have been built, operating costs are levied on consumers through a few methods. Operating costs include chemical and material costs for the system, costs for new filters, labor costs, distribution costs, and facility costs. Communities with water departments in their town budgets pay for operating costs through taxes, usually property taxes. Tax-funded water systems must share a budget and resources with other agencies in town, sometimes leading to conflicts in management. Rates are based on many variables including water supply, and consumption. Rate-funded systems have the advantage of remaining independent of the town budget and politics (Stiegler, 2002).

2.5.3 - Regionalization

Regionalization involves structural maintenance and institutional change for struggling water systems similar to water and wastewater utility services. Regionalization reflects structural change in terms of consolidating water utility ownership, operations, or management within a geographic area (Beecher, 1996). Some considerations of water systems can include sharing resources or services between the regionalized entities (Adams, 1973). This is where the physical combination of water systems includes interconnecting water systems, or a merger of all the water systems under one new entity (Beecher, 1996).

Regionalization has its advantages and disadvantages. Sharing resources provides many benefits. One benefit is regionalization improves the quality of the water supplied (Hurd, 1979). A second benefit is it decreases the cost of output water by increasing the amount of the output (Hurd, 1979). Despite these benefits there is a fear of relinquishing control over a water supply to a larger political body and there is the need for a reasonable proximity of service areas (Hurd, 1979). With today's competition for growth, disputes over how to control the regional entity and cost of facilities come about causing a disadvantage in regionalization (Hurd, 1979). Furthermore, as analysed by Dr. Robert Raucher, a noted expert on matters of water resource management, even though “nonstructural approaches are less expensive, offer some cost savings through efficiency gains, and are relatively simple to setup (or exit), the fear of losing local autonomy may be enough to limit the popularity of such arrangements” (Raucher, 2004).

2.5.4 - Types of Water System Management

A few methods of water management exist: public, fully private, and a public-private partnership. Public systems may use either the rate-payer system, or taxpayer system, as municipal and/or state governments manage the water systems. Private systems are wells for individual homes or neighborhoods, owned and run by the individuals living there, as well as systems run by companies who must compete with other companies to provide water at a low price while still maintaining profit. Public-private partnerships are when municipal governments own the water source, while a private company treats and distributes the water. This final method allows the town to keep taxes low and maintain ownership of their water while handing the burden and responsibility of running a water system to companies (Agranoff, 2003).

2.6 - Raising Awareness

The public must always be aware of issues related to their well-being, so information on Charlton’s water contamination, and possible solutions, must be made available and useful to residents. Residents have the right to know what is in their drinking and water, and why it matters. To inform residents, we developed an accurate understanding of the situation ourselves. This was done through interviews, surveys, and research. Interviews were conducted with experts, town officials, and state agencies. We distributed surveys to the residents of Charlton to gauge the public’s awareness of the situation. From this information, we developed recommendations for Charlton residents to obtain potable water within their homes, compiling our results into informational videos. The following chapter details the steps we followed to inform residents.

CHAPTER 3: METHODOLOGY

Our project goal was to inform Charlton residents on implications of Charlton's water contamination, methods of independent water testing, the benefits of connecting to town water, and approaches for Charlton residents to decontaminate their private wells. To accomplish this goal, we developed the following five objectives:

1. Assess Charlton's drinking water sources, methods of well testing, and treatment.
2. Gauge public awareness of Charlton's drinking water contamination.
3. Research strategies to identify and mitigate contamination in private wells.
4. Develop a list of recommendations for Charlton residents and officials.
5. Produce two informational videos for Charlton residents.

To achieve all five objectives, we conducted interviews and surveys, analyzed the content of water quality reports and other documents, and created a detailed map, incorporating our findings into a proposed solution for Charlton residents to tackle water contamination. In the following sections of this chapter, we discuss each objective and the corresponding tasks we used to accomplish each objective.

Objective 1: Assessed Charlton's water sources, methods of well testing, and treatment.

To achieve this objective, we conducted in-person interviews with the list of contacts provided to us by the Town Administrator of Charlton, Robin Craver. We used a semi-structured interview style to have some flexibility with the flow of the interviews (Bailey, 2007). This type of interview was the best fit because it allowed the interview to flow naturally, without forcing it to go in any certain direction. We also used this style when we conducted additional interviews to fulfill this objective. The questions for these interviews can be found in Appendix B. Completing interviews with many different departments and offices in Charlton and Massachusetts helped triangulate what we found, validating information from multiple sources.

Some of these contacts were Andrea Briggs and Marielle Stone from the Massachusetts Department of Environmental Protection, or MassDEP; James Philbrook from the Charlton Board of Health; and Chris McClure from McClure Engineering. We asked them questions about their respective knowledge of the water contamination in Charlton, how it is affecting the community and environment, and different technologies to potentially tackle water contamination. These interviews gave us expert input on the sources and effects of the contamination. During and after these interviews, we constructed and analyzed data tables, graphs, charts, and maps related to Charlton's water contamination.

We mapped the water contamination sources, contaminated streets, and areas of concern. We based this map on existing maps of Charlton and edited them in Microsoft Paint. The map includes all of the point sources, wells, and areas of contamination in the Town of Charlton we gathered from our sources. This map was needed not only to further our own knowledge, but as a tool for increasing the public awareness aspects of the water contamination.

Objective 2: Gauged public awareness of Charlton's drinking water contamination.

After we analyzed the information from the interviews with experts and town officials, we surveyed Charlton residents to gauge the public's awareness of Charlton's water contamination issues. We distributed this survey in-person at Ted's Package Store in Charlton, the Market Basket in Oxford, and the Senior Center in Charlton's town hall. We also created an online survey using Qualtrics, which we distributed on Charlton's town website, and Facebook. The strategy behind this was to pull information from many groups of Charlton residents, with each group having been affected differently by the contamination (Berg & Lune, 2012). With many wells and areas of the town being affected by different contaminants, at different levels, this gave us a greater understanding of a larger population's view of the situation.

We had several questions we wanted answered in our survey with Charlton residents. First, we wanted to know whether or not people are aware of where their home tap water comes from. We asked residents to specify if they use town water (imported from Southbridge) or a private well. These questions helped us establish a baseline of how informed town residents are about the source of their water.

We also asked if they believed they had been affected by water contamination. We provided the residents a list of the streets known to be affected by water contamination and asked them if they live on, or adjacent to, any of these streets. If they believed they had been affected by the contamination, they were then asked to define how. This helped us to understand how many people think water contamination in Charlton is a problem. Please see Appendix B and Appendix C for the Interview and Survey Questions respectively.

The survey helped us better understand what residents know as well as what we needed to cover in the informational portion of our project needed to cover. Since the residents of the town only had a general understanding of the problems with their water, we focused on the health aspects of the contamination, well costs, town water, independent well testing, and ways they may move forward in order to obtain clean water.

Objective 3: Researched strategies to identify and mitigate contamination in private wells.

Using our findings from Objective 1, we researched the following: point of entry treatment (POET) systems identified by engineers and the MassDEP, connecting to town water as a method of obtaining clean drinking water, and methods of well testing such as certified lab testing. The POET systems we researched utilize carbon filters and resin beds. We investigated different suppliers of these systems to get a basic understanding for each type of identified POET system. We searched the MassDEP's website to compare different certified labs and what contaminants each lab tests for.

We analyzed town water connection and different POET systems based on their effectiveness in mitigating the impact of Charlton residents' drinking water contamination. Our analyses consisted of identifying the strengths, weaknesses, opportunities and threats (SWOT) of the systems identified (David, 2011). We also analyzed the costs of town water and POET systems, through the funding required to implement them. We compared the long-term costs for town water with the costs POET systems entail. We compared the cost in time and energy it would take to implement each system

After analyzing costs, we looked at benefits. We researched to see how many types of contaminants can be neutralized or removed as well as how much potable water can be filtered daily by the POET systems. We then compared these benefits with the benefits related to a town water supply. We analyzed the labs based on the contaminants they test for, their precision, and their reviews. The purpose of this approach was to provide a rich body of information to aid decision-makers faced with difficult investments, thus creating a general economic argument supporting the investment (Benefit- cost analysis, 2009). By using cost benefit analysis, we were able to see if the POET systems are good investments (Benefit- cost analysis, 2009).

Objective 4: Developed a list of recommendations for Charlton residents and officials.

Using our findings from objectives 1-4, we developed recommendations for how Charlton residents could improve the quality of their drinking water. Our recommendations were based on our findings of Charlton's water sources in objective 1, our findings on public awareness from objective 2, and our findings on strategies and related analyses in objective 3.

After we gathered information on the status of Charlton's water sources, we analyzed the data. Using the map we produced, we highlighted the areas most heavily affected by contamination as well as the areas with the safest water supplies. The water source data also informed us on what contaminants are in the water, and at what levels. This information helped shape our recommendations.

Once we knew the primary issues with Charlton's water sources, we chose the most effective solutions to provide residents potable water based on costs, contaminants removed, and convenience to residents. In objective 1 we asked professionals for their input regarding how often residents' private wells should be tested, if connecting to town water would be more cost-effective for residents than using private wells, and if residents do not live along the water line, what types of POET systems they should install on their wells. These systems were then weighed in objective 3 to give better understanding on pros and cons. Our recommendations also include costs, perceived repairs and maintenance, operating costs, feasibility, and sizing. The recommendations served as options for Charlton residents, including how they may move forward in their attempts to decontaminate their water.

Objective 5: Produced two informational videos for Charlton residents.

Using the information obtained from objectives 1-4 we developed the first video to explain the implications of Charlton's drinking water contamination, technologies and strategies used to conduct independent water testing, and our recommendations to mitigate the impact of Charlton's drinking water contamination, developed in objective 4. The intended audience of the video was residents of Charlton, over 18 years of age, so they might push for legislation and other governmental changes in their town, and inform their family members if they do not already know. We reported our findings in an accessible manner so residents of Charlton would not be bogged down by legalese or scientific lingo (Penn-Edwards, 2012). We also produced a second video introducing the water reservoirs and treatment facility in the neighboring Town of Southbridge to show the cleanliness of the water imported from Southbridge to Charlton residents. This video was directed towards Charlton residents living along two separate water lines being installed by Casella and ExxonMobil. These residents expressed uncertainty about whether they wanted to tap into the available public water.

We filmed these videos throughout Charlton. We created storyboards and shot lists early in the project to get a sense of direction and film technique. Early video content was discussed with town officials as well as Jim Monaco of WPI's Academic Technology Center (ATC) for feedback and guidance on filming. Between interviews and surveys, we took zooming, panning, and focus-changing shots of the town, as these clips were simple and added artistic/entertainment value. We also filmed our talking points in Charlton, to give viewers a sense of familiarity. We based the script on our findings, keeping a clear, consistent vocabulary level throughout. We quieted any background music when speaking to reduce distractions from speech. We utilized various transitions, but not enough for the videos to feel hackneyed. We filmed using a mixture of equipment and our phones. After principal filming, we used Camtasia Studios to edit the film, as this software is free to WPI students. We consulted with Jim Monaco of WPI's ATC for questions involving filming and editing, and consulted with Robin Craver and James Philbrook for feedback on the content of the videos.

CHAPTER 4: FINDINGS

We spent many days during this project at Charlton's town hall working with James Philbrook, Health Director in Charlton, and Robin Craver, Town Administrator of Charlton. We already had an understanding of Charlton's contamination, the sources of the contamination, and what the town has done to solve the issue (see chapter 2 section 1), but after gathering data obtained from our field research we found even more issues with Charlton's drinking water contamination. We grouped our findings into three themes: drinking water contamination, public awareness, and solutions. This chapter details the findings we developed.

4.1 - Drinking Water Contamination in Charlton

Throughout our project, we gathered data regarding Charlton's contamination culminating in the following four findings. These findings detail issues we had not foreseen at the start of this project. Some of these issues are minor and may be solved by distributing educational videos, while other issues require further work from officials and experts.

Finding 1: There is no proven method for treating 1,4-Dioxane.

During interviews with various officials and experts, we were told no proven method exists for treating 1,4-Dioxane. Mr. Philbrook explained the filters meant for removing MtBE are also removing 1,4-Dioxane, but they are not supposed to. In three separate interviews, Gary Magnuson of CMG Environmental; Chris McClure of McClure Engineering; Andrea Briggs, Deputy Regional Director of the Massachusetts Department of Environmental Protection's (MassDEP) Bureau of Administrative Services; Mark Baldi, Deputy Regional Director of MassDEP's Bureau of Waste Site Cleanup; and Marielle Stone, Deputy Regional Director of

MassDEP's Bureau of Water Resources, all of MassDEP's Central Massachusetts Region, confirmed Mr. Philbrook's statement.

All of these experts agree 1,4-Dioxane is being removed from the water during carbon filtration, however, not enough research has been conducted to explain how or why this occurs, causing concerns of 1,4-Dioxane build-up on the filter, potentially released at dangerous levels if the filter fails. The filters also do not remove enough 1,4-Dioxane to lessen officials' concerns; the filters remove just enough 1,4-Dioxane to meet the current standard of 0.3 ppb. The MassDEP lowered drinking water standards for 1,4-Dioxane in 2011 when more information on its health effects was found, and if they lower standards again, carbon filters may not remove enough 1,4-Dioxane to meet standards (Marielle Stone, personal communication, 2017).

Ms. Briggs, Ms. Stone, and Mr. Baldi noted there is potentially effective technology for removing 1,4-Dioxane in Arizona and California, but there is not enough research to implement the technology for a whole town. This technology, Trojan Systems, remove high concentrations of 1,4-Dioxane at low levels of water flow, but homes have high water flow so the technology needs improvement (Mark Baldi, personal communication, 2017).

Finding 2: There is competing information regarding drinking water safety in Charlton.

Throughout our research we discovered competing information regarding Charlton's drinking water contamination. While some town officials, local experts, and residents are primarily worried about MtBE and 1,4-Dioxane, some MassDEP officials believe arsenic is a larger threat to Charlton residents. Mr. Philbrook, and Mr. Magnuson argued MtBE and 1,4-Dioxane are poison, even if the chemicals are not listed as carcinogens by the USEPA, so they must be removed from the aquifer as soon as possible. Mr. Baldi recognizes the danger of MtBE and 1,4-Dioxane, but argued arsenic is a more important chemical to focus on, because it is a known carcinogen and it bioaccumulates in consumers' bodies (Mark Baldi, personal communication, 2017).

Two Charlton residents, Marc and Melissa Widing, expressed concern with 1,4-Dioxane in particular. The Widings learned they had unsafe levels of 1,4-Dioxane in the fall of 2015, and have dealt with the impact ever since. The Widings live in Charlton near the Southbridge landfill, the alleged source of the town's 1,4-Dioxane contamination. Because they live within a half mile radius of the landfill, there home was tested every 3 years until 2015 when their water was found to have high levels of 1,4-Dioxane. Since the Widings learned of their well's contamination, Casella has been sending the family 15 cases of bottled water per month, as well as 5 gallon jugs for a water cooler. Although the bottled water is a safe supply for drinking, it is inconvenient to try to make pasta by emptying a bunch of water bottles. Showering with water bottles is impractical and so is cleaning laundry, so the Widings still use their well for these purposes. Two of the Widings' dogs have passed away over the course of 8 years, which they believe may be linked to the 1,4-Dioxane in their water. Having dealt with 1,4-Dioxane first hand, the Widings believe the chemical should be a top priority for the town. The Widings believe 1,4-Dioxane may be more dangerous than experts believe because not enough research has been conducted on its human health effects (Marc and Melissa Widing, personal communication, 2017). The Widings noted how 1,4-Dioxane is treated in a similar manner as asbestos was treated in the early 20th century; asbestos was also used in many industries even though its negative health effects discovered as early as 1899 (Luus, 2007). After hearing Mr. Baldi's professional opinion and the story of the Widings' struggles, we had difficulty deciding whether we should focus more on 1,4-Dioxane and MtBE because they are more prevalent in Charlton, or arsenic because many Massachusetts residents are unaware of its prevalence in the state. We chose to highlight all three contaminants in the educational video because all three pose health risks.

Finding 3: Some Charlton residents have a misperception about the public water quality.

From our surveys, we found Charlton residents have a misperception regarding water imported from neighboring Southbridge. Of the residents we surveyed who owned private wells, less than ⅓ would be willing to connect to public water. Mr. Philbrook stated many residents are wary of Southbridge water, because the notion city water is dirty and smells bad. During our in-person survey, a few residents confirmed Mr. Philbrook's statement, saying the water from Southbridge is polluted and has poor quality. Mr. Philbrook stated Southbridge has a state of the art treatment facility producing pristine water (James Philbrook, personal communication, 2017). Many local and state officials agree with Mr. Philbrook's statement, so we toured the treatment facility to investigate further. WhiteWater, the company treating Southbridge's water, described in great detail how the water is treated to meet all drinking water standards (WhiteWater, Inc., personal communication, 2017). We could not find evidence supporting the belief Southbridge water is dirty, but we addressed their concerns in the second video.

Finding 4: Property laws and contamination clean-up laws need stricter standards.

An important recurring theme we found throughout our project was the need for stricter laws, and regulations. According to Ms. Briggs, Mr. Magnuson, and Mr. Philbrook, new homes do not require testing for MtBE and volatile organic compounds (VOCs) before they are bought and sold (Gary Magnuson, Andrea Briggs, James Philbrook, personal communication, 2017). This means homes within Charlton who have not been tested for MtBE, 1,4-Dioxane, and other VOCs can be bought and sold. Homebuyers do not typically worry about testing their well water for VOCs, and the idea was foreign to us when Mr. Philbrook explained it. Mr. Magnuson also believes tighter regulations, whether passed by the town, state, or federal government, could require homeowners to prove their wells meet all maximum contaminant level goals before selling them, or at least inform potential buyers whether the home has been tested or not.

The USEPA may also set the contaminant guidelines too high. Mr. Magnuson and Mr. Philbrook believe the current limit for MtBE of 70 parts per billion (ppb) should be lowered to around 20-40 ppb. They argue just because a contaminant is below a certain level does not mean the contaminant is harmless (Gary Magnuson, James Philbrook, personal communication, 2017). Humans can smell MtBE at levels as low as 25 ppb, leading experts to push for lowered limits to reduce concerns over scent. These proposed levels of 20-40 ppb may also be too high, as guidelines for both MtBE and 1,4-Dioxane changed when new evidence of their health effects was published (Gary Magnuson, James Philbrook, personal communication, 2017).

We also found the limits to MtBE and 1,4-Dioxane are not strict formulas easy to enforce, but rather guidelines set by states. Because the USEPA does not have maximum contaminant levels (MCLs) for MtBE and 1,4-Dioxane, state agencies do not have to enforce strict standards. When MtBE and 1,4-Dioxane reach levels at or above standards, the MassDEP may choose how to act: whether to continue monitoring, or require treatment and clean-up (Mark Baldi, personal communication, 2017). Because the enforcement is case by case, there is room for error in allowing some homes to continue living with low levels of contaminants.

According to Ms. Craver and Mr. Philbrook, Massachusetts General Law Chapter 21J also lacks provisions regarding contamination clean-up. Ms. Craver and Mr. Philbrook state when contamination sources are found, only the site the contamination is leaking from is required to be cleaned by the contaminating party. According to Mr. Baldi the soil around the former LaMountain Gas Station was completely cleaned of gasoline and its additives by Exxon, but because law did not require clean-up outside of the LaMountain site, MtBE spread as far as

Heritage Elementary School, as shown in Figure 2 below (James Philbrook, Mark Baldi, personal communication, 2017).

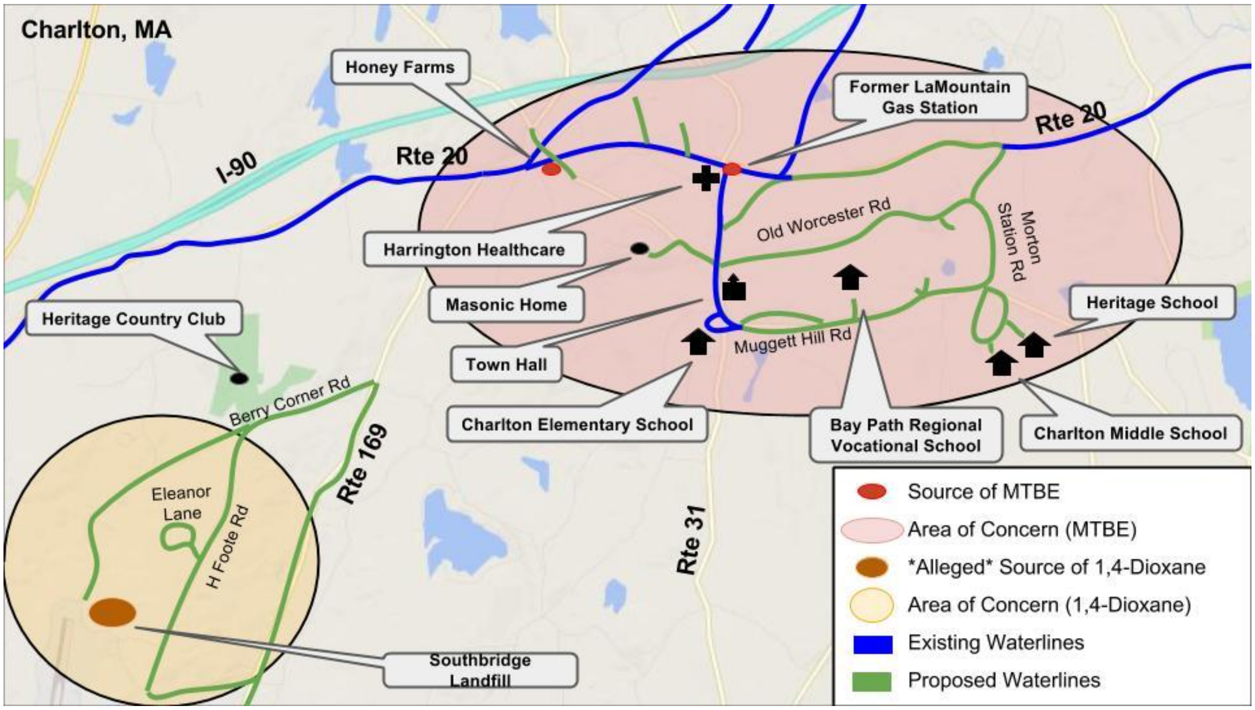

Figure 2: Areas of Concern and Waterlines, Charlton, MA

4.2 - Public Awareness

After speaking with officials, experts, and residents, we developed a strategy for how to educate residents, and learned what many residents know, or do not know, about Charlton's groundwater contamination.

Finding 5: At least one in four Charlton residents are unaware of local contamination.

In all of our interviews we were encouraged to inform as many Charlton residents as possible of the contamination, its impact, and steps to obtaining clean water. Before we developed the educational videos we conducted a survey to get a basis for what residents are aware of. Mr. Philbrook estimated 60-70% of residents know about contamination in Charlton (James Philbrook, personal communication, 2017). Two-thirds of the 141 residents who completed our survey live on or near affected streets, and of those residents only ⅓ believe they have been affected by water contamination. Out of all 141 residents surveyed, only 29% believe they have been affected by contamination, as shown in Figure 3 below. We were surprised when we found only 26% of the 141 residents surveyed never heard of MtBE, and 32% never heard of 1,4-Dioxane. Since at least two thirds of all the residents surveyed know of MtBE or 1,4-Dioxane, Mr. Philbrook's estimate was accurate. These results indicate a majority of residents have heard of Charlton's contamination but are unaware of the location of the contamination.

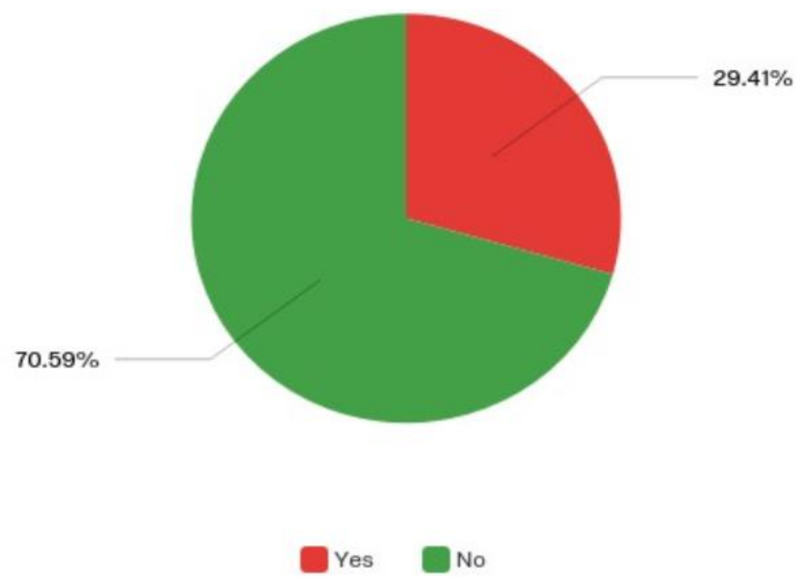

Figure 3: Results for the Question "Do you believe you have been affected by water contamination in Charlton?"

Finding 6: There are multiple effective methods for informing residents of contamination.

Charlton is a geographically large but sparsely populated town with over 42 square miles of land but less than 14,000 residents (US Census, 2015). Because of the rural makeup of the town, and we needed to make sure we could reach out to residents. During our research we found there are many useful methods for informing residents. For example, we supplied brochures detailing MtBE and 1,4-Dioxane while we conducted our in-person survey. We decided to use brochures during our survey because we believed asking questions was not enough to inform residents. Many Charlton residents and residents of neighboring towns were interested in the brochures, with one third of individuals we surveyed taking brochures home for their friends and family. These brochures were helpful because they allowed residents of other towns to stay informed as well as allow Charlton residents. To view the brochure, please see Appendix F. We also included links at the end of our online survey to pdfs providing more information on 1,4-Dioxane and MtBE, to replace the brochure we used for in-person surveys. Since 141 residents were interested enough to complete the survey, we believe a majority of the surveyed residents read the pdfs. Another method we found to inform residents was going on a talk show. Richard "Dick" Vaughan has nearly 60 years of experience with radio programs, and according to Mr. Philbrook and Ms. Craver, many Charlton residents watch his show on Charlton Community Television Channel 12 (Robin Craver, James Philbrook, personal communication, 2017). Mr. Vaughan records his show then airs it all day long, including the early morning, allowing residents to see our conversation at whatever time is most convenient for them.

Informational Videos

The most important method we used to inform residents was creating two informational videos. Instead of requiring residents to read a brochure or a pdf, these videos explained every aspect of our findings from contamination to solutions. These videos will be posted on the town website, and aired on Charlton Community Television Channel 12, to inform as many residents as possible.

In our first video we identified the effects of Charlton's water contamination on the community. We also discussed existing technologies and strategies to conduct independent water testing in one's home and possible solutions they could implement to mitigate any water contamination found. After watching the video, Charlton residents should understand basic information on how to test their drinking water as well as find further resources for POET systems and their town water supply.

In the second video, we tried to encourage Charlton residents to tap into the water lines by explaining the methods Southbridge uses to ensure clean drinking water. These methods were discovered in our interview and tour with a WhiteWater engineer who explained how the water treatment system in Southbridge works. We also broke down the costs and benefits of tapping into the water lines versus maintaining their own private wells. Our interviews with professionals such as Mr. McClure gave us insight into many of these costs and benefits, which we included in the video to provide residents analyses.

4.3 - Solutions for Charlton Residents

While we conducted our research, we spoke with environmental protection agents, civil engineers, environmental engineers, and town officials who have dealt with water contamination. We recorded and considered everything they told us, and developed key findings on independent water testing, the connection to public water, and methods of treating private wells.

Finding 7: Certified labs are the most reliable means of testing drinking water.

The contamination in Charlton covers a large area of land, from the south-western border, to the center of town. Because of the widespread contamination, we wanted expert advice on how residents may test their private well water. Mr. McClure, Mr. Magnuson, and Mr. Philbrook overwhelmingly supported lab testing of water as opposed to using simple in-home testing kits. Mr. McClure and Mr. Magnuson stated while in-home kits may inform residents of contamination, the kits do not test for 1,4-Dioxane and MtBE, the chemicals the kits do test for are often not reported in quantities but rather the presence or absence is reported, and kits range in price from $20 to over $500, which can be more expensive than having a certified lab test your water (Chris McClure, Gary Magnuson, personal communication, 2017).

Lab testing is done by private companies who charge upwards of one hundred dollars for testing specific contaminants (Mark Baldi, personal communication, 2017). Labs may test for arsenic, MtBE, 1,4-Dioxane and other VOCs. Labs report contaminant levels quantitatively and may recommend certain filtration systems if contamination is found. Some labs, such as Advanced Water Quality in Charlton, test wells for free if the homes lie within contaminated areas. Additionally, residents who own wells within a half mile of the Southbridge Landfill receive well testing paid for by Casella (James Philbrook, personal communication, 2017). For a comparative analysis of different types of testing, see Table 1 below.

Water Testing Kits	Certified Lab Testing of Water
Do not test for MtBE and 1,4-Dioxane	Can test for both MtBE and 1,4-Dioxane
Does not provide expert input	Conducted by experts who may provide input
Qualitative results	Quantitative results with explanation
Costs $20 - $500+	Costs $100+

Table 1: Comparison of Testing Methods

Finding 8: Public water is more advantageous for Charlton residents than private wells.

According to Ms. Craver and Mr. Philbrook, ExxonMobil and the Town of Charlton settled out-of-court to build new water lines throughout areas affected by MtBE contamination. Additionally, Casella and the Town of Charlton are discussing plans to build water lines for areas affected by 1,4-Dioxane. ExxonMobil has agreed to waive connection fees and betterment fees for residents who connect to the new line within a year of the start of its operation. This means residents would only have to pay a quarterly fee to the Town of Charlton for clean water, similar to paying an electricity bill. Residents who own private wells are advised to test their wells at least once a year, replace filters, and maintain their wells, which may cost thousands of dollars when attempting to remove specific contaminants such as 1,4-Dioxane and MtBE. For example, carbon bed systems have capital costs exceeding $2000 (Gary Magnuson, personal communication, 2017). MtBE and 1,4-Dioxane are also more expensive to remove, requiring carbon filters which do not remove all the 1,4-Dioxane present in wells. The public water, imported from Southbridge, is routinely monitored for safety and quality. If residents connect to town water, they will not have to deal with the hassle of testing and maintaining private wells as shown in Table 2 below.

Private Wells	**Public Water**
Must remember to test and take care of maintenance	Water is monitored everyday.
POET system installation costs upwards of $3000 for systems Charlton residents may need.	No connection costs or betterment fees for Charlton residents.
$100- $300 Annual Testing Cost.	All costs are included in the quarterly fee of $100-$120
Total Annual Costs can exceed $500	Annual Costs range from $400-$480

Table 2: Private Wells vs Public Water Comparison

Another issue involved with low public water usage is blowoff bills. According to Mr. Philbrook the town had to pay blowoff bills because water sits too long in the pipes as not enough residents are connected to the line. This costs about $50,000 each time the water lines are cleaned. If more residents connected to town water, the town would not have to flush the system so frequently (James Philbrook, personal communication, 2017). Additionally, Mr. Philbrook and Ms. Craver believe business along Route 20 would greatly improve if a water supply was added along the route. Businesses are sprawling along Route 20 in Sturbridge and Oxford, but within Charlton, where there is no water supply, business is much lower (Robin Craver, James Philbrook, personal communication, 2017).

Finding 9: POET systems are the most effective well treatment option for residents.

According to the MassDEP, Mr. Philbrook, Mr. McClure, and Mr. Magnuson, if Charlton residents have contamination in their wells but they do not live along the new and existing water lines, they should install point of entry treatment (POET) systems. POET systems may have many different filters for various contaminants, but the two most useful to Charlton residents are carbon bed and resin bed filters. Resin bed filters remove arsenic while carbon bed filters remove MtBE, VOCs, and some 1,4-Dioxane (Mark Baldi, James Philbrook, Chris McClure, Gary Magnuson, personal communication, 2017).

POET systems may not be a feasible option for everyone because they cost several thousand dollars to install and can cost a few thousand more to maintain over a lifetime. For some residents, POET systems are the only effective solution available. There needs to be more work done in the town of Charlton to provide more solutions for residents who are unable to afford the appropriate POET system for the contamination present in their wells.

CHAPTER 5: RECOMMENDATIONS

Our research led us to creating several recommendations for both the Town of Charlton, and for future Worcester Polytechnic Institute (WPI) projects. We divided our recommendations into two categories: recommendations for Charlton officials and residents, and recommendations for future research. In this chapter we list short-term and long-term recommendations to combat Charlton's contamination.

5.1 - Recommendations for Charlton Officials and Residents

We developed recommendations aimed at aiding Charlton residents. We incorporated recommendations for Charlton into videos for residents allowing officials to inform residents who are unaware of Charlton's contamination issues, or residents who want more information on obtaining clean water. These recommendations include distributing the informational videos, testing private wells, connecting to public water if possible, and installing POET systems.

<u>Recommendation 1: Distribute Informational Videos</u>

The informational videos we produced contain important information for Charlton residents regarding local groundwater contamination, its impacts, and ways they may mitigate those impacts. The video should be seen by as many Charlton residents as possible in order to spread awareness and encourage residents to take action towards ensuring they have a clean water supply. We recommend playing these videos on local television stations, radio stations, websites, social media pages, and in schools.

<u>Recommendation 2: Test Well Water</u>

After receiving expert advice on water testing and researching their advice for ourselves, we recommend residents have their private well water tested through certified labs. Although lab testing costs roughly the same as using in-home testing kits, labs test for more chemicals, test more precisely, provide clearer results, and may give you advice on what further steps should be taken if contamination is found. The MassDEP's website lists certified testing labs, allowing viewers to refine their search by contaminants to test for, state, region, and lab name.

Recommendation 3: Connect to Public Water if Possible

After analyzing the pros and cons for both private wells and public water supplies, we recommend all Charlton residents connect to public water if they live along areas where new water lines are being installed. According to town officials, betterment fees and connection fees will be waived for residents living along new lines, reducing the cost to connect to public water. Residents who connect to public water will no longer have to worry about the costs and inconvenience of changing filters, and testing and maintaining their own wells. Instead, residents will only have to pay a quarterly fee which incorporates all costs related to water treatment and consumption. Connecting to public water will also raise residents' property values. Public water may also help improve Charlton's economy, specifically along Route 20, where new businesses would have clean water supplies to grow. On top of the economic and financial factors, public water systems are routinely monitored and treated, as laws require, ensuring a safe and lasting supply.

Recommendation 4: Install POET Systems

Although the area of concern for contamination is large, only certain sections of town are receiving new water lines. For Charlton residents who do not have the opportunity to receive public water, or for residents who wish to keep their wells, we recommend installing point of entry treatment (POET) systems. Local companies are capable of providing POET systems suitable for residents' needs: carbon bed filters remove MtBE, volatile organic compounds

(VOCs), and 1,4-Dioxane, while resin bed filters remove arsenic. Some of these companies, such as WhiteWater and Millennium, are already maintaining Bay Path, and Charlton Middle Schools' water supplies until the schools connect to town water.

5.2 - Recommendations for Future Research

The town officials of Charlton have their hands full with contamination issues, on top of their routine duties operating the town government. Our project goal was to inform Charlton residents on the contamination in Charlton, how residents may test and treat their wells, and the benefits of tapping into town water if residents had the option. During our time working at the Board of Health we developed a positive relationship between Charlton and WPI which could lead to future cooperation, and projects. Future WPI projects in Charlton may go even further than ours in attempting to solve Charlton's main issue: water contamination. We created a list of recommendations detailing ideas for future projects, whether they are conducted by WPI students or professionals in relevant fields.

Recommendation 5: Charlton Well Testing Price Reduction

During our research we found well water testing can be expensive, with prices exceeding $100 per test, and experts recommending at least annual testing. We believe it is detrimental to avoid well water testing in order to save some money since testing is necessary to ensure residents' safety. We feel town officials could address the issue of cost by negotiating lower lab testing costs with companies near Charlton. Town officials could survey Charlton residents on how often they test their wells, their concerns regarding their wells, their willingness to test their wells, and the price they are willing to pay. Officials would then speak with various local and regional companies who provide testing to find a range of prices, what the companies test for, and if the companies would be willing to lower the prices for Charlton residents if more residents went through their company. After gathering data on the prices residents would be willing to pay, prices companies offer, and how many residents would realistically test, officials could try to create competition between companies to provide the lowest price. A lowered price would be extremely beneficial to Charlton residents, allowing more residents to test their wells, and test their wells more often, making sure their water is safe to drink. If their tests reveal water is not safe to drink, at least they would know what chemicals they need to have filtered rather than ignoring the possibility of contamination and its related risks altogether.

Recommendation 6: Methods of Municipal Groundwater Decontamination

One particular project we believe would benefit Charlton is researching and analyzing methods of groundwater decontamination. Researchers familiar with groundwater contamination, geology, civil engineering, and chemistry could work together to look at techniques being used to decontaminate groundwater. They could focus on areas where bedrock is an issue so they might apply what they learn to Charlton. During this project, researchers could run simulations on different modeling softwares to find effective solutions for Charlton. Researchers could work alongside professionals, and government officials to create new step-by-step methodologies and technologies to decontaminate groundwater. Along with the Town of Charlton, sponsors might include the MassDEP, the USEPA, and environmental consulting companies.

Recommendation 7: POET System Analysis

Another project to help the Town of Charlton would be an analysis of existing POET systems. Researchers would analyze existing POET systems, speaking with representatives from multiple suppliers to get input as to what contaminants are filtered, how much water can be processed, how much maintenance costs, how often maintenance is required, and what typical prices are. This data would be collected run through cost-benefit analysis, and SWOT analysis (strengths, weaknesses, opportunities, and threats) regarding each system's relevance to Charlton's contamination. Following detailed analyses, the best system will be selected and recommended to town officials, giving them a fact-based answer to which system they should recommend.

Recommendation 8: Analysis of Carbon Filters for Removing 1,4-Dioxane

One of the most important facts we learned was carbon filters work to remove 1,4-Dioxane, but no one is sure why. One or more WPI project groups could research carbon filters and how they work, as well as 1,4-Dioxane and its characteristics. Once they understand this information, they would run tests with water contaminated by 1,4-Dioxane through carbon filters. During tests they would analyze the amount of 1,4-Dioxane before and after the water is filtered, how often the filter needs replacement, any chemical reactions or phenomena occurring during testing, and how much water can be processed daily. Students would also examine current testing methods to see if these methods properly test for 1,4-Dioxane, or if the methods are ineffective. This project would provide much needed research into 1,4-Dioxane as experts are uncertain why carbon filters appear to filter 1,4-Dioxane to begin with.

5.3 - Conclusion

At the beginning of this project, we had little knowledge of the implications of groundwater contamination and how it affects people relying on groundwater for their wells. We know groundwater contamination is a serious issue as a result of multiple factors. Contaminants can travel far and wide, affecting many wells over time. Not only do these contaminants travel far, but they can also be difficult to remove from water sources used by local residents. For instance, 1,4-Dioxane is very soluble in water and is potentially harmful to human health in concentrations as low as 0.3 ppb. Groundwater contamination can also go unnoticed or unregulated since the regulations governing water contamination are reactionary, rather than proactive.

We were also unaware of how complicated the interactions between local government, state and federal government, and corporations are. Government agencies have to regulate corporations and ensure they take responsibility for their actions. In the case of groundwater contamination, agencies such as the MassDEP have to supervise corporations who pollute groundwater with waste or chemicals. Through this supervision, the MassDEP enforces regulations and ensures these corporations take action to remove the contamination and help people who are negatively affected. Local government has to ensure the people who are negatively affected are heard and considered by these corporations and government agencies. Each one of these groups have their own agendas and people who they answer to, which makes these interactions a long and tedious process.

A lot of work still needs to be done for the town of Charlton. More research is necessary on MtBE and 1,4-Dioxane, since their negative health effects are unclear and the regulations on their contamination levels are not strictly enforced. It is insufficient to label these contaminants as possible carcinogens because Charlton residents are potentially suffering due to the lack of research. Experts should look into whether or not the 1,4-Dioxane is being removed from tap water with carbon filters because there is no science supporting this as of 2017. Because many Charlton residents are unsure if their tap water is safe to drink and use, the town requires more research to ensure the mental and physical well-being of its residents.

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APPENDICES:

Appendix A: Comparative Summary of Laws

Law	Reason for Passage	What it Regulates
Federal Safe Drinking Water Act (1974)	To create enforceable, national standards to combat water contamination. At the time of passage, water regulation was handled at the state, county, and/or municipal level.	Creates mandatory maximum levels for over 80 water contaminants. Grants the USEPA authority to regulate and enforce, but states may self-regulate so long as the state's drinking water regulations and procedures are more stringent than those used by the USEPA.
Massachusetts Water Management Act (1986)	To ensure adequate water supplies for current and future needs.	Requires permits for water withdrawals over 100,000 gallons per day, or 9 million gallons over 3 months. Permit holders must report operational changes, plan to conserve, and report withdrawal amounts.
Massachusetts Interbasin Transfer Act (1984)	To assure any transfer of water from a basin is done in a way protecting the water-dependent resources of the donor basin.	Requires permits for interbasin water transfers, with few exceptions. Requires transferring parties to report their processes, and water conservation plan.

Table 3: Comparative Summary of Laws

Appendix B: Interview Questions

Preamble:

We are a group of students from Worcester Polytechnic Institute (WPI) working on a project with the Town of Charlton. We are conducting this interview in order to learn more about the contamination in Charlton as well as possible solutions. Your participation is completely voluntary and you can choose to end the interview at any point. If you would like, we can keep your identity confidential. We greatly appreciate your participation. If you would like, we can provide you with our final project report.

Potential Interview Questions for Officials

1. How long have you worked for [X]?
2. What are your concerns about the groundwater contamination [or specific contaminant]?
3. Do you think anyone should be held accountable for the groundwater contamination [or specific contaminant]?
4. Who is affected by the groundwater contamination [or specific contaminant]?
    a. How are they affected?
5. Where is the contamination located?
    a. What wells/streets are affected?
6. Do you have any maps outlining the water sources and contaminated areas?
7. In your experiences, are there any strategies or ideologies to follow when working with small town water systems?
8. Do you know of any towns or cities with similar situation as Charlton?
9. What are the current costs involved in treating, distributing, and acquiring water?
10. What could be done to help Charlton provide potable water within its borders?
11. What do you think would be a viable solution for Charlton's water contamination problem?
12. Has the water contamination in Charlton affected economic growth?
13. What is the allowable ballpark budget maximum, i.e. how much could a new solution cost?
14. Where do you see future economic development in Charlton?
15. [X] is one of our ideas to improve the water quality. Do you see any holes in our logic we need to consider?
16. What are some of the drawbacks with implementing [X] idea?
17. If this model were to be implemented, what are the steps necessary for its success?

Appendix C: Survey

We are a group of Worcester Polytechnic Institute (WPI) students working with WPI's Water Resource Outreach Center (WROC) and the town of Charlton to investigate resident knowledge of Charlton's groundwater quality. Your answers will be very helpful to our research. All answers will be confidential. You are welcome to contact us at any time through wrocers@wpi.edu. You can reach our faculty advisors: Corey Dehner through cdehner@wpi.edu and Derren Rosbach through drosbach@wpi.edu. Thank you for your time.

1. Are you 18 years or older?

	Yes
	No

2. Are you a Charlton resident?

	Yes
	No

3. Do you live on, or adjacent to, any of these streets?

Ayers Road	Berry Corner Road	Bond Road	Brookfield Road
Burlingame Road	Carpenter Hill Road	Cemetery Road	Center Depot Road
Dodge Lane	Eleanor Lane	Flint Road	Freeman Road
Gillespie Hill Road	H. Foote Road	H. Putnam Extension	L. Stevens Road
L. Turner Road	Main Street	Maple Street	Masonic Home Road
Morton Station	Muggett Hill Road	North Main Street	Northside Road
Old Muggett Road	Old Worcester Road	Oxford Road	Power Station Road
Prenier Road	South Sturbridge Rd	Stafford Street	Worcester Road

	Yes
	No

4. Do you know where your in-home tap water comes from?

	Town water (imported from Southbridge)
	Private well
	Not sure

5. If you use a private well, would you be interested in connecting to town water?

	Yes
	No
	Unsure
	I have town water

6. Are you satisfied with the quality of your in-home tap water?

	Very Satisfied
	Somewhat Satisfied
	Not Satisfied

7. Are you satisfied with the __________ of your tap water?

Taste	Smell	Look	
			Yes
			No
			Sometimes
			I do not know

8. Do you believe you have been affected by water contamination in Charlton?

	Yes
	No

   a. If you answered yes above, in what ways have you been impacted by water contamination in Charlton? (Check all applicable ways)

	Psychologically
	Physically
	By property value
	By cost (any expenses)
	By the environment
	Other

9. Have you heard of ________ ?

MtBE	1,4-Dioxane	
		Yes
		Somewhat
`		No
		Maybe, I'm not sure

10. Are you aware of the presence of _______ in Charlton's groundwater?

MtBE	1,4-Dioxane	
		Yes
		Somewhat
		No
		Maybe, I'm not sure

11. Are you aware of the impact of _______ on Charlton residents?

MTBE	1,4-Dioxane	
		Yes
		Somewhat
		No
		Maybe, I'm not sure

Appendix D: Informed Consent Form

Investigators: Jacob Grealis, Blake Rice, Tristam Winship, James Gadoury

Contact Information:
Jacob Grealis: Tel. 978-590-1536, Email: jmgrealis@wpi.edu
Blake Rice: Tel. 203-871-7815, Email: brice@wpi.edu
Tristam Winship: Tel. 603-563-4077, Email: twinship@wpi.edu
James Gadoury: Tel. 508-353-9022, Email: jgadoury@wpi.edu

Title of Research Study: Drinking Water Contamination in Charlton: Education and Solutions
Sponsor: Town of Charlton

Introduction:
You are being asked to participate in a research study. Before you agree, you must be fully informed about the purpose of the study, procedures to be followed, and any benefits, risks or discomfort you may experience as a result of your participation. This form presents information about the study so you may make a fully informed decision regarding your participation.

Purpose of the study:
The purpose of this study is to identify aspects of the drinking water contamination the Town of Charlton is facing and potential technologies and strategies to mitigate the contamination. We will prepare a comparative analysis for each available solution which may help Charlton improve its water quality and meet its current and future water demands.

Procedures to be followed:
Before each interview, we will have each of the participants sign a written consent form. During this process, one member of our group will read our prepared preamble to introduce the participants to the purpose of the activity. Once we gain permission to continue our research activity from each willing participant, we will begin the interview or focus group with any initial questions or brief overview of completed research. The main goal of these interviews is to obtain their input and any data they have on Charlton's contamination. If the participants are unwilling to answer specific questions, for any reason, they will not be pressed further on the question.

Risks to study participants:
If we uncover any incidental findings potentially leading to enforcement action by the MassDEP, these findings may prove to be detrimental to the subject's reputation. Depending on the subject's connection to these findings, enforcement actions or any other actions to address the situation will be taken as the MassDEP sees fit.

Benefits to research participants and others:
Participants in our research will not receive any individual benefits. The Town of Charlton can expect to have solution(s) to choose from when implementing a new water plan in their town. These solutions would have the goal of removing contaminants from Charlton's groundwater as well as supplying municipal water to residents.
Record keeping and confidentiality:

Records of your participation in this study will be held in confidentiality so far as permitted by law. However, the study investigators, the sponsor or it's designee and, under certain circumstances, the Worcester Polytechnic Institute Institutional Review Board (WPI IRB) will be able to inspect and have access to confidential data identifying you by name. Any publication or presentation of the data will not identify you. If we, the investigators, wish to use your name in our publication or presentation, we will ask for your written consent to do so, which you retain the right to allow or deny.

Compensation or treatment in the event of injury:
This research does not involve any risk of physical injury or harm to the participant. You do not give up any of your legal rights by signing this statement.

For more information about this research or about the rights of research participants, or in case of research-related injury, contact:
WPI IRB Chair, Professor Kent Rissmiller: Tel. 508-831-5019, Email: kjr@wpi.edu
University Compliance Officer, Jon Bartelson: Tel. 508-831-5725, Email: jonb@wpi.edu
For contact information of the Investigators, please refer to the top of this document.

Your participation in this research is voluntary. Your refusal to participate will not result in any penalty to you or any loss of benefits to which you may otherwise be entitled. You may decide to stop participating in the research at any time without penalty or loss of other benefits. The project investigators retain the right to cancel or postpone the research activities at any time they see fit.

By signing below, you acknowledge you have been informed about and consent to be a participant in the study described above. Make sure your questions are answered to your satisfaction before signing. You are entitled to retain a copy of this consent agreement.

____________________________ Date: ____________________
Study Participant Signature

____
Study Participant Name (Please print)

_____________________________________ Date: ____________________
Signature of Person who explained this study

Appendix E: Written Consent Form

I, ______________________________, give my permission for the Drinking Water Contamination in Charlton: Education and Solutions project group to identify me by name and position title in their final project report. I reserve the right to withdraw this permission at any time via written and verbal communication with the project investigators.

___________________________ Date: ___________________

Study Participant Signature

____

Study Participant Name (Please print)

Appendix F: Informational Brochure

Independent Water Testing Locations:

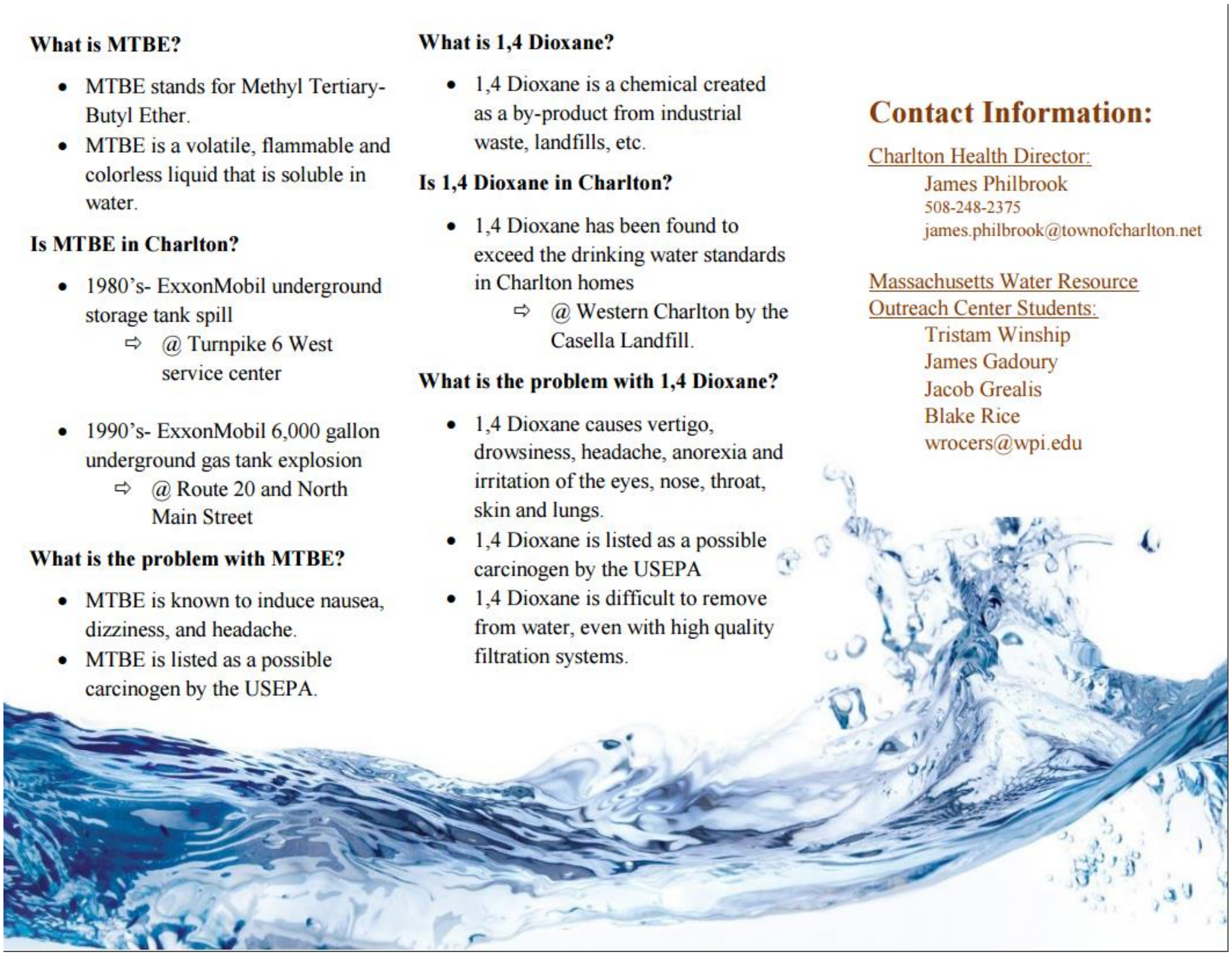
1. Go to this website: http://public.dep.state.ma.us/Labcert/Labcert.aspx
2. Enter search criteria
   - Lab location (state or region)
   - Contaminate of concern
3. Click Search to see Lab Testing location

Additional Information

- MTBE: https://www.cancer.org/cancer/cancer-causes/mtbe.html
- 1,4-Dioxane: https://www.atsdr.cdc.gov/phs/phs.asp?id=953&tid=199

Fill out a survey online located on the Town of Charlton Website

Figure 4: Outside of the Informational Brochure (from right to left: front page, back page, right fold)



What is MTBE?

- MTBE stands for Methyl Tertiary-Butyl Ether.
- MTBE is a volatile, flammable and colorless liquid that is soluble in water.

Is MTBE in Charlton?

- 1980's- ExxonMobil underground storage tank spill
  - ⇨ @ Turnpike 6 West service center
- 1990's- ExxonMobil 6,000 gallon underground gas tank explosion
  - ⇨ @ Route 20 and North Main Street

What is the problem with MTBE?

- MTBE is known to induce nausea, dizziness, and headache.
- MTBE is listed as a possible carcinogen by the USEPA.

What is 1,4 Dioxane?

- 1,4 Dioxane is a chemical created as a by-product from industrial waste, landfills, etc.

Is 1,4 Dioxane in Charlton?

- 1,4 Dioxane has been found to exceed the drinking water standards in Charlton homes
  - ⇨ @ Western Charlton by the Casella Landfill.

What is the problem with 1,4 Dioxane?

- 1,4 Dioxane causes vertigo, drowsiness, headache, anorexia and irritation of the eyes, nose, throat, skin and lungs.
- 1,4 Dioxane is listed as a possible carcinogen by the USEPA
- 1,4 Dioxane is difficult to remove from water, even with high quality filtration systems.

Contact Information:

Charlton Health Director:
James Philbrook
508-248-2375
james.philbrook@townofcharlton.net

Massachusetts Water Resource Outreach Center Students:
Tristam Winship
James Gadoury
Jacob Grealis
Blake Rice
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Figure 5: Inside of the Informational Brochure