Water System Sustainability Study

Final Report

Prepared for:

Dover, Massachusetts

Issue Date:

March 2024

CDM Smith

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Section 1

Introduction

This report documents the Water System Sustainability Study conducted by CDM Smith to provide short- and long-term recommendations for the future improvement of the Town of Dover's (the Town's) drinking water sustainability. CDM Smith was contracted by the Board of Selectman (BOS) in July 2022, to conduct a study that includes the following tasks:

- Review historical information,
- Gather local input through stakeholder and public meetings,
- Perform an engineering evaluation and develop a prioritized list of sustainable water supply alternatives,
- Prepare conceptual level cost analyses for three selected alternatives, and
- Present cost analysis and recommendations to the BOS to inform future water supply solutions and future financial planning.

The intent of this study is to provide water recommendations that address all Dover residents, including existing public water systems (PWS), private well systems, and other small and/or private water systems in Dover. A driver for the request to perform this study and why it continues to be a priority for the BOS is the multitude of water quantity and quality resident complaints in recent years. As part of this study work, CDM Smith conducted multiple stakeholder meetings, during which participants provided helpful insight by sharing ideas and inquiring on topics under consideration as part of this study. The feedback demonstrated that despite considerable efforts by community members and governing officials to address water supply concerns, some residents may be unfamiliar with the publicly available information, improvements made and ongoing efforts.

This section summarizes the project background with the intent of clarifying important elements related to the Dover water supply, an outline of remaining report sections is summarized below:

- Section 2 – User Groups and Franchise Area
- Section 3 – Population Projections and Water Demands
- Section 4 – Evaluation Criteria and Alternative Identification
- Section 5 – Comparative Analysis of Alternatives
- Section 6 – Conceptual Cost Analysis
- Section 7 – Recommendations and Conclusions

1.1 Project Background

The Town of Dover is located in Norfolk County, Massachusetts, and home to approximately 5,923 residents according to the 2020 United States Census (US Census). Dover is located southwest of Boston, along the south banks of the Charles River. A map of the Massachusetts official river basins (**Figure 1-1**[1]**)**, shows most of Dover lies in the Charles River Basin, except for the southeastern corner of Dover which is in the Boston Harbor Basin. The Town is approximately 15 square miles (mi^2) and bordered by the communities of Natick, Wellesley, Needham, Dedham, Westwood, Sherborn, Walpole, and Medfield. Dover was identified in the 2020 US Census as one of the wealthiest Towns in Massachusetts, with a median household income of more than $250,000. Like many local Town governments, the BOS are elected and serve as the chief executive body for Dover. Additionally, residents can volunteer and contribute their time towards the betterment of the Town of Dover. Many volunteers actively participate in government affairs by serving on community Boards, Commissions, and Committees.

[1] Kleinfelder. (2020). Town of Dover Hydrology Study. https://www.doverma.gov/DocumentCenter/View/1089/Kleinfelder-Report-3-2020-1

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PLATE 2
Hydrography and Environmental Map

Dover, MA

FIGURE
1-1

For this study, CDM Smith reviewed historical water supply information provided by Dover, which demonstrates the Town's significant concern and actions regarding the sustainability, quality and reliability of the current and future water supply. Through the efforts of multiple Dover committees, boards and Town staff, Dover has taken steps to better understand and address water quality and quantity concerns for all residents. Highlights of recent actions include:

- **2015:** the Dover BOS established a Water Resources Study Committee (WRSC, or Committee) to address water resources concerns, which was transitioned over to the Dover BOH in 2017.
- **2007 – 2017**: According to MassDEP records, 134 wells have been removed from service, drilled deeper, or hydrofracked to resolve water quantity concerns. The Board of Health (BOH) is concerned about recent cases of private well owners needing to perform work on wells to increase yield.
- **2018 – 2020:** The BOH engaged Kleinfelder to conduct a hydrology study of the local water source to identify, map, and monitor the Town's water resources with a goal of establishing a baseline for water conditions. Monitoring wells, piezometers and stream gauges were installed as part of this work, the final report is publicly available online via the Town website[2].
- **2020- 2021:** CDM Smith was engaged by Dover to prepare a Town-owned water assets inventory and valuation as well as to prepare a new geographic information system (GIS) for the Town-owned water infrastructure.
- **Summer 2021:** Observed water quality concerns in the public water supply system included both color and E. Coli contamination events in the water distribution system owned and operated by Colonial Water (since purchased by Aquarion Water Company). In June 2021, the Massachusetts Department of Environmental Protection (MassDEP) responded to approximately 30 complaints regarding discolored water from residents. Discoloration is typically associated with elevated iron and/or manganese concentrations in well water, plus iron from corroding pipe walls in unlined cast iron mains. DEP issued a Statement of Deficiency and Colonial presented a Corrective Action Plan to address the issues.
- **Winter 2021 – August 2023**: The Town Administration and the MassDEP are continuing to advocate for improved water supply practices and service from private water supplier Aquarion Water Company to address Dover resident water quality complaints. Aquarion has presented the progress of current actions and future steps to improve water quality and water conservation[3]. Aquarion is implementing their proposed corrective actions and

[2] The 2020 Kleinfelder report can be found on Dover's website: https://www.doverma.gov/DocumentCenter/View/1089/Kleinfelder-Report-3-2020-1

[3] Two presentations from Aquarion on current actions and future steps can be found on Aquarion's website: https://aquarion-prod.azurewebsites.net/community/dover-update/docs/default-source/community/dover/August-18-2022-Selectmen-Presentation and on Dover's website: https://www.doverma.gov/DocumentCenter/View/2134/Aquarion-January-2022-update-?bidId=

keeping the DEP and Dover informed as to progress through presentations at BOS meetings.

- **May 2022**: The BOS passed a mandatory water restriction bylaw for all residents, with an update to by-law enforcement actions in August 2022. The bylaw approval was a culmination of the concern regarding the severe drought conditions, the desire to protect the water supply resources, and the community's overall desire to practice sustainability[4].

- **July 2022:** CDM Smith was hired to prepare a Water System Sustainability Study (the subject of this report).

- **2020 – Current:** Dover water personnel in collaboration with the Dover Water Resources Committee and local volunteer efforts have continued the collection of monitoring well data from groundwater wells installed in 2020[5]. The Water Resources Committee updates their website page with frequently asked questions (FAQ's) and other useful water resource documents[6].

- **November 2023:** In late 2023, the Town authorized CDM Smith to initiate work on an Aquifer Resilience assessment whereby historic data including precipitation, temperature and groundwater water levels are being used, in conjunction with climate change models, to simulate future groundwater response of the aquifer serving wells within Dover. Results from that work will be summarized in a memorandum included in Appendix C of this report. appended to the larger Report.

1.2 Water Supply Withdrawal, Conservation and Sustainability

Public water suppliers must operate their systems under the provisions of the Massachusetts Water Management Act (WMA), which is implemented by the Massachusetts Department of Environmental Protection (MassDEP). The WMA established a permitting program to govern water withdrawals by public water suppliers and other entities which withdraw water at rates above a specified threshold. These withdrawal permits are issued to PWS and limit the annual average withdrawal and the maximum day withdrawal for respective River Basins. The permits have extensive water conservation and demand management requirements, as well as performance standards on residential water use and unaccounted-for water. Both Aquarion and the Dover PWS hold WMA permits (for their respectively owned water systems) that they must adhere to be in compliance.

The conservation-related requirements in the WMA permits are coordinated with the Massachusetts Water Conservation Standards, most recently updated in 2018. These standards are published by the Massachusetts Water Resource Commission (MWRC). As stated by MWRC in the introduction to the standards, "The 2018 Standards reflect new thinking and include reasonable, practical and common sense approaches to help us better use water in a manner that increases efficiency, ensures sustained water supply to meet increasing demand, and protects the environment. The Standards provide guidance on the most current conservation measures, bring

[4] Water restriction by-law can be found on Dover's website: https://www.doverma.gov/625/Water-Restriction-Bylaw
[5] Monitoring data can be found on Dover's website: https://www.doverma.gov/592/Monitoring-Wells-Dashboard
[6] The Water Resource Committee's homepage can be found on Dover's website: https://www.doverma.gov/504/FAQs-and-Resources

greater awareness to all user groups about water use and water waste, strengthen our infrastructure, and move us forward toward more efficient water use."

Seasonal droughts have been declared in recent years as seen in **Figure 1-2** and **1-3** below, with Dover being in the Northeast drought region on the maps. The changing climate contributes to increased durations without precipitation (droughts) and increased temperature. Other water stressors include increased development and water demand by an increasing population. The underlying theme of this report is to explore sustainable, alternative options to supplement Dover's water supply in the future. A sustainable source should incorporate social equity, environmental stewardship, and economic stability.

The primary metric in the Dover water solution is to keep all users at or below the Massachusetts Conservation guidance threshold of 65 gallons per capita (per person) per day (GPCD) of water use. A goal for all water users is for the sustainable use of the source water and to follow best water management act practices. To achieve this, improved communication and wide-spread partnerships with all water users (including private well owners, public water supply customers and all public water suppliers) is needed to meet future sustainability goals.

Sustainability is a frequently used word that may be interpreted differently. For this study, the definition of sustainability, includes the long-term reliability of the Dover water supply as well as opportunities to improve water stewardship among all users and to recommend sustainable water investments. CDM Smith has worked with many clients to improve their water sustainability and stewardship. Detailed recommendations for such are included in the short- and long-term alternatives presented in this report.

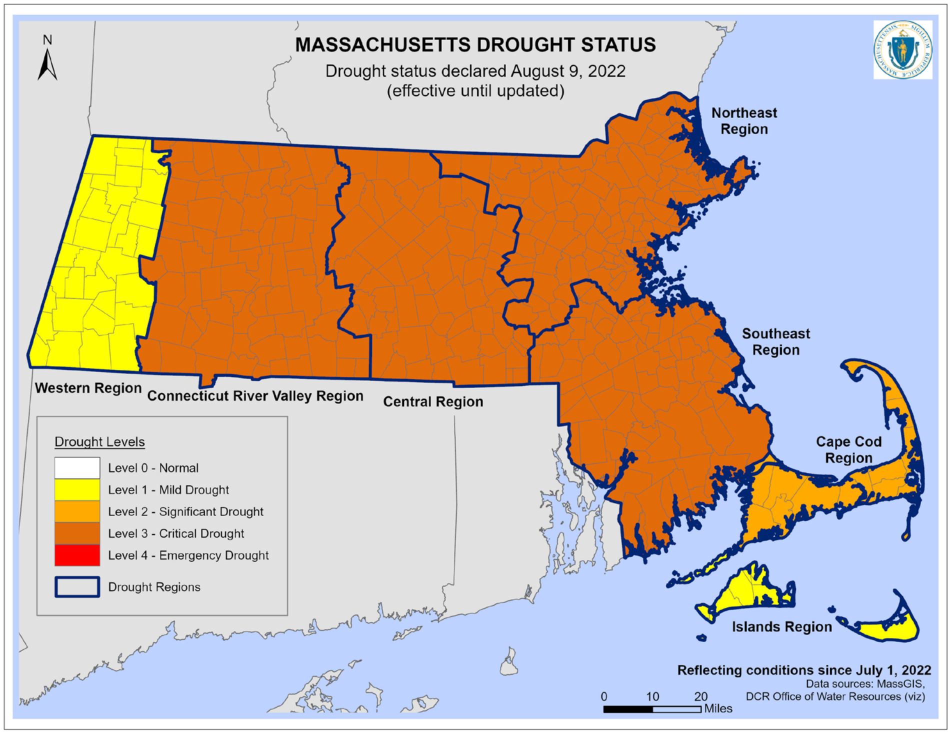

Figure 1-2. 2022 Massachusetts Drought Status - Dover, MA in "Level 3 – Critical Drought"(Source: Commonwealth of Massachusetts Office of Energy and Environmental Affairs)

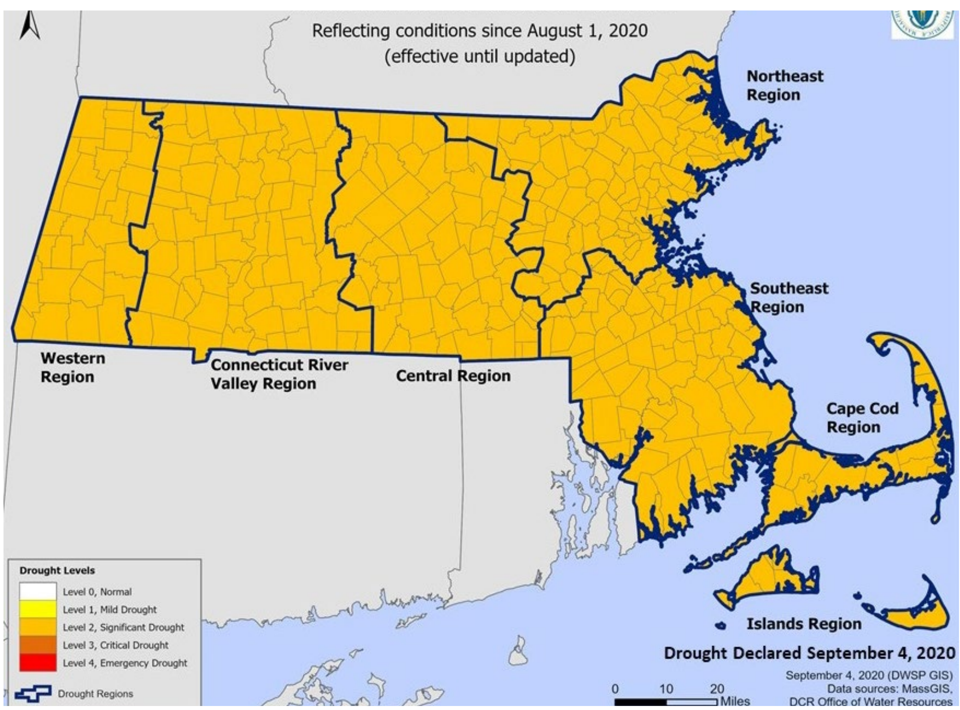

Figure 1-3. 2020 Massachusetts Drought Status - Dover, MA in "Level 2 –Significant Drought" (Source: Commonwealth of Massachusetts Office of Energy and Environmental Affairs)

1.3 Project Purpose

Collectively, the actions outlined in Section 1.1 are positive steps toward improved water supply sustainability and will be helpful to this study in the development of long-term solutions. To develop a sustainable water supply solution, it is important for the residents of Dover to understand how aquifers function and the complex factors that can impact groundwater water supply quantity and quality. This section will describe aquifer function and the overall Dover water supply.

1.4 Overview of Water Supplies and Aquifers

In this section, CDM Smith has included a summary of important terms that will be used throughout the report to inform individuals who may be unfamiliar with water resources and the hydrologic cycle. It is important to note that the term 'River Basin' is used in this section and refers to the MWRC-regulated entities that have a permitted withdrawal allowance for PWS. Whereas the term aquifer(s) is used as a general hydrology term defined in subsequent sections. These definitions are intended to support the fundamental concepts portrayed in this report and offer clarity as to the important role that all Dover residents play as it pertains to the shared aquifers.

When rain falls on the ground, it can travel in one of three directions:

- **Surface Water**: Some water flows over the land surface in the form of streams and rivers, and can collect in ponds, lakes, wetlands, or reservoirs. Factors that influence the amount of rain that flows over the land surface include the imperviousness of the land, the slope of the land, the time of year, and the amount of water already underground in the shallow soils.

- **Groundwater**: Some water infiltrates ground surfaces that are permeable, such as lawns, fields, and forests. The water may penetrate only the upper layer of soil (the "surficial aquifer"), or it may flow into deeper aquifers, including those in fractured bedrock. Underground aquifers function as storage reservoirs that can be depleted naturally or through withdrawals, and also replenished by rain or snowmelt, a process commonly referred to as "recharge."

- **Evaporation**: Some of the water flowing either as surface water or shallow groundwater will evaporate. This can occur directly depending on air temperature and saturation, or it can happen in the form of evapotranspiration, in which shallow groundwater is absorbed by plants and returned in part to the atmosphere.

Freshwater may be accessed from either surface water or groundwater. Surface water is typically drawn from streams or impounded reservoirs. Groundwater sources typically involve drilled and dug wells to access water beneath the Earth's surface. Groundwater is found in rock and soil pore spaces and fractures in deeper rock formations. Water moves through pores and cracks until it reaches a depth where all of the spaces in the openings of the soil(s)/rock are filled, which is called the saturated zone. The water in this saturated zone is called groundwater. The aquifer is the saturated soil/rock. **Figure 1-4** displays how the hydrologic cycle impacts groundwater and an aquifer's role in drinking water supply.

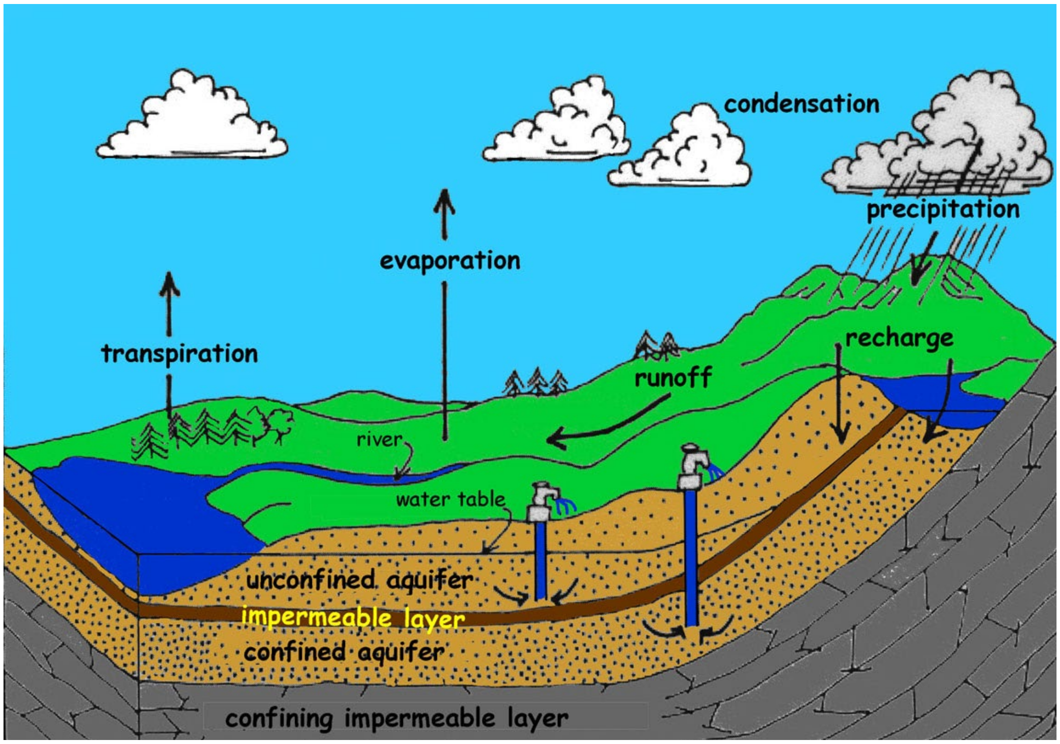

Figure 1-4. The Water Cycle and Groundwater Relationship (University of Georgia, 2002)

Aquifers are layers of saturated rocks and unconsolidated materials containing freshwater. In Dover, all residents receive water from the Boston Harbor and Charles River Basins, by tapping into the groundwater supply through wells. **Figure 1-5** presents a hydrogeology map of Dover, the coarse glacial sand-and-gravel deposits which form Dover's major (non-bedrock) aquifer(s) are shown by the orange coloring.

N
0 0.125 0.25 0.5
Miles

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PLATE 1
Hydrogeology Map

Dover. MA

FIGURE
1-5

Most aquifers are naturally recharged by the natural water cycle; rainfall, snow melt, and surface water infiltrate the ground in recharge zones. However, every aquifer recharges at a different rate and if demand is greater than recharge, then aquifers can deplete over time, which then impacts drinking water supplies. Aquifer depletion without adequate recovery can lead to challenges with respect to drinking water treatment and contamination, which ultimately impacts public health. **Figure 1-6** presents a cross-section view of an aquifer. While this cross section is not representative of typical aquifers in New England, it has been included to depict the slow timescale of groundwater flow and recharge.

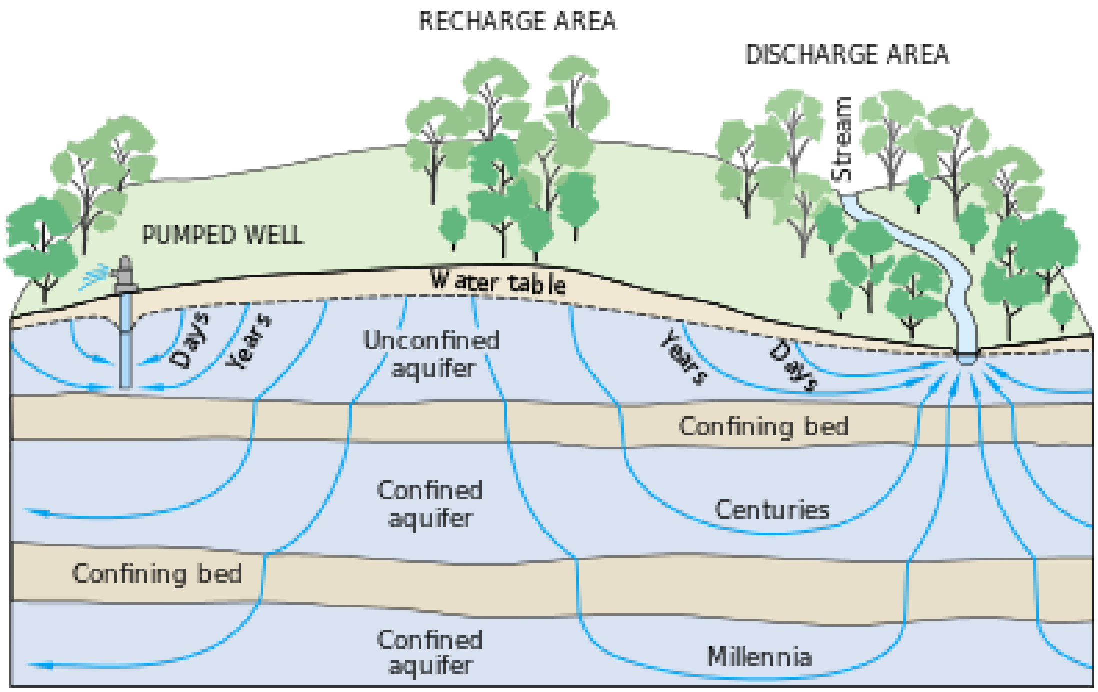

Figure 1-6. Aquifer Cross Section and Depth Layers (Source: USGS, 2013)

In Dover, most private residential wells are either naturally developed in sand and gravel (unconfined aquifers) or are bedrock wells, both of which are used to access drinking water from the aquifers. Approximately 1,300 Dover households receive water from private wells at various depths. Details on the distribution of private wells are included in Section 2. A visual representation of different types of wells is presented in **Figure 1-7**.

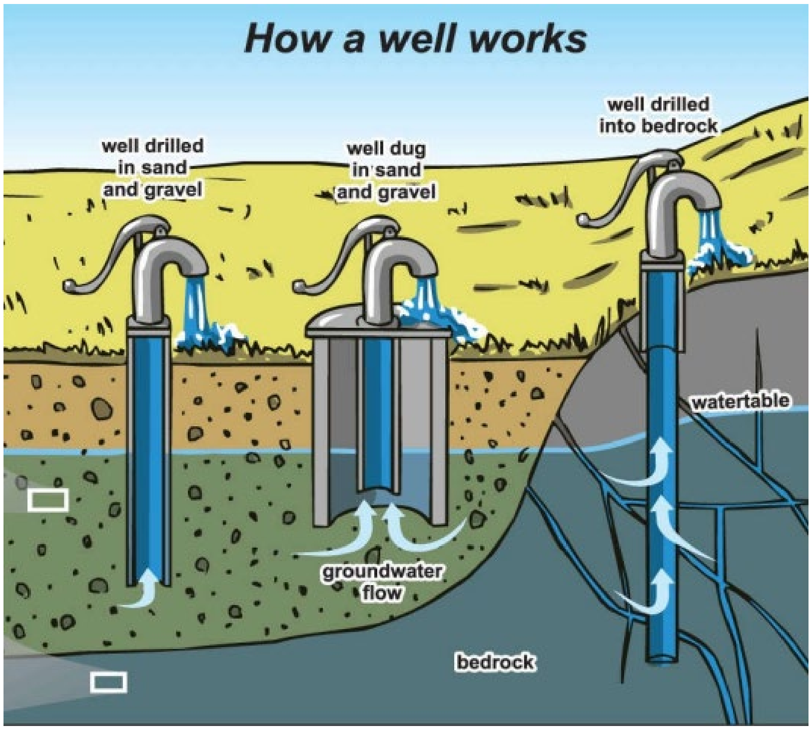

Figure 1-7. Variations of Groundwater Wells (Island Health, 2017)

For over 20 years the Town of Dover has wrestled with water quantity and quality concerns which have become more apparent recently due to a culmination of factors. In the northeast, communities are often considered "water rich" due to the availability of water in the region. However, this isn't always true at the local level – supply reliability is a function of the rate of replenishment from rainfall, the rate of use by the population, and the amount of storage available, either in aquifers or reservoirs. Another significant factor is whether sanitary wastewater is returned to the environment through septic systems (like Dover) or instead is piped away to a wastewater treatment plant. Recent concerns about the long-term reliability of the Town's water supply from both private well and public wells compounded by uncertain future climate conditions have prompted Dover to study their water supply options for both short- and long-term sustainability. Additionally, recent water quality concerns in the Town's groundwater, such as PFAS, iron, and manganese, have accelerated the need to evaluate the long-term efficacy of the Town's underlying aquifers.

1.4.1 Dover's Water Supply

Currently, the sole source of drinking water for Dover residents' is groundwater from the aquifers beneath the Town. The Town of Dover has surficial sand-and-gravel (unconfined) and bedrock aquifers that supply residents with drinking water; however, the method in which the water is brought to each household is different, with water supply in the form of:

- Private wells or small homeowner's association well systems;
- Public water supply from privately owned water company, Aquarion; or

- Public water supply from Town owned infrastructure (some of which is supplied by Aquarion)

Figure 1-8 presents the distribution of the water user groups in Dover, the largest of which is represented by private well owners at 63-percent (represented by dark blue), followed by Aquarion and other private water systems at 29-percent (represented by light blue), then the Town and other small PWS at 5-percent (represented by green), and lastly those served by Walpole/Natick at 3-percent (represented by turquoise blue).

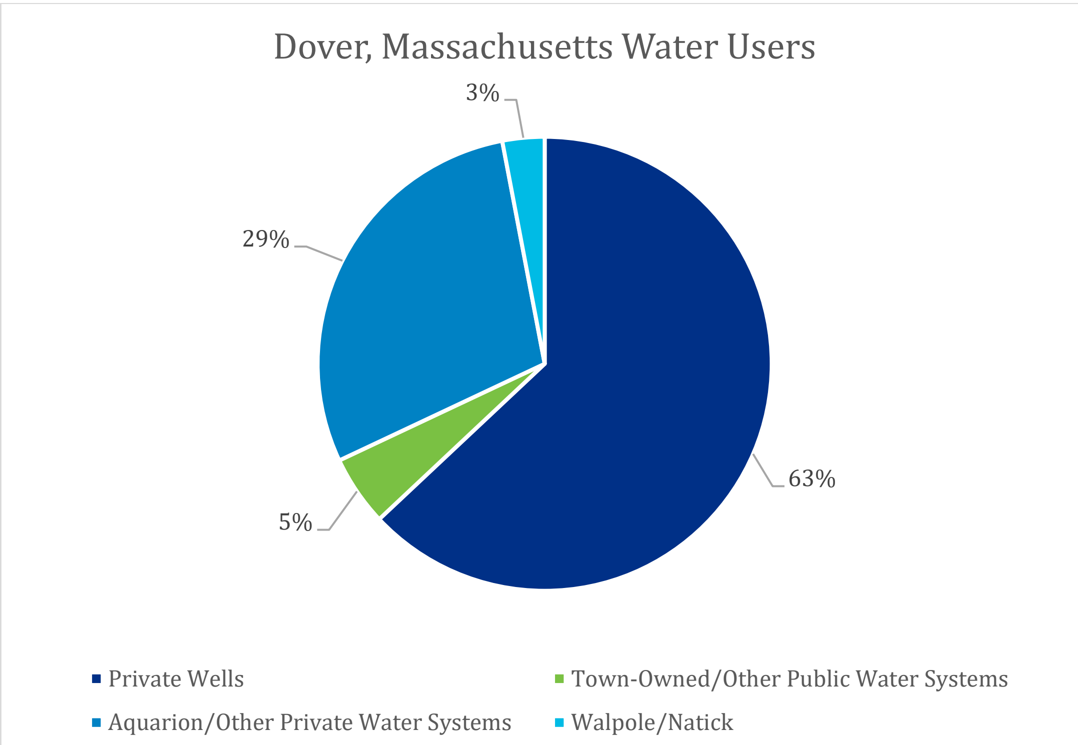

Figure 1-8. Distribution of Dover Water Users (Adapted from 2020 Kleinfelder Hydrology Study which considered 2017 data)

Detailed information identifying the user groups described in **Figure 1-8** is described in Section 2.

These user groups impact one another through the shared water supply. The aquifers serve as an underground storage reservoir for the Town's water, which is depleted with each use and replenished with each rainfall. This unification of supply further supports the need for all Dover residents, water users and water supply stakeholders to work together as stewards of their water supply.

Public water supply wells in Dover are identified in **Figure 1-9,** though it should be noted that some sources are inactive while others do not supply the Town of Dover (Elm Bank). This figure shows major roads in the Town and distinguishes where community and non-community groundwater sources are located. Based on MassDEP's definition of a community water system, it is one that serves at least 15 service connection year-round or regularly serves at least 25 year-round residents. These are shown in red on the map below. On the other hand, MassDEP defines a non-community groundwater source as one with an approved yield of less than 10,000 gallons per day (gpd). These are shown in yellow on the map below.

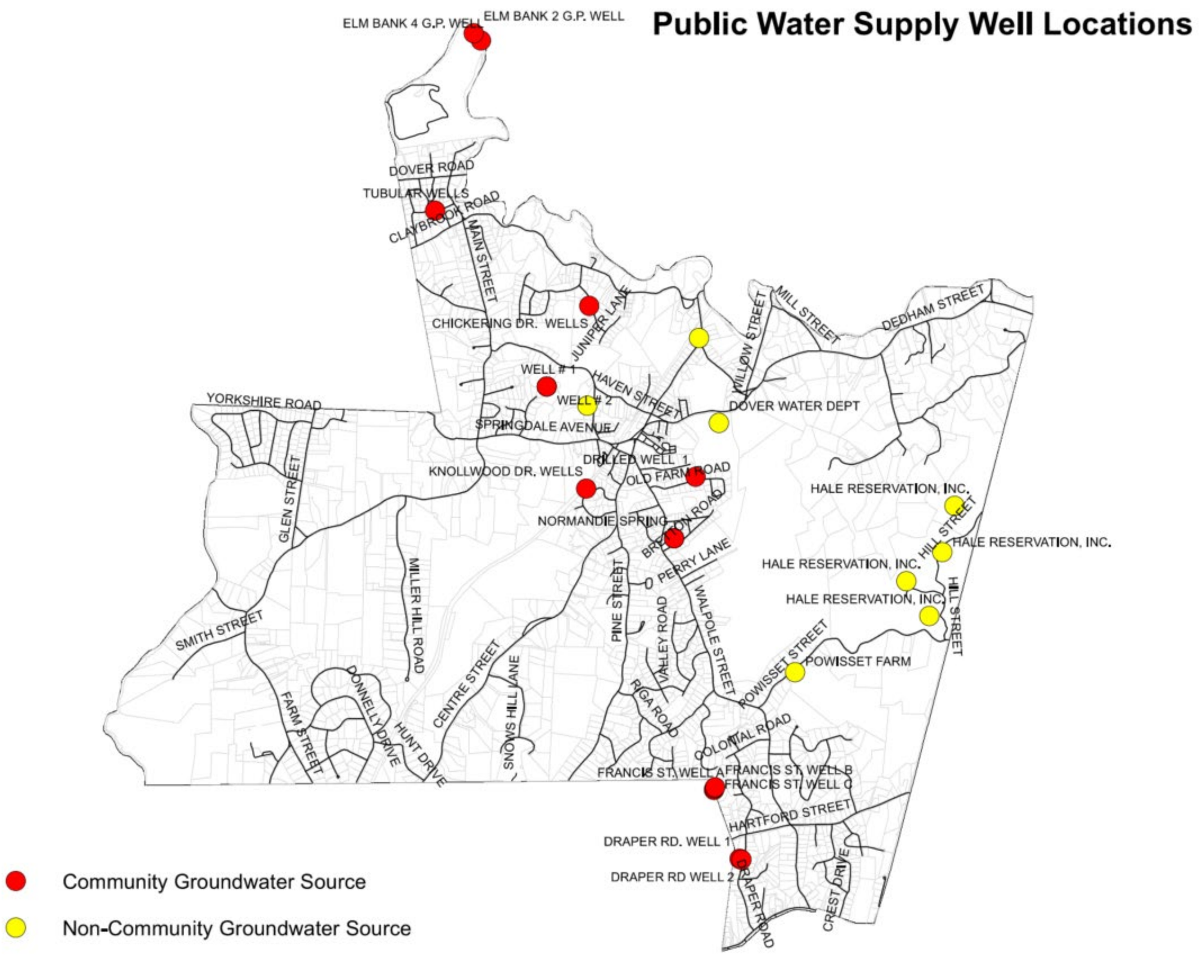

Figure 1-9. Public Water Supply Well Locations (Town of Dover, 2022)

1.4.2 Groundwater System Key Elements and Related Dover Water Supply Challenges

Drinking water is a fundamental resource essential to human and ecological life. It is also a limited resource that requires careful consideration and protection to support the delicate hydrologic cycle that is crucial for ecosystems and communities alike (Saito et al., 2021). Drinking water can be limited physically and/or economically, and both bring unique challenges. "Physical water scarcity is the insufficiency or lack of water itself. Economic water scarcity is an insufficiency of water associated with lack of capacity to use water resources despite its availability or abundance. Economic water scarcity is often associated with inadequate infrastructure development and poor management (Oki et al., 2020)." Water scarcity can result from a variety of environmental or non-environmental factors but can be reduced by demand management and conservation. Many times, several contributing factors accentuate water quantity and quality concerns, stressing the importance this fundamental resource has on daily life. Some factors that impact water supplies include:

- Climate change
  - Increased temperatures and decreased precipitation events result in drought conditions *(limit supply available)*
- Development
  - Additional infrastructure causing more runoff and less infiltration *(hinders aquifer recharge)*
  - Increased water demands associated with commercial and residential users
- Changing consumption patterns
  - Increased residential irrigation
  - Improved living standards
  - Wasteful or inefficient water use
  - *Reductions in use* associated with organized and systematic water conservation programs could help alleviate stress on the aquifer.
- Constituents
  - Changes in water tables can introduce newly detected and/or increased concentrations of contaminants *(such as Per- and Polyfluoroalkyl (PFAS) substances which were recently detected in two water supply wells located in Dover, MA)*[7]
- System deficiencies
  - Water is supplied to customers through a network of infrastructure that needs to be properly maintained to deliver good water quality and quantity

As mentioned in Section 1.1, historical materials provided by the Town of Dover as well as available resources on the Town's Board and Committees' webpages were reviewed as part of this evaluation. These documents served as the basis for background information relating to water concerns. Based on this review, the major water-related challenges for Dover include:

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[7] *PFAS are a group of manufactured chemicals that have been used in industry and consumer products. One common characteristic of concern of PFAS is that many break down very slowly and can build up in people, animals, and the environment over time – impacting public drinking water supply and private wells (EPA, 2022).*

- Water quantity limitations – the aquifer acts effectively as a dynamic underground reservoir that is depleted by water use and replenished by rain, induced infiltration, and snowmelt. The principal concern is that if water use patterns and rain patterns change, future depletion may or may not be balanced each year by replenishment, and the source may not be a viable source over the long-term. Such impacts could be localized to a neighborhood in Dover or impact a larger area.
- Water quality concerns – presence of iron and manganese leading to discolored water as well as recent PFAS detection in the Aquarion PWS wells. PFAS compounds detected in Aquarion's groundwater wells may be indicative of a larger water quality concern. Dover residents that operate a private well should be aware of the potential for these emerging contaminants of concern to contaminate additional water supplies in Town and could consider sampling their wells for the presence of PFAS. Although firefighting foams and industrial activities are common high concentration sources, PFAS are also discharged from septic systems associated with household chemical and product usage.
- Deficient infrastructure – non-working fire hydrants and older un-flushed pipes,
- Multiple water user-groups each with a differing government or management entity,
- Increased development (eight percent population growth over the past decade) (AICP, 2021),
- Consumption rates consistently in exceedance of the state's performance standard of 65 gallons per capita per day (GPCD) for residential users,
- Increased frequency of droughts and potential long-term climate change impacts and the reliability of the water supply.

1.5 Importance of Dover's Aquifer Monitoring Wells

As a part of the hydrology study completed in 2020, 15 monitoring wells were installed to better inform the Town of water levels throughout the aquifer. In addition, stream-bed piezometers (pressure sensors to measure water depth) were installed to correlate the relationship between groundwater and streams, and gauges were installed in streams to measure flows. The study lasted 278-days from February through November of 2019 and the Town has continued to monitor wells for a more comprehensive understanding of seasonal well trends. The well depths are read monthly, with over 230 readings to date, the earliest taken by Town staff members in late 2019. These graphs can be found on the Town website[8] and are presented below in **Figure 1-10**.

CDM Smith noted that the monitoring well levels from March through December of 2019, were marked by generally high rainfall, and it is expected that a robust and sustainable groundwater system to draw down partially during the summer months of high usage (outdoor watering), and then recover during the later months of the year. That is, just like a reservoir or lake from which

[8] Monitoring data can be found on Dover's website: https://www.doverma.gov/592/Monitoring-Wells-Dashboard

water is withdrawn, it is expected that the water level would decline during periods of high usage and less rain, and then rise during periods of lower usage and more rain.

Indeed, most of the monitoring wells exhibit this trend, either replenishing completely to water levels observed earlier in the year or significantly recovering and exhibiting an upward trend by year's end. However, several of the monitoring wells did not fully recover and one indicated a declining trend at the end of 2019. The Town of Dover engaged New England Geotech to install two new monitoring wells in 2022; MW18, located at the end of Francis Street and MW19, located on Knollwood Drive near the Colonial pump house.

Between 2021 and 2023, Massachusetts experienced an unusually wet year (2021) followed by an unusually dry year (2022) and another wet year (2023). The Aquifer Resilience Study, Appendix C of this report illustrates the ability of the aquifer to rebound quickly following dry periods, and even extended multi-year dry periods, without prolonged or downward-trending patterns. The study demonstrates the resilience of the aquifer during and following 2022 – despite the prolonged dry conditions through spring and summer, the aquifer drew down and recovered quickly. The Aquifer Resilience Study explores this resilience over a 50+ year period, and superimposes future climate patterns to help understand future aquifer resilience. The information can provide Dover a clearer picture of how robust the aquifer and well system might be against a broad array of both current conditions and uncertain future trends in demand and climate. Continued monitoring could help improve the understanding of historical aquifer drawdown and replenishment patterns. Additionally, this data could be evaluated along with statistical analysis of future climate patterns to better understand the long-term future reliability of the Town's aquifers. It is therefore recommended that Dover continue the use of and data collection from the existing monitoring wells. Findings of the Aquifer Resiliency work indicate that the groundwater wells within the Town generally follow the same trends. As such, CDM Smith does not recommend the installation of additional groundwater monitoring wells unless there is a desire to observe groundwater fluctuation in a very specific location.

Well Monitoring
Dashboard

Well Monitoring Info

History of the Monitoring Wells in Dover

The Town of Dover, in coordination with the Kleinfelder Report, authorized a drilling program at 16 locations throughout Dover on Town-owned parcels. The well installation was completed between December 17 and December 20, 2018, in the shallow overburden aquifer at areas of concern around the Town.

Wells were drilled using a Geoprobe drilling rig to 25 feet deep, or refusal, whichever was first encountered. The well construction typically consisted of a 10-foot long, two-inch diameter slotted screen coupled to a two-inch diameter SCH40 PVC pipe extended to 2.5 feet above grade.

Three locations (MW-07, MW-08, and MW-10), which at first appeared to be located in suitable locations (as determined by USGS surficial geology maps) and to have sufficient water at the time of installation, were later observed to go dry and deemed unsuitable for monitoring. The remaining 13 wells are monitored from early Spring through late Fall.

Links

Dover Water Resource Page

How to Use Wetted Tape

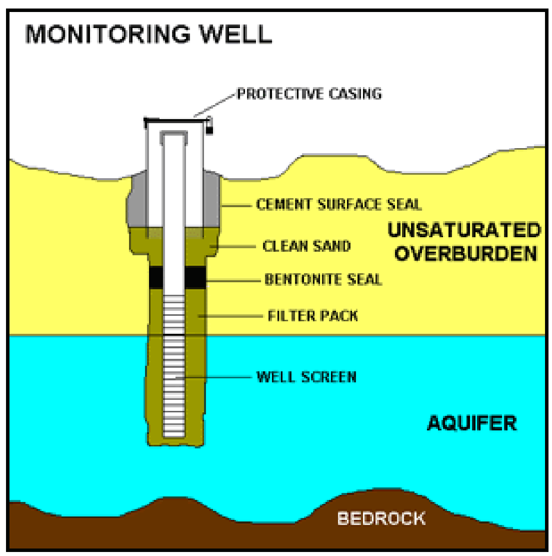
WellTypes.jpg

well locations.pdf

What is a Monitoring Well

Monitoring well means a well that is used to measure or monitor the level, quality, quantity, or movement of subsurface water.

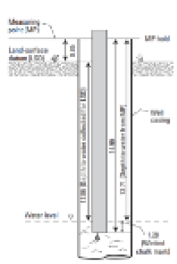
For example, monitoring wells can either be specifically drilled for monitoring groundwater or may be preexisting domestic or public-supply wells that are also used for monitoring.



How do we measure

Using steel tape or "wetted tape", we lower the tape into the well and take the measurements once the tape hit water.

Measure Diagram (click to enlarge)



Dover's Monitoring Wells

Well Info

The Town of Dover has 15 monitoring wells that were installed as part of the work performed by Klienfelder. These wells help the town understand how our ground water moves and better determine the resource needs for the future.

The well depths are taken monthly from the Spring to the Fall. Currently Town staff members are responsible for taking these readings.

How many monitoring wells are in Dover?

15

Monitoring Wells

How many readings have been taken?

245

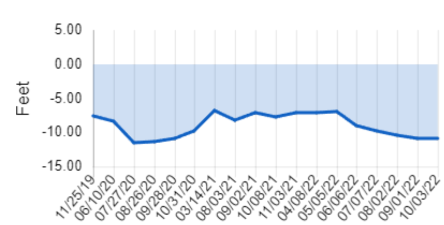
Readings

Current Drought Status

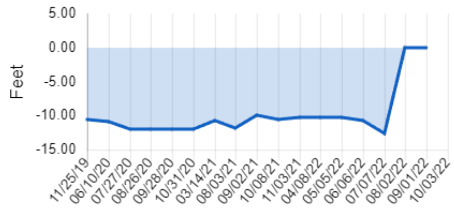
Level 3 - Critical Drought

Curent Drought Status

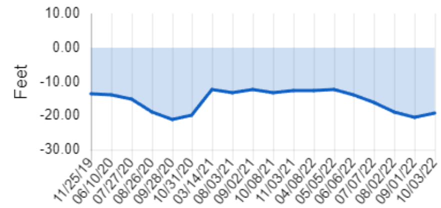
MW01 (1 Hunters Path) Data



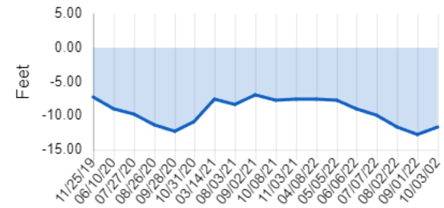
MW02 (2 Tubwreck Drive) Data



MW03 (8 Snow's Hill Lane) Data



MW04 (11 Grand Hill Drive) Data



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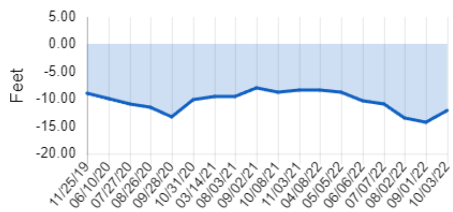

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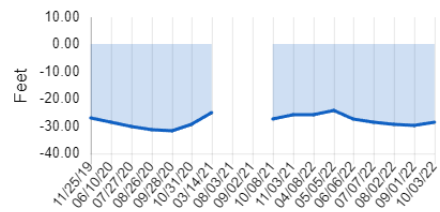

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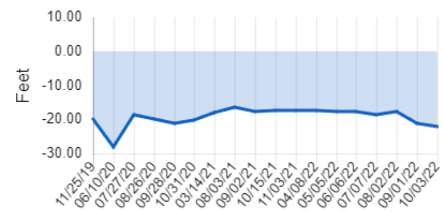

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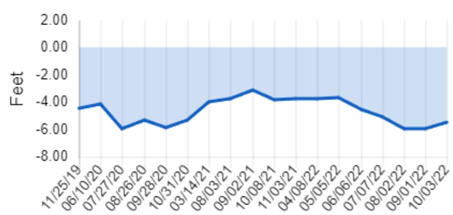

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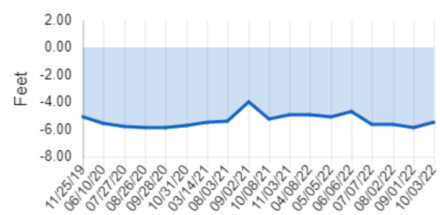

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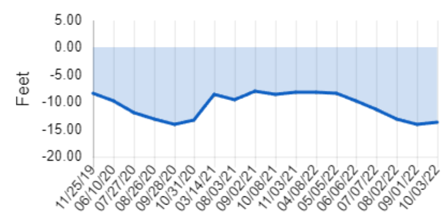

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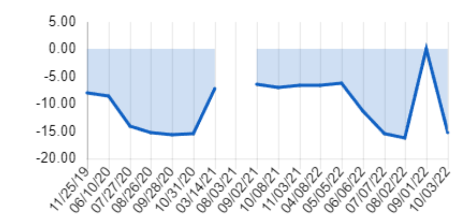

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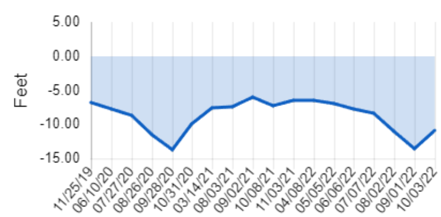

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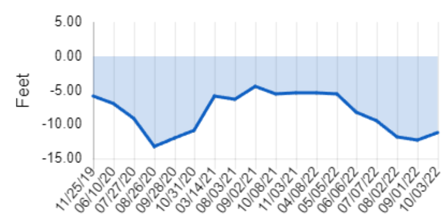

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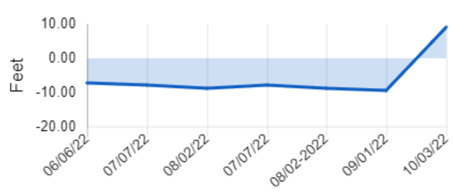

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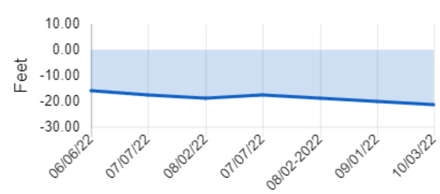

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Section 2

Water User Groups and Franchise Area

This section identifies the various user groups outlined in Section 1, including available water use data, locational boundaries and franchise areas (where applicable). **Table 2-1** displays the water use data for Public Water Systems (PWS) in Dover.

PWS are those which are regulated at the state level by MassDEP and at the federal level by the United States Environmental Protection Agency (USEPA). These agencies dictate the regulatory requirements to which a PWS must adhere to be in compliance and provide water for human consumption. Broadly speaking, PWS systems are any that serve an average of at least 25 people for at least 60 days a year.

Table 2-1. Dover Public Water Systems and Usage

Water System	PWS ID#	Dover Population Served	Average Daily Pumping (gal/d)	Average Use per Resident (GPCD)
Aquarion Water (Reported as prior Colonial Water system)	3078007	1,674	146,284	87.4
Springdale Farms Trust (Purchased by Colonial Water in 2018)	1078008	150	18,987	126.6
Town of Dover Water Department	3078000	500	1,795	3.6
Old Farm Rd. Water Trust	3078001	40	3,410	85.3
Glen Ridge Trust	3018002	122	12,042	98.7
Meadowbrook Water Trust	3078005	57	5,031	88.3
Precious Beginnings	3078010	44	80	1.8

Note: Data in table retrieved from 2009 – 2017 MassDEP ASR 2009-2017 (Adapted from Kleinfelder, 2020).

Based on the data presented in **Table 2-1** it can be concluded that prior to 2017 virtually all the PWS in Dover exceeded the recommended MassDEP performance standard of 65 GPCD. For additional context, the Massachusetts Water Resources Authority (MWRA) Advisory Board Annual Rates Report includes the assumption that the industry annual average household water usage is 90,000 gallons/yr. Using the data presented in Task 2-1, the average household usage (assuming a 4 person household) would range between 127,000-185,000 (using the Aquarian Water and Springdale Farms Trust data) annual gallons, in excess of the MWRA published value. Dover's most recent records have been requested of the Town and once received can be used to update the water use data table above. A visual representation of pre-2017 average daily demands associated with the various PWS is presented in **Figure 2-1**.

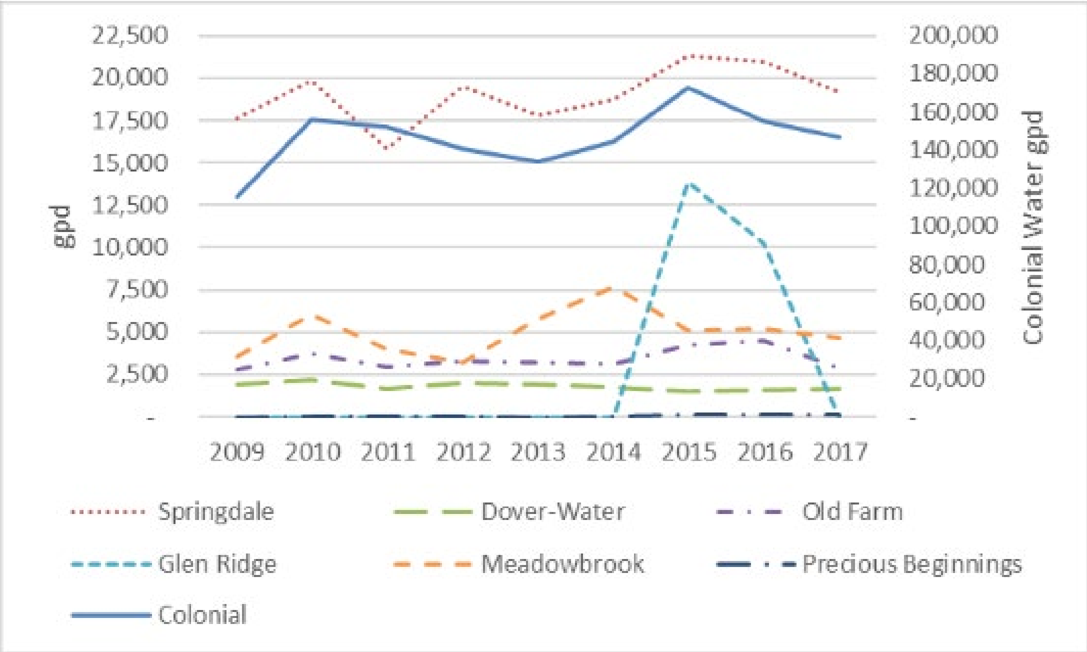

Figure 2-1. Average Daily Demand for PWS (2009-2017) (Kleinfelder, 2020)

2.1 Private Well Owner

Private well owners account for approximately 63-percent or over 1,300 of Dover households and are the largest user group. The 2020 hydrology study included obtaining private well data through MassDEP's Well Driller program SearchWell database and summarizing the findings. The results of this records search present approximate locations and work completed for private wells. This map was previously presented in Section 1 as **Figure 1-5**. Records accessed as part of the hydrology study indicate that of the 902 private wells that were listed and categorized, 752 were domestic and ranged in the extent of work performed. Some wells were decommissioned or replaced while others were deepened, hydrofracked, repaired, or a new well was drilled. Of those domestic wells, about 70-percent were over 300 feet in depth and 40 were over 1,000 feet in depth. Of the private wells captured, 48 wells were intended for irrigation. Other well categories listed include industrial, public water supply, and monitoring wells. Based on the ten-year period reviewed as part of this hydrology study (2007-2017), 134 wells were decommissioned, drilled deeper, or hydrofracked in an attempt to increase available yield. During a recent stakeholder meeting as part of this work, the BOH expressed that only one well has run dry in the 2022 calendar year to date (August 2022).

A private well owner is one that owns and operates their own well (on their property) and is responsible for the infrastructure. Unlike a PWS, these private well owners are not monitored for their water consumption rates, therefore no use data is included in this evaluation. Private well owners are also responsible for their own water sampling to assess potential contaminants.

2.2 Aquarion Water Franchise in Dover

Aquarion Water Company (Aquarion) is a private water supplier with customers and systems in many locations in Connecticut, Massachusetts and New Hampshire. Aquarion provides public water service to a portion of Dover residents through the recently acquired water system infrastructure and franchise area purchased from Colonial Water Company. The Aquarion infrastructure system in Dover is regulated as a PWS which is comprised of three sub-systems as follows:

- Chickering system (portion of PWS ID# 3078006),
- Springdale system (PWS ID# 3078008), and
- Main system (portion of PWS ID# 3078006).

A map of the Aquarion system is included as **Figure 2-2**. The Main system is split into two pressure zones, one of which is referred to as the Main Zone and the other is referred to as the Downtown Zone. The Main Zone is the higher-pressure zone and connects to the Dover water system. The Downtown Zone is the lower hydraulic gradient area. Supply wells in the Aquarion service area include the Chickering Wells, Springdale Wells, Knollwood Wells (Downtown zone), Francis Street Wells (Main zone), and the Draper Road Wells (Main zone). The Draper wells are not in use due to PFAS6 contamination, alternate wellfields are utilized and capable of meeting system demands.

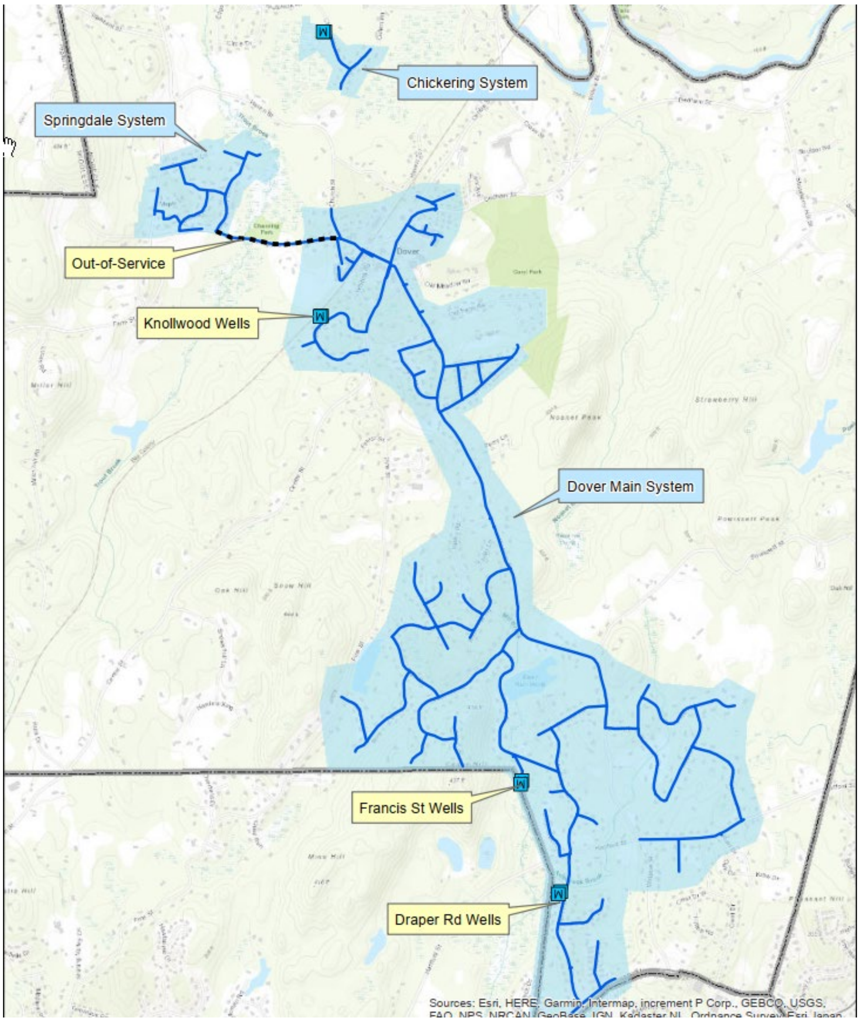

Figure 2-2. Aquarion System Extent (Aquarion, 2022)

Aquarion acquired Colonial Water in December of 2021, which included both the assets and the water franchise area. A franchise is defined as a group that is authorized to perform specified commercial activities or services. The Colonial Franchise means that within the geographic boundaries of that Franchise Area, Colonial or successor companies (Aquarion) have the exclusive right to provide centralized water service. No other private company or the Town can provide such service without purchasing that right from Aquarion, either in a negotiated sale or through eminent domain in the case of the Town. Aquarion, in terms, is subject to public utilities oversight and regulation regarding the quality of service and the rates charged to customers under the jurisdiction of the Public Utilities Commission (PUC). This is an important consideration for the Town of Dover, of which approximately 29-perecent of residents are served by Aquarion.

As part of the stakeholder meetings included in this study, CDM Smith met with the Town and Aquarion to receive an update on the progress and improvements to their system, which were also shared with the public at the January and August Dover BOS meetings. A summary of Aquarion's initiatives is included below:

- Initiated strategies to address discolored water issues (iron and manganese),
- Improved compliance with Water Management Act requirements and water conservation communications with customers, and
- Investigated avenues to address infrastructure deficiencies and detected contaminants.

The discoloration issues associated with elevated iron and manganese levels (Francis Street wells) were limited by adjusting the wells in operation and relying more heavily on other wellfields with better quality water (Knollwood). Moving forward, Aquarion plans to increase capacity and service area for the Knollwood wellfield given its water quality. Projects to achieve this reliance are underway and anticipated completion is early 2023. In addition, water main flushing was completed in March 2022 and five water quality bleeders were operated for several months in the winter. As drought conditions continued to worsen, Aquarion increased conservation measures through communications with regulatory agencies and notifying customers of water use restrictions.

The Draper wellfield is offline due to elevated PFAS6 levels in excess of the MassDEP regulatory limit of 20 nanograms per liter (ng/L). It should be noted that this standard may become more stringent with the anticipated promulgation of the Environmental Protection Agency's (EPA) National Primary Drinking Water Regulation for PFAS. Interim drinking water health advisories were released on June 15, 2022 for four PFAS compounds and the establishment of formal regulatory limits are expected before the end of 2022. PFAS levels detected at the Chickering and Springdale wellfields range between 10 and 20 ng/L (or part per trillion, ppt). Aquarion has initiated projects to construct treatment for PFAS at both wellfield locations. Additional information on Aquarion's actions to address Dover water quality and quantity concerns are included in two presentations to the Dover BOS (Jan 2022 and August 2022) which are available on the Dover Town website and Aquarion website.

Aquarion supplies public drinking water to approximately 29-percent of Dover residents through the infrastructure described above. Additionally, Aquarion provides drinking water to approximately 70 service connections using the Dover-owned water infrastructure via a meter vault. Additionally, Aquarion provides water to the Town-owned public water supply. There are two meter vaults located at Old Colony Drive and Centre Street which connect the Town PWS infrastructure to Aquarion. Dover has had a water purchase agreement with Aquarion and its predecessor utility dating back approximately 28 years. That contract has minimal requirements regarding the operation and maintenance of the infrastructure owned by the Town. As part of CDM Smith's work in 2020, it was noted that the contract has expired, but CDM Smith understood that the Town and Colonial (now Aquarion) had agreed to a six-month extension. The review of the Agreement between the Town and Colonial (now Aquarion) stated that water will not be provided for general fire protection but only for refilling the Fire Department's tanker trucks following a fire.

2.3 Town-owned Dover Water System

The Town of Dover owns and operates two PWS areas consisting of water supply infrastructure. These systems are split between two areas of Town, one of which is an approximately 2-mile-long water main and associated infrastructure located in the center of Town, which receives water from Aquarion through a water supply Agreement. The second consists of a wellfield and associated distribution system and infrastructure.

The systems owned and operated by the Town include:

- Downtown Water Supply Infrastructure (a portion of PWS ID#3078000)
- Caryl Park Wellfield (a portion of PWS ID#3078000)

2.3.1 Dover-owned Downtown Water Infrastructure

Dover owns approximately 2 miles of water mains which service approximately 70 customers. CDM Smith previously authored a memorandum which evaluated whether the Town should consider selling Colonial Water the infrastructure in July 2020. As part of that work, an inventory of existing infrastructure was completed, and the results are summarized in **Table 2-2**.

Table 2-2. Downtown System Infrastructure Inventory

Pipe/Valve Size (inches)	Pipe Material	Approximate Total Length (feet)	Total Number of Valves
4	Cast Iron	440	2
6	Cast Iron	2,470	10
8	Cast Iron	2,630	9
4	Ductile Iron	940	4
6	Ductile Iron	620	2
12	Ductile Iron	2,420	6
	Total Approximate Length	9,520	33

The oldest main is a 6-inch cast iron (CI) line located on Church Street which was installed in the 1950s. The majority of the other mains were installed between the 1950s and 1970s, with the exception of the 6-inch ductile iron (DI) main on Meeting House Hill Road which was installed in 1986 and the 12-inch DI main on Springdale Avenue which was installed in 1989.

In addition to the pipeline infrastructure summarized above, the Town also owns 13 fire hydrants, 5 of which were replaced in 2015, and 2-meter vaults. The third meter vault in Town, located by the fire station on Centre Street, is owned by Aquarion. Currently, all of the existing fire hydrants are turned off, as there is not adequate water supply for firefighting needs. The pressure in the system is reportedly around 55 pounds per square inch (psi) which is adequate to supply customers under normal operation.

The Town also owns approximately 70 water service connections which includes the length of pipe from the main to the curb stop. Approximately 90% of the water service lines are thought to be copper, while the remaining 10% have been replaced by high density polyethylene (HDPE). The majority of water service lines are 1-inch in diameter while the four that supply municipal buildings are 4-inch cast iron lines.

The extent of the downtown section of the Dover-owned system is presented in **Figure 2-3.**

Water System

Dover, MA
5-9-2022

Figure 2-3

For the Dover PWS, insufficient water capacity limitations in the downtown portion of the system hinder the ability to perform required maintenance such as flushing and has left areas in Town without working fire hydrants. During the August 2022 stakeholder meeting with Aquarion, it was indicated that following the completion of construction projects in early 2023 the Town should be able to receive required flushing volumes.

2.3.2 Caryl Park Wellfield

The Town also owns and operates a small water supply called the Caryl Park Wellfield, to serve an elementary school and two nearby Town buildings. As part of CDM Smith's on-call engineering services, the Town requested a review of the Caryl Park Wellfield, which have recently experienced increased demand interruptions during peak hours of operation . The August 2022 site visit observations are summarized below.

The Caryl Park Wellfield serves the Chickering School (elementary school), a Parks and Recreation Department building, and a Town-owned historical building (Caryl Farm Historic Site). The house at the Caryl Farm Historic Site is served with a 1-inch PVC pipeline. The school system is served with an 8-inch DI pipeline, which transitions down to 4-inch at the school and was installed in 2000. Daily usage for the Caryl Park Wellfield is on the order of 3,000 to 4,000 gallons per day (gpd). Five wellheads are present at the site. Their nominal capacities include:

- One at 35 gallons per minute (gpm) (off-line at present),
- Four at 65 gpm each (on-line and available at present).

The wells are 2-1/2-inch in diameter with screens at a depth of approximately 25-feet below ground surface. Water in wells has been observed at 18-feet from top of well at present. The wells have never gone dry at this site, despite the water depth dropping during times of drought. Among the wellheads, there is a monitoring well across the dirt path from the soda ash building, also present on the site, which was designed in the 2001-2002 timeframe. The structure is a precast concrete building and sits directly on gravel. Besides soda ash to increase pH, there are no other chemicals dosed to the water supply. Monitoring of water quality parameters for this system have indicated PFAS6 have been detected at 6.4 ppt. These results are less than half of the Massachusetts MCL for PFAS6, however the system could be at risk of violation if the promulgation of the EPA regulatory limit for PFAS proceeds as anticipated. As such, it is recommended that the Town begin testing individual wells in the Caryl Park wellfield to proactively monitor and prepare for potential future regulatory limits. This structure is accessed via an underground vault which houses the pump, tank, and electrical systems. This is a confined space that requires confined space entry precautions operationally.

As a whole, the systems owned and operated by the Town of Dover raise questions of safety for users and community members. The lack of fire protection is one of the concerns which must be considered with any of the alternatives included in the Water Sustainability Study assessment.

2.4 Other Water Sources

Approximately 3-percent of Dover residents live on streets served by either the Town of Natick or the Town of Walpole. The extents of both the Natick and Walpole systems are identified in **Figure 2-4.**

The Natick system is the water source for three small areas of Dover, namely the Glen Ridge Water System, Meadow Brook Road Water System, and a small portion of Dover Road, represented as bright green, dark green and turquoise green on the map, respectively. The Glen Ridge System supplies small portions of Glen Street, Greystone Road, and Yorkshire Road, and all of Sterling Drive. The Meadow Brook System serves the residents of Meadow Brook Road and Brook Road, and a small portion of Claybrook Road.

The Walpole Water System is shown in black on **Figure 2-4** which identifies a small portion of County Street (at the end of Draper Road) as being supplied by Walpole.

PROJECT NO.	20192428
CREATED:	1/21/2020
CREATED BY:	CPerez
CHECKED BY:	KRyan
FILE NAME:	Plate4 - Water System Infrastructure 22x34.mxd

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PLATE 4
Water System Infrastructure

Dover, MA

FIGURE
2-4

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Section 3

Population Projections and Water Demands

3.1 Historical Population and Future Population Projection

3.1.1 Historical Population Data (1990-2020)

US Census data from 1990 through 2020 for the Town of Dover (Dover) are presented in **Table 3-1**. This table also presents the calculated percent change per decade based on the US Census data.

Table 3-1. Historical Population

Year	1990	2000	2010	2020
Population (US Census 1990 - 2020)	4,915	5,558	5,589	5,923
Calculated Percent Change (%/Decade)		13%	1%	6%

From 1990 to 2000 the Town of Dover grew by approximately 13-percent, the largest percent growth by decade observed in the data presented. The decades of 2000 to 2010 and 2010 to 2020 also showed growth in population, though less significant.

3.1.2 Future Population Projection (2030)

Table 3-2 shows prior projections from the University of Massachusetts' (UMass) Donahue Institute[1] (Donahue Institute) and the Metropolitan Area Planning Council (MAPC)[2] which were considered in the Dover Housing Production Plan[3] published in December 2021. The Dover Housing Production Plan did not consider the 2020 US Census data as it was not available at the time of the assessment.

The percent changes calculated for the MAPC 'Status Quo Scenario', the MAPC 'Strong Region Scenario', and the Donahue Institute were averaged and used as the basis for this study's projection. The MAPC scenarios both indicated a decline in population from 2020 to 2030, whereas the Donahue Institute projected a small increase. The result of averaging these projections is a -0.45% decline in population for the Town of Dover. This percent change was applied to the 2020 US Census data and projected to 2030, resulting in a projection of 5,896.

[1] UMass Donahue Institute | Massachusetts Population Projections (donahue-institute.org)
[2] Dover.pdf (mapc.org)
[3] Dover-Housing-Production-Plan-FINAL (doverma.gov)

Table 3-2. Prior Population Projections

Comparison of 2020 and 2030 Population Projections			
	2020 Projection	2030 Projection	Percent Change
MAPC Status Quo Scenario	5,367	5,301	-1.2%
MAPC Strong Region Scenario	5,411	5,371	-0.7%
Donahue Institute	5,512	5,546	0.6%
Average of Percent Change Estimates (%/Decade)			-0.45%[1]

[1] This value is based on the average of MAPC Status Quo Scenario, MAPC Strong Region Scenario, and the Donahue Institute Population Projections.

Figure 3-1 is a graph of the data displayed in **Tables 3-1** and **3-2**. The historical population in Dover over the past three decades (shown in black) and the projected future population for this study (shown in blue) are connected with trend lines. Projections for 2020 and 2030 for each of the projections considered in this work (MAPC and the Donahue Institute) are also shown on the figure.

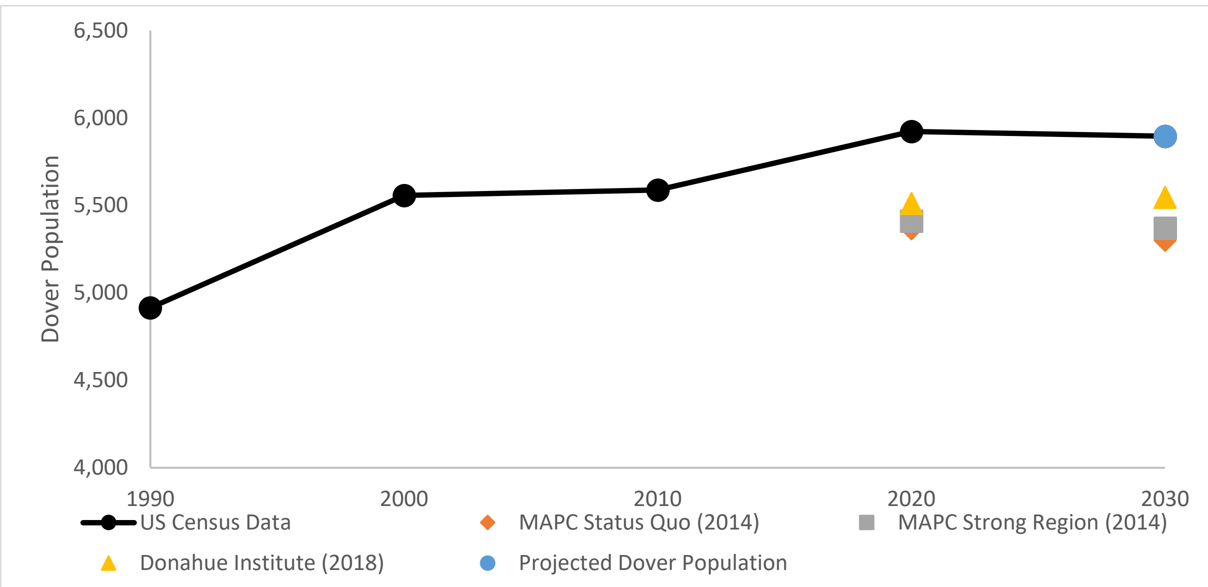

Figure 3-1. Dover Historical and Projected Population

3.2 Water Demands

The average day demand (ADD) is the total consumption of water in one calendar year divided by the number of days in the year. The ADD is composed of "revenue water" and "non-revenue water". Revenue water is composed of meter readings from homes and businesses. Non-revenue water includes any water demands that are not metered, including flushing hydrants, main breaks, water quality instrumentation, and fire protection. When those measured or estimated flows are subtracted from the non-revenue water, unaccounted-for water (UAW) remains.

The maximum day demand (MDD) is the largest amount of water used in one day. The MDD typically occurs during the summer, which is typically peak water consumption.

3.2.1 Current Water Demand

A summary of the Dover water demands categorized by user group is presented below in **Table 3-3**. It should be noted that this table summarizes the currently available water withdrawal data from public water systems, but it does not capture the entire Dover population due to the lack of private well owner withdrawal monitoring.

Table 3-3. Dover Water Demand by User Group

User Groups	Water Demand (MGD)
Dover PWS[1]	See Note 2
Aquarion[1]	0.17
Small Community Systems (Old Farm Rd. Water Trust, Glen Ridge Trust, Meadowbrook Water Trust, Precious Beginnings)[3]	0.02
Remaining Private Well Areas	No Data Available

[1] Data based on 2021 Annual Statistical Report

[2] Dover PWS demand is included in Aquarion demand

[3] Data based on 2009-2017 ASR, adapted from Kleinfelder

3.2.2 Town-Wide Water Demand

It is understood that some Dover officials and/or residents may be interested in learning the total Town-wide water withdrawals. One way to develop such an estimate is presented here.

MassDEP's water withdrawal permitting program makes frequent use of two performance standards:

- Residential water use should not exceed 65 gallons per capita per day
- Unaccounted-for Water (UAW) should not exceed 10% of the total withdrawal

Table 3-4 shows a Town-wide water demand projection which is based on the assumption that Dover would meet these two performance standards. This estimate also assumes that non-residential water use (such as businesses, municipal buildings, private schools, churches, etc.) would be 10% of the residential use. As shown on the table, the total Town-wide average day demand estimate is 0.47 million gallons per day (MGD). The total Town-wide MDD was also calculated by assuming a peaking factor of 2.5, resulting in an estimate of 1.18 MGD for MDD conditions.

Table 3-4. Dover Town-Wide Demand Projection

2030 Population Projection	5,896
Residential Demand (65 gallons per capita per day) (MGD)	0.38
Non-Residential Demand (Assumed 10% of Residential Demand) (MGD)	0.04
Unaccounted-for Water (10%) (MGD)	0.05
Town-Wide Average Day Demand (MGD)	**0.47**
Town-Wide Maximum Day Demand (Assumed 2.5 Peaking Factor) (MGD)	**1.18**

3.2.3 Town-Wide Water Distribution System

It is understood that some Dover officials and/or residents may be interested in the capital cost of providing public water to the entire Town. One way to develop an estimate for a Town-wide water distribution system is presented here and summarized in **Table 3-5**:

- The total length of roadways in Dover is 61.8 miles.
- The total length of existing distribution system mains currently in use is approximately 17.4 miles. It was assumed that this existing infrastructure could be repurposed into the Town-wide system.
- An additional 44.4 miles of main would be needed to create a Town-wide system that could serve all customers in Dover.

Table 3-5. Dover Town-Wide Distribution System Information

	Miles of Distribution Pipe in System[4]
Total Miles of Road in Dover[5]	61.8
Dover Public Water Supply Mains	1.8
Aquarion - Dover Water Main System	10
Aquarion - Springdale Water Main System	1.4
Natick Water System Mains	0.3
Walpole Water System Mains	0.3
Small Community Systems Water Mains:	
Old Farm Rd. Water Trust	0.4
Glen Ridge Trust (Natick)	1.2
Meadowbrook Water Trust (Natick)	0.9
Dover Waterworks Inc.	0.9
Bedell Water System	0.1
Total Miles of Main for Public Water Systems in Dover	17.4
Calculated Dover Potential Water Expansion Area (Calculated as Total Road miles minus existing water main miles)	44.4

The estimated project cost is presented in **Table 3-6**. Using a conceptual unit cost of $550/foot based on CDM Smith's experience in planning studies, the cost to implement a Town-wide distribution system of this scale would be approximately $129,000,000. The unit cost of $550/foot considers pipes, fittings, valves, hydrants, service connections, paving, and contingencies for all work needed for the expansion. Note that the volatile construction atmosphere has greatly impacted unit costs throughout the COVID pandemic due to supply chain delays and manufacturing difficulties. The cost presented may be adjusted if the design and implementation of this work is pursued in a post-COVID environment.

[4] Aquarion provided records which indicated the distribution system pipe lengths. All other distribution system piping was estimated from the Plate 4 – Water System Infrastructure map authored by Kleinfelder.
[5] https://www.doverma.gov/Faq.aspx?QID=90

Table 3-6. Dover Town-Wide Distribution System Information and Estimated Potential Costs

Town-Wide Distribution System Expansion Cost	
Estimated Distribution System Expansion (Miles)	44.4
Estimated Distribution System Expansion (Linear Feet)	234,598
Estimated Cost per Linear Foot of Distribution Main	$550
Estimated Cost to Construct a Town-Wide Water Main Expansion	**$162,000,000**[1]

[1] Cost includes total construction cost with allowances for Construction Contingency, General Conditions, Permitting, Bonds and Insurance, and Contractor Overhead and Profit. The cost does not include allowances for Engineering, Permitting, and Inflation considerations.

Given the enormous cost of constructing a Town-wide distribution system network, the supply alternatives outlined later herein do not include a Town-wide system expansion. Nevertheless, it is possible that customers along or near the routes of any transmission mains associated with future supply source alternatives may be interested in connecting to such mains. This will be discussed further in Section 5.

Section 4

Evaluation Criteria and Alternative Identification

4.1 Evaluation Criteria

Alternatives evaluation criteria for this study, were presented by CDM Smith to Dover committees, including the Water Sustainability Study Committee, the Open Space Committee, the Planning Board, and the Board of Health. During these stakeholder input meetings, the draft criteria were discussed and refined to address input and questions received. The final evaluation criteria are listed and defined below:

1. **Estimated Project Costs** – the estimated Construction, Engineering, and Implementation cost with planning level contingencies for an alternative.
2. **Funding Opportunities** – the potential for an alternative to receive funding support through low interest loans, grants, or other available funding options.
3. **Long-term Reliability/Redundancy of Infrastructure or Source –** how consistent the alternative is in quality and performance, also if the alternative offers secondary infrastructure and/or sources, thereby limiting risk.
4. **Operational Workforce Demands –** the workforce demands or requirements i.e., the number and level of water operator required for an alternative.
5. **Regulatory Compliance Risk with Current/Future** – the likelihood that an alternative would contribute to improved compliance with current and potential future regulations.
6. **Long-term Water Supply Sustainability –** the ability for an alternative to provide a sustainable solution to water quality and quantity concerns for the foreseeable future, and how adaptable it is with drought and water conservation practices.
7. **Resiliency for Climate Change –** an alternative's adaptability or resistance to drought conditions.
8. **Startup Timeline and Implementation Demands –** the duration it takes to implement and commission an alternative such that the infrastructure associated is functional and operational.
9. **Institutional Efforts –** the level of legal, land ownership and/or easement coordination, and intermunicipal agreements that are required to implement an alternative.
10. **Future Project Permitting –** the permitting efforts necessary to implement a given alternative.

11. **Level of Control and Influence** – Dover's decision making authority with regard to the future operation and water rates associated with an alternative.

12. **Public Acceptance –** the public's perception of an alternative and the general opinion and level of approval/support.

13. **Protection of Open Space, Recreation, and Biodiversity –** opportunities or impacts to open space, recreational space, and flora and fauna through the implementation of an alternative.

These evaluation criteria were applied in the comparative analysis of the alternatives, detailed further in subsequent sections.

4.2 Alternatives Identification

The study scope called for the initial identification and engineering evaluation of up to five alternatives to address Dover's goal of a long-term sustainable water supply, followed by prioritization of up to three solutions. This section identifies the initial alternatives and evaluation. The evaluation included application of engineering judgement in the areas of alternative feasibility, functionality, implementation timeline, as well as the potential benefits and challenges for Dover residents all of which are presented in the Alternatives Matrix, described below.

The ultimate goal of this study is to determine sustainable solutions for long-term water use in Dover by evaluating alternative water sources to supplement the existing supply.

4.2.1 Alternatives Matrix

The five (5) alternatives selected for this water sustainability study include the following:

1. Improved management and stewardship of Dover's existing supplies including public systems and private wells. As described in more detail below, this alternative is considered both a short-term solution and an important foundation for any long-term supplemental water supply solution. Thus, it is included within all of the subsequent longer-term alternatives.

2. Supplemental water supply through connection to a neighboring water system (non-MWRA supplied community), in addition to improved management and stewardship of Dover's existing supplies.

3. Supplemental water supply through direct or indirect connection to the MWRA system, in addition to improved management and stewardship of Dover's existing supplies.

4. Supplemental water supply through establishment of new Town-owned municipal water supply source, in addition to improved management and stewardship of Dover's existing supplies.

5. Improved current public water service, quality and operational efficiencies through combining the two existing PWS (Aquarion and the Town) into one water system, in addition to improved management and stewardship of Dover's existing supplies.

It is important to note that per the Massachusetts Department of Environmental Protection (MassDEP) regulatory requirements, prior to pursuance of any supplemental supply options, require the preparation of an alternatives analysis of all local options.

A summary matrix of all five alternatives, and some 'sub-alternatives' that could be considered, is presented in **Table 4-1**. Those alternatives preliminarily selected for continued investigation in the subsequent sections of this project are highlighted in green and shown with a check mark, indicating they will be progressed further. Following the matrix, each of the five alternatives is discussed in more detail.

Table 4-1
Overall Matrix

Implementation Timeframe	Alternative	Sub-Alternative	Anticipated Infrastructure, Operation and/or Maintenance Investments	Alternative Considerations	Prioritized for Further Evaluation
Short Term	1. Improved management and stewardship of Dover existing supplies (including public and private wells) ***Alternative No. 1 is hereby incorporated into all subsequent alternatives below***	A. Improved water sustainability stewardship and operation of existing water infrastructure	- Capital cost to improve existing deficiencies - New full time town position for the administration of Water Stewardship, Monitoring and Compliance	-Dover officials should continue their outreach with DEP and Aquarion to follow the progress of Aquarion's water system Corrective Actions progress and plans for improved water quality -No resiliency for climate change or potential future regulations -No redundancy -Lowest capital cost to the Town -Some additional workforce demands for the Town -No improvement to water supply sustainability (supplemental source) -Quick implementation timeline and limited institutional efforts -Improved Stewardship and coordination among user groups -Resolves existing infrastructure deficiencies such as: inactive hydrants (fire protection risk), inability to flush pipes (discoloration concerns), aging infrastructure	√
In addition to addressing the short-term recommendation, if additional long-term sustainable solutions are necessary the following alternatives were considered under this evaluation.					
Long Term	**2. Supplemental water supply through connection to a neighboring community's water system (non-MWRA supplied community)**	A. Natick	- New transmission main from the supplying community to Dover -Offers potential for private well owners along or near the new transmission main to connect -Investigate occurrence and impact of PFAS	-Natick is permitted under the Water Management Act and would have to be contacted to determine interest/ability to supply Dover[1] -Natick lies primarily in the Charles River Basin, except for the northeast side of Natick which lies in the SuAsCo River Basin -Wells located in the SuAsCo River Basin may provide a sustainable supplemental source and redundancy for Dover -Natick has been involved in discussions with the MWRA regarding a direct connection as part of the westward expansion -Potentially offers future resiliency for climate change and regulations if Natick connects to the MWRA system -Expensive capital cost -Future regulatory compliance risk limited -Hydraulic study needs to be performed -A disinfection and corrosion control study would need to be conducted	√
		B. Medfield	-New transmission main from the supplying community to Dover -Offers potential for private well owners along or near the new transmission main to connect -Investigate occurrence and impact of PFAS	-Medfield is permitted under the Water Management Act and would have to be contacted to determine interest/ability to supply Dover[1] -Medfield lies primarily in the Charles River Basin, except for the northeast to southeast side of Medfield which lies in the Boston Harbor River Basin -Given Medfield lies within the same River Basins as Dover, a connection to this community would not offer a sustainable supplemental and redundant source for Dover -Expensive capital cost -Future regulatory compliance risk limited -Hydraulic study needs to be performed -A disinfection and corrosion control study would need to be conducted	
		C. Walpole	- New transmission main from the supplying community to Dover -Offers potential for private well owners along or near the new transmission main to connect -Investigate occurrence and impact of PFAS	-Walpole is permitted under the Water Management Act and would have to be contacted to determine interest/ability to supply Dover [1] -Walpole lies primarily in the Boston Harbor River Basin, except for the southwest side of Walpole which lies in the Charles River Basin -Given Walpole lies within the same River Basins as Dover, a connection to this community would not offer a sustainable supplemental and redundant source for Dover -Expensive capital cost -Future regulatory compliance risk limited -Hydraulic study needs to be performed -A disinfection and corrosion control study would need to be conducted	
		D. Aquarion Water Company	- New transmission main from the supplying system to Dover -Offers potential for private well owners along or near the new transmission main to connect -Investigate occurrence and impact of PFAS	-Aquarion Water Company operates water supplies located in the Boston Harbor and Charles River Basins, which are the same basins that the Town of Dover lies within -Given Aquarion water supplies lie within the same River Basins as Dover, a connection to this system would not offer a sustainable supplemental and redundant source for Dover -During a stakeholder meeting in August 2022 Aquarion expressed limited capacity to provide additional water volume, especially with Water Management Act requirements in place	
Long Term	**3. Supplemental water supply through connection to the MWRA system**	A. Direct connection, new transmission main from MWRA system to Dover	-New transmission main from closest MWRA main to Dover's system -Cost of MWRA water (subject to rate changes)	-May have the highest cost of any alternative -Distance from nearest MWRA transmission main -Connection fee waived for next 5 years (would require fast-paced decisions to achieve) -Resiliency for climate change -Long term water sustainability -Lengthy implementation time and extensive institutional efforts	
		B. Indirect connection, new transmission main from neighboring community served by the MWRA system	-New transmission main from selected MWRA system to Dover's system -Cost of MWRA water (subject to rate changes) plus costs paid to MWRA-served community to receive portion of their capacity -Investigate occurrence and impact of PFAS	-Very high capital cost -Connection fee waived for next 5 years (would require fast-paced decisions to achieve) -Resiliency for climate change -Long term water sustainability -Lengthy implementation time and extensive institutional efforts	√
		1. Needham		-In 2018 Needham gave up their Water Management Act permit and became a 'Registered Only' community and would have to be contacted to determine interest/ability to supply Dover[1] -Needham lies exclusively in the Charles River Basin -Hydraulic study needs to be performed -A disinfection and corrosion control study would need to be conducted	
		2. Dedham-Westwood Water District (DWWD)		-DWWD is permitted under the Water Management Act and would have to be contacted to determine interest/ability to supply Dover[1] -The Towns of Dedham and Westwood lie primarily in the Boston Harbor and Charles River Basins -Hydraulic study needs to be performed -A disinfection and corrosion control study would need to be conducted	
		3. Wellesley		-Wellesley is a 'Registered Only' community under the Water Management Act and would have to be contacted to determine interest/ability to supply Dover[1] -Wellesley lies exclusively in the Charles River Basin -Hydraulic study needs to be performed -A disinfection and corrosion control study would need to be conducted	
Long Term	4. Supplemental water supply through establishment of new Town-owned municipal water supply source	A. New wellfield and potentially a new filtration facility	-Institutional/legal issues associated with another Elm Bank well would need to be researched -For other potential sites, extensive testing and permitting would need to be performed to see if a suitable location and quality for a supply source exists in Dover (typically about 7 years from start of field testing to placing a new supply source on line) - New wellfield and new well pump(s) - Potentially a new water filtration facility - New transmission main from the wellfield to the existing Dover water mains - Offers potential for private well owners along or near the new transmission main to connect - Additional water operations staff (both treatment and distribution system certified operators) - Investigate occurrence and impact of PFAS	-Very high capital and operation and maintenance costs associated -Would require additional staff be hired -Most of Dover lies in the Charles River Basin, except for the southeastern corner of Dover which is in the Boston Harbor Basin -Given that the new water source will be located in Dover within the same River Basins, this would not offer any redundancy -Town responsible for compliance risk associated with current/future regulations -Minimal impact to resiliency for climate change -Very lengthy implementation timeline, extensive institutional efforts, significant permitting	√
Long Term	5. Improve current public water service and operational efficiencies by combining existing public water systems into one water system	A. Transfer Dover's town-owned public water systems to Aquarion; if future public water use decreases through conservation efforts and supply is available, then potential to expand service to private well users as needed.	- No capital infrastructure costs to the Town - Legal and other institutional costs to facilitate the transfer/agreement	-Eliminates Public Water Supply responsibility for Dover -No improvement to quantity concerns -Does not provide a sustainable supplemental source -Does not improve long term reliability/redundancy	√
		B. Dover to purchase and operate Aquarion's infrastructure and franchise; if future public water use decreases through conservation efforts and supply is available, then potential to expand service to private well users as needed.	-Town to purchase the Aquarion infrastructure/franchise as well as future operation and compliance of larger PWS	-Greatly increases Public Water Supply responsibility for Dover -Allows ability for all residents to be served by one supplier (no franchise area limitations) -No impact to reliability/redundancy -Town responsible for compliance risk associated with current/future regulations -No improvement to quantity concerns -Does not improve long term reliability/redundancy	

[1] The amount of water that may be available would need to be determined through discussions with each respective water system and review of projected withdrawals and of their Water Withdrawal Permit

4.2.2 Alternative 1 - Improved Management and Stewardship of Dover Existing Supplies

The overall objective of this work is to offer a sustainable solution to the Town of Dover's drinking water challenges. In order to successfully achieve this objective it is important to develop a partnership with all user groups within Dover to establish reasonable sustainability goals that residents can work towards to improve the resiliency of the shared drinking water resource. There are many facets involved when determining sustainability goals especially as it pertains to drinking water. The residents of Dover are all connected through the commonality that is the shared groundwater resource and all residents contribute to the overall withdrawal from the Dover River Basins. The impacts correlated with the withdrawal from private and public water users could be monitored through the implementation of a new Water Stewardship Town position. This arrangement would facilitate improved drinking water consumption and communication among all Dover residents and governing entities. With a focus on monitoring and conservation, the new Town position would offer a consistent point of contact to collect data and enforce rules in order to refine resource management strategies to help meet sustainability goals. The purpose of this new Town position would be to develop mutually beneficial drinking water goals and standards while also offering public education and engagement. The Town official to hold this new position would share information and act as an advocate, by being aware of sustainability and resiliency issues for the water source and taking steps to secure long-term reliability. This position would allow Dover to take a holistic approach to water stewardship and management of resources.

As part of the alternative's identification and evaluation process and through discussions with the BOS, Alternative 1 considers improvements to the existing Town-owned water infrastructure and the development of a new full time Town position. It is recommended that Dover implement Alternative 1 as soon as possible to facilitate organized water sustainability stewardship and maintain regulatory compliance with the Town infrastructure and water supply. Thus, going forward an important facet of the Town controlling their own system is to properly maintain the system in conformance with MassDEP's Guidelines for Public Water Systems including but not limited to water main flushing and fully operational hydrants and valves. Implementing Alternative 1 would support any future long-term solution to the water sustainability concerns and offer a single point of contact for residents and stakeholders to receive information.

CDM Smith's prior work for the Town included a Water System Infrastructure Evaluation of the Downtown water system authored August 5, 2020, and a subsequent site visit and evaluation of the Caryl Park Wellfield authored September 9, 2022. Both documents are included in this report as **Appendix A** and **B,** respectively.

As aforementioned in Section 2, the existing Town PWS is in need of improvement to meet MassDEP guidelines and would require capital investment and additional operation and maintenance (O&M) considerations for the foreseeable future to maintain compliance. As a first step in this process, a detailed engineering assessment would be necessary to determine the condition of the Downtown water system infrastructure and Caryl Park Wellfield. The need for fire protection flows at appreciable pressures has been described by the BOS as an important consideration that should be captured in future planning efforts for the Downtown system.

However, formal policy decisions including to what extent the Town would restore fire flow supply capabilities and reestablish fire hydrants would need to be agreed upon. For example, if providing fire flow for every parcel of land supplied by the Town system is essential, this would be captured as part of the engineering assessment. Depending on the results of the assessment and the policy decisions made by the Town of Dover, a Dover-dedicated pump station may be necessary to achieve fire flow requirements. A list of tasks that could be included in this assessment are summarized below:

- Determination of assessment objectives
- Detailed assessment of existing infrastructure
- Determination of necessary fire flows and extent of supply
- Determination of hydraulic conditions and available pressures
- Assessment of infrastructure necessary to meet fire flow objectives
- Proposed construction and rehabilitation efforts

In addition to the assessment, Dover should continue to have discussions with Aquarion to establish a better understanding of the water system construction happening Downtown. Through discussion with Aquarion, Dover could consider expanding the existing infrastructure to connect the Downtown system and the Caryl Park Wellfield. Dover should also confirm that Aquarion has the capability to meet the fire flow capacities required.

Dover must also consider what is the best path forward for the Caryl Park Wellfield, which is in need of rehabilitation based on the evaluation performed in September 2022. This memorandum is included as **Appendix B** and the possible alternatives for the Caryl Park Wellfield are summarized below.

- **Conditions assessment -** would help the town to have a better understanding of what funds will need to be available to continue to operate/repair the current system; an estimate as to what types of funds may be required to replace such as system should spare parts no longer be available could be prepared. In a conditions assessment, electrical systems, instrumentation systems and mechanical systems are assessed by a professional engineer in those respective fields.
- **Replacement -** Dover's system is years beyond a period of reliability, therefore, it may be more practical to perform a concept plan for a new replacement facility for improved reliability and long-term use, instead of investing funds to contract for a detailed condition assessment of 70+ year equipment and considering the challenges of the sub-grade vault.
- **System Extension -** Determine the engineering requirements and feasibility of feeding water to this school system from an extension of the water main on Dedham Street. If such a supply was feasible it would eliminate the need for the Town to maintain the well and the pumping facilities. Such a connection would require discussion between Dover and

Aquarion Water with regard to water availability and any potential limits on the local system.

Dover should utilize the findings included as **Appendix A** and **Appendix B** to make policy decisions for the future of the Downtown water system infrastructure and Caryl Park Wellfield before proceeding with capital investments.

Alternative 1 should be considered to be implemented in the immediate future, given the nature of Dover's water concerns, and the need to improve Stewardship and coordination among user groups. This alternative would lessen the risk for the Town associated with lacking infrastructure and provide more reliable water supply for those served by the existing water supply infrastructure. Additionally, homeowner's insurance rates may improve after hydrants are re-activated and fire protection is no longer a significant concern. Further, guidance developed by MassDEP (https://www.mass.gov/info-details/private-well-guidelines) on private wells could be conveyed to private well users with regards to water conservation best practices.

4.2.3 Alternative 2 - Supplemental Water Supply Through Connection to a Neighboring Water System (Non-MWRA Supplied Community)

In Alternative 2, a supplemental water supply would be provided through the establishment of a new transmission main and connection of the Dover water system to a neighboring water system. The neighboring water systems assessed at a desktop level as part of Alternative 2 are those that do not receive water from the MWRA, namely Natick, Medfield, Walpole, and the Aquarion water system. Considerations associated with these systems are summarized in **Table 4-1**.

A summary of the neighboring water system demands, respective Water Management Act (WMA) permit and/or registration limits, and other system information is included in **Table 4-2**. This table also cites the River Basin(s) associated with each water supply source, to offer insight as to whether the water system would provide a redundant and resilient water supply. For the purposes of this work, water systems that receive their drinking water supply from the same River Basin(s) as the existing Dover PWS were considered not redundant, resilient, or sustainable.

Table 4-2 provides a high-level comparison of demand estimates vs. WMA permitted/registered withdrawal limits based on available data. Any water system pursued as a supplemental water supply source for Dover would need to be contacted and their capacity/interest to supply Dover would need to be confirmed. It should also be noted that for some water systems the column labeled "Estimated Supply Surplus" may appear as if the community has plenty of water to sell. However, that is not necessarily the case, as one must consider demands on high-demand days. It is possible that there may be little water available from some or all of the water systems.

A review of **Table 4-2** indicates that the Aquarion water system may not have the capacity to provide the additional water volume that Dover is pursuing. This was confirmed during a stakeholder meeting in August 2022 where Aquarion expressed limited capacity to provide additional water volume, especially with Water Management Act requirements in place. Given this information and understanding of the other considerations associated with the Aquarion water system, this sub-alternative was withdrawn from the alternatives analysis. It should be noted that all remaining communities assessed as part of Alternative 2 are considered the supplemental water supply, but it is assumed that both the supplemental water system and Aquarion water system would be utilized and provide water to Dover residents simultaneously. Meaning the Aquarion water system and associated infrastructure would remain as-is and Aquarion would continue to supply current Dover customers within the existing franchise area with drinking water, without expanding infrastructure or increasing demands.

All remaining water systems evaluated would require the construction of a new transmission main from the suppling community to Dover and would offer the potential for some amount of private well owners to connect into the transmission main if they are along or near the route of the new pipeline. Depending upon system hydraulics, a pumping station may be needed to provide proper pressures in Dover. The user groups addressed by this alternative include the existing Dover PWS supplied customers and any residents along the path of the transmission main route.

Table 4-2 Neighboring Water System Summary (Non-MWRA Communities)

Water System	WMA Status	River Basin	Effective Dates	Registration/Permit Number	Number of Withdrawal Points	Type	Source ID(s)	Source Name(s)	WMA Withdrawal Capacity				2021 ASR Withdrawals		Estimated Supply Surplus on Average Day (MGD)	Notes
									Average Volume per Day (MGD)		Total Annual Volume (MGY)		Average Volume per Day (MGD)	Total Annual Volume (MGY)		
Medfield	Permitted AND Registered	Charles	March 1, 2010 - February 28, 2029 (permitted) January 1, 2008 - December 31, 2017 (registered)	9P322017502 (permit number) #22017501 (registration number)	4	Groundwater	2175000- 01G, 02G, 05G, 0BG,	Well #1, #2, #6, State Hospital Wellfield	1.39 (permitted) + 0.11 (registered)	1.5	507.35 (permitted) + 40.15 (registered)	547.5	1.01	369.79	0.49	
	Registered	Boston Harbor	January 1, 2008 - December 31, 2017	#21917501	2	Groundwater	2175000- 03G, 04G	Well #3, #4	0.92		335.8		0.09	31.146	0.83	
Natick	Permitted AND Registered	Charles	March 1, 2010 - February 28, 2029 (permitted) January 1, 2008 - December 31, 2017 (registered)	9P332019801 (permit number) #32019801 (registration number)	6	Groundwater	3198000- 03G, 04G, 05G, 06G, 11G, 12G	Morse's Pond, Pine Oaks #1, #2, #3, Elm Bank Well #2, #4	1.31 (permitted) + 0.22 (registered)	1.53	478.15 (permitted) + 80.3 (registered)	558.45	1.63	595.94	-0.1	
	Registered	Concord	January 1, 2008 - December 31, 2017	#31419801	6	Groundwater	3198000- 01G, 14G, 02G, 07G, 09G, 13G	Springvale #1, #2, #3, #4, Evergreen #1, #3	4.1		1,496.50		1.24	452.91	2.86	
Walpole	Permitted AND Registered	Boston Harbor	December 16, 2021 - February 28, 2025 (permitted) January 1, 2008 - December 31, 2017 (registered)	9P41930702 (permit number) #41930701 (registration number)	18	Groundwater	4307000- 01G, 02G, 03G,11G, 16G, 17G, 18G, 19G, 08G, 09G, 14G, 15G, 20G, 21G, 22G, 23G, 12G, 13G	Mine Brook #1, #2, #3, #5, #1A, #2A, #3A, #5A, Washington #5, #6, #4A, #4B, #2A, #2B, #3A, #3B, Neponset #1, #2	0.53 (permitted) + 2.25 (registered)	2.78	821.25	1,014.70	2.14	780.39	0.64	
Aquarion - Dover Water System	Permitted	Charles	December 8, 2019 - February 28, 202	9P432007801	2	Groundwater	3078006- 02G, 03G	Chickering Drive Tubular Wellfield, Knollwood Drive Tubular Wellfield	0.13		47.45		0.03	9.42	-0.02	
	Permitted	Boston Harbor	Expired, Aquarion has not yet received updated permits from MassDEP	9P231907801	6	Groundwater	3078006- 01G, 04G, 05G, 08G, 09G, 10G	Walpole Street Tubular Wells, Draper Road Wells #1, #2, Francis Street Wells A, B, C					0.13	46.19		Walpole Street Tubular Wells have been abandoned
Aquarion - Springdale Water System	There is no WMA permit for Springdale wellfield because its production is less than 100,000 GPD				2	Groundwater	3078008- 01G, 02G	Old Colony Drive Wells #1, #2	Not Applicable				0.02	7.68	0.04[1]	

[1] Estimated supply surplus based on MassDEP approved daily pumping yield of 0.03 MGD according to 2021 ASR for Springdale.

0.17

The remaining communities of Natick, Walpole, and Medfield were compared based on the evaluation criteria selected as part of this work to determine which water system would provide Dover with the most sustainable solution. Any of the three sub-alternatives would require an expensive capital investment, discussions between the Town and adjacent community to understand the current status of PFAS occurrences, and a hydraulic study and a disinfection and corrosion control study. Natick is the only water system that has a source of supply outside of the existing Dover River Basins – Natick has wells in the Concord River Basin in addition to those in the Charles River Basin.

In addition, Natick has been involved in discussions with the MWRA regarding a direct connection as part of the 'Westward Expansion' that MWRA is pursuing. Connecting to Natick could potentially offer a second redundant source for Dover in the form of MWRA water, which is supplied by the Quabbin and Wachusett Reservoirs. To achieve this second redundant source, Natick would have to agree to participate in the 'Westward Expansion' and this assumes the expansion proceeds as planned. This additional potential benefit associated with connecting into the Natick system would offer significant additional resiliency. With these considerations in mind, Natick was selected as the system that could offer Dover the most sustainable solution and will be evaluated further in Section 5.

4.2.4 Alternative 3 - Supplemental Water Supply Through Direct or Indirect Connection to the MWRA System

The Massachusetts Water Resources Authority (MWRA) operates the largest water system in the Commonwealth, serving over 2 million residents. MWRA's water sources are Quabbin Reservoir, the Ware River, and Wachusett Reservoir. These sources are in the Chicopee and Nashua River Basins.

MWRA has significant excess capacity, and is actively seeking additional customers in the MetroWest area and elsewhere, as mentioned above. A connection from Dover to the MWRA could be in the form of a direct connection to the MWRA system (Alternative 3A) or through an indirect connection via an MWRA-supplied community's water distribution network (Alternative 3B). Either way, the permitting process to achieve admission to MWRA's waterworks division is rigorous and time-consuming.

Implementing a direct connection to the MWRA distribution system would likely have the highest cost of any alternative being considered in this study, given the distances from Dover to the nearest MWRA transmission mains. While a direct connection would offer solutions to many of the water concerns in Dover, it would require fast-paced decision making to avoid additional costs associated with an MWRA connection fee (waived for the next 5 years) and require extensive institutional efforts.

An indirect connection to the MWRA system through an MWRA-supplied water system would present Dover with a more cost-effective solution to receive MWRA water, because of the shorter transmission main lengths. This sub-alternative considers a new transmission main from a neighboring community served by the MWRA to Dover. An indirect connection to the MWRA system still requires fast-paced decisions making and extensive institutional efforts but is more feasible than a direct connection.

The neighboring MWRA member communities that were assessed at a desktop level as part of Alternative 3B are summarized in **Table 4-1**. They are the Needham, Dedham-Westwood Water District (DWWD), and Wellesley water systems, all of which border Dover. All three would require the construction of a new transmission main from the supplying community to Dover and would offer the potential for some amount of Dover private well owners to connect into the transmission main if they are along or near the route of the new pipeline. Depending upon system hydraulics, a pumping station may be needed to provide proper pressures in Dover. The user groups addressed by this alternative include the existing Dover PWS supplied customers and any residents along the path of the transmission main route. A summary of the neighboring water system demands, respective WMA permit and/or registration limits, and other system information is included in **Table 4-3**.

Table 4-3 Neighboring MWRA Served Community Water System Summary

Water System	WMA Status	River Basin	Effective Dates	Registration/Permit Number	Number of Withdrawal Points	Type	Source ID(s)	Source Name(s)	WMA Withdrawal Capacity: Average Volume per Day (MGD)		WMA Withdrawal Capacity: Total Annual Volume (MGY)		2021 ASR Withdrawals: Average Volume per Day (MGD)	2021 ASR Withdrawals: Total Annual Volume (MGY)	Estimated Supply Surplus on Average Day (MGD)	Notes
Dedham-Westwood Water District	Permitted AND Registered	Boston Harbor	March 1, 2005 - February 28, 2010 (permitted) January 1, 2008 - December 31, 2017 (registered)	9P31907301 (permit number) #31907301 (registration number)	5	Groundwater	3073000- 06G, 07G, 08G, 09G, 18G	White Lodge Wells #1, #2, #3, #4, #3A	0.49 (permitted) + 2.62 (registered)	3.11	178.85 (permitted) + 956.3 (registered)	1,135.15	2.63	959.63	0.48	DWWD purchased a portion of water from the MWRA every month of 2021
	Registered	Charles	January 1, 2008 - December 31, 2017	#32007303	10	Groundwater	3073000- 01G, 02G, 03G, 04G, 05G, 14G, 15G, 16G, 17G, 10G	Bridge St Well A2, B1, D1, E, F, B2, D2, E1, E2, Rock Meadow Well #11	1.91		697.15		1.28	467.83	0.63	
Needham	Registered	Charles	January 1, 2008 - December 31, 2017	#32019901	3	Groundwater	3199000- 01G, 04G, 02G	Charles River Well #1, #2, #3	2.63		959.95		2.39	873.82	0.24	Needham purchased a portion of water from the MWRA every month of 2021 except January and December
Wellesley	Registered	Charles	January 1, 2008 - December 31, 2017	#32031701	5	Groundwater	3317000- 02G, 03G, 04G, 05G, 06G	Wellesley Avenue Wells, Morses Pond Wells, Rosemary Brook, Longfellow Road Well, T.F. Coughlin Wells	2.62		956.3		1.07	391.86	1.55	Wellesley purchased a portion of water from the MWRA every month of 2021

A review of **Table 4-3** indicates that the three water systems assessed may have the capacity to provide the additional water volume that Dover is pursuing, though only water from the MWRA would be considered a redundant source based on the River Basins that each system lies within. Any water system pursued as a supplemental water supply source for Dover would need to be contacted and their interest to supply Dover would need to be confirmed. The MWRA would also need to be involved in these discussions to confirm their ability to increase water supply to the selected MWRA community. It is also important to consider the cost of MWRA water, which is subject to rate changes, and that those costs will be included in the total cost paid by Dover to the MWRA-served community to receive a portion of their capacity. Connection into any of the three communities would require an expensive capital investment, discussions between the Town and adjacent community to understand the current status of PFAS occurrences, and a hydraulic study and a disinfection and corrosion control study be conducted to mitigate risk and assess compatibility of water matrices.

With these considerations in mind, an indirect connection to an MWRA-supplied water system was selected as the more-feasible sub-alternative. The three water systems named herein will be evaluated in more detail in Section 4.

4.2.5 Alternative 4 - Supplemental Water Supply Through Establishment of New Town-owned Municipal Water Supply Source

Alternative 4 considers the Town of Dover establishing its own municipal water supply source. While this would offer additional water quantity and provide the Town with the highest level of control, this alternative would also require the greatest amount of institutional effort and longest implementation time.

To pursue this alternative, the Town would need to either reconsider the Elm Bank site or conduct extensive studies to select a different potential site for the new well(s).

Chapter 624 of the Acts of 1986 governed the development of the Elm Bank site in Dover for water supply purposes. It stated that Dover, Natick, Needham and Wellesley are the four towns that can share the water. The towns were prohibited to sell Elm Bank water to any other community or water supplier. Currently, the Natick water system includes two gravel-packed wells located within the Town of Dover at the Elm Bank Reservation site. During the applicable time frame of the Act, Natick was the only town to proceed with water supply development. Further legal review would be needed to determine whether the Act would govern any future attempt by Dover to install a well for its own use.

The operation of Natick's Elm Bank Wells is governed by Natick's MassDEP Water Withdrawal Permit. Natick is required to turn off the wells in dry seasons when the Charles River flow recedes to a certain trigger level. A similar provision would be included in any water withdrawal permit issued to Dover for a well at the Elm Bank site. This means that Dover could not depend on year-round operation of a new Town-owned water source at Elm Bank, which is a disincentive to considering this site further.

If the Town were to consider pursuing a source other than Elm Bank, this would require extensive testing and permitting to select a wellfield site, determine treatment requirements (which could include filtration), and estimate costs. A new wellfield would require additional water operations staff to be hired in order to maintain the necessary infrastructure, resulting in very high capital and O&M investments.

It is also important to note that any site selected would not provide the Town with a sustainable solution to the water quantity concerns, given the new groundwater source would still be supplied by the same River Basin(s).

The time to place a new supply source online can be 7 years or more from the initiation of field testing. MassDEP's Source Approval Guidelines include a 25-step process that must be completed, as outlined in **Table 4-4** below.

Table 4-4. MassDEP's 25-Step Source Approval Process

MassDEP's 25-Step Source Approval Process (From Chapter 4 of the 2008 "Guidelines and Policies for Public Water Systems")
1. Explore Potential Sources of Groundwater
2. Water Management Program Site Screening Requirements
3. Application for Approval to Site a Source and Conduct a Pumping Test
4. Conduct Site Exam/Pumping Test Proposal Approval
5. Federal Notice of Intent (NOI) Application 404 Permit/MassDEP 401 Water Quality Certification Program
6. Conduct Pumping Test
7. Pumping Test Shutdown
8. Submit Source Final Report to MassDEP Regional Office
9. Assess Capacity (Community and NTNC systems only)
10. Water Management Permit Application
11. Submit Interbasin Transfer Application to DCR
12. Submit Environmental Notification Form (ENF) to MEPA
13. Submit MassDEP 401 Application
14. Submit Environmental Impact Report (EIR) to MEPA (if required)
15. Submit Final Environmental Impact Report (FEIR) to MEPA (if required)
16. Submit 404 Permit Application to Army Corps of Engineers
17. Source Final Report Approved (WMA Permit Approved)
18. Submit Design Plan for Permanent Works to MassDEP Regional Office
19. Begin the Wellhead Protection and/or Best Effort Compliance Process
20. Submit Notice of Intent (NOI) to Local Conservation Commission
21. Notify MassDEP Regional Office When Construction is Complete
22. Site Inspection of Permanent Works
23. Final Source Approval
24. Meet Requirements of the Surface Water Treatment Rule
25. Implications of the Groundwater Rule

Table 4-4 illustrates how daunting the process of implementing a new water supply source is, a process which Dover has not yet initiated. With the considerations detailed above and in **Table 4-1,** pursuing a new Town-owned municipal water supply source (Alternative 4) would be a significant undertaking.

4.2.6 Alternative 5 - Improve Current Public Water Service and Operational Efficiencies by Combining Existing Public Water Systems into One Water System

In Alternative 5, the Town of Dover could improve current public water service through combining the Aquarion and Town systems into a single system owned by one entity. However, the anticipated benefits of combining into a single system assume that the necessary investments are made in infrastructure and maintenance. Either Dover would sell the Town-owned infrastructure to Aquarion (Alternative 5A), or Dover would purchase and become responsible for the Aquarion infrastructure and franchise area (Alternative 5B). This alternative would offer several benefits including service improvements but would not provide a redundant additional source as some other alternatives will.

Sale of the existing Town-owned infrastructure would result in costs associated with legal and other institutional efforts to facilitate this transfer and agreement. The Town would need to determine whether Aquarion has interest in owning the Town's current infrastructure. If so, then the PWS-related responsibilities and risks would be eliminated for Dover. This would reduce the liability and remove anticipated future capital and O&M costs associated with the downtown and Caryl Park PWS, as aforementioned in Alternative 1.

Alternatively, if the Town chose to purchase the Aquarion franchise area and associated infrastructure, this would greatly increase the PWS responsibility and risk for Dover. The Town would be responsible for compliance with all current and future regulations. In addition to the costs associated with purchasing the franchise area and maintaining the water system, Dover would need to hire the staff to operate the larger system. This would offer the Town much greater control in terms of expanding and operation of the system, but with this comes increased responsibility and cost.

Both sub-alternatives have their own advantages and disadvantages but Alternative 5A offers a reduction in risk, liability and future costs associated with the existing Dover-owned PWS. As such, Alternative 5A is advanced to the next step in the evaluation.

4.2.7 Alternatives Summary and Next Steps

In conclusion, **Table 4-1** and Sections 4.2.2 through 4.2.6 provide a summary of the five (5) alternatives and sub-alternatives that were assessed at a desktop level. Based on the results of the preliminary evaluation, several 'sub-alternatives' were withdrawn from the engineering assessment based on the evaluation criteria described in Section 4.1. The five remaining alternatives are listed below:

1. Improved Management and Stewardship of Dover Existing Supplies
2. Supplemental Water Supply Through Connection to the Natick Water System (Non-MWRA Supplied Community)
3. Supplemental Water Supply Through an Indirect Connection to the MWRA System
4. Supplemental Water Supply Through Establishment of New Town-owned Municipal Water Supply Source

5. Improve Current Public Water Service and Operational Efficiencies by Transferring the Dover-Owned Public Water Systems to Aquarion

A comparative analysis was conducted for the five remaining alternatives to select the three prioritized alternatives to be carried forward into the Financial Evaluation phase of this work. This comparative analysis is presented as **Figure 4-1**.

Figure 4-1. Draft Comparative Analysis Matrix
Dover, MA Water Sustainability Study

<u>Evaluation Criteria</u>	**Alternative 1** Improved management and stewardship of Dover existing supplies (including public and private wells)	**Alternative 2A** Supplemental water supply through connection to a neighboring community's water system (non-MWRA supplied community)	**Alternative 3B** Supplemental water supply through an indirect connection to the MWRA system	**Alternative 4** Supplemental Water Supply Through Establishment of New Town-owned Municipal Water Supply Source	**Alternative 5A** Improve current public water service and operational efficiencies by combining existing public water systems into one water system, through the transfer of Dover's town-owned public water systems to Aquarion
1. **Estimated Project Costs** - the estimated Construction, Engineering, and Implementation cost with planning level contingencies for an alternative	● positive	● negative	● negative	● negative	● positive
2. **Funding Opportunities** – the potential for an alternative to receive funding support through low interest loans, grants, or other available funding options	● negative	● neutral	● neutral	● neutral	● negative
3. **Long-term Reliability / Redundancy of Infrastructure or Source -** how consistent the alternative is in quality and performance, also if the alternative offers secondary infrastructure and/or sources, thereby limiting risk	● neutral	● positive	● positive	● negative	● neutral
4. **Operational Workforce Demands -** the workforce demands or requirements i.e., the number and level of water operator required for an alternative	● positive	● neutral	● neutral	● negative	● positive
5. **Regulatory Compliance Risk with Current/Future** – the likelihood that an alternative would contribute to improved compliance with current and potential future regulations	● positive	● positive	● positive	● negative	● positive
6. **Long-term Water Supply Sustainability** - the ability for an alternative to provide a sustainable solution to water quality and quantity concerns for the foreseeable future, and how adaptable it is with drought and water conservation practices	● positive	● positive	● positive	● negative	● neutral
7. **Resiliency for Climate Change** – an alternative's adaptability or resistance to drought conditions.	● positive	● positive	● positive	● negative	● neutral
8. **Startup Timeline and Implementation Demands –** the duration it takes to implement and commission an alternative such that the infrastructure associated is functional and operational	● positive	● negative	● negative	● negative	● positive
9. **Institutional Efforts** - the level of legal, land ownership and/or easement coordination, and intermunicipal agreements that are required to implement an alternative	● positive	● negative	● negative	● negative	● positive
10. **Future Project Permitting** - the permitting efforts necessary to implement a given alternative	● positive	● negative	● negative	● negative	● positive
11. **Level of Control and Influence** – Dover's decision making authority with regard to the future operation and water rates associated with an alternative	● positive	● negative	● negative	● positive	● neutral
12. **Public Acceptance –** the public's perception of an alternative and the general opinion and level of approval/support	● positive	● positive	● positive	● negative	● neutral
13. **Protection of Open Space, Recreation, and Biodiversity** - opportunities or impacts to open space, recreational space, and flora and fauna through the implementation of an alternative	● positive	● neutral	● neutral	● negative	● positive
<u>Preliminary Overall Rating</u>	● positive	● negative	● negative	●● negative	● neutral

●: negative

●: neutral

●: positive

Through discussions with the BOS, including virtual progress meetings and workshops, the group reviewed the comparative analysis. While some of the criteria presented are quantitative or measurable, many factors considered qualitative were ranked by the BOS based on overall importance to the Town of Dover residents. Ultimately, some of these qualitative factors were deemed more critical to the overall selection process and the success of this work. This resulted in Alternative 3B being selected over Alternative 5A despite the color-coded attributes displayed in **Figure 4-1**. The three that were selected during a workshop held on December 20, 2022 and were carried forward into the Financial Evaluation are listed below:

- Alternative 1: Improved Management and Stewardship of Dover Existing Supplies
- Alternative 2A: Supplemental Water Supply Through Connection to the Natick Water System (Non-MWRA Supplied Community)
- Alternative 3B: Supplemental Water Supply Through an Indirect Connection to the MWRA System

Sub-alternatives considered during the evaluation of the prioritized alternatives are described in detail in Section 5.

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Section 5

Detailed Analysis of Three Prioritized Alternatives

As detailed in Section 4.2.7, a comparative analysis was developed to aid in the selection process for the three prioritized alternatives. Based on a December 20, 2022, workshop the following alternatives were selected for more detailed analysis.

- Alternative 1: Improved Management and Stewardship of Dover Existing Supplies
- Alternative 2A: Supplemental Water Supply Through Connection to the Natick Water System (Non-MWRA Supplied Community)
- Alternative 3B: Supplemental Water Supply Through an Indirect Connection to the MWRA System

A detailed assessment of the three prioritized alternatives and the design criteria, assumptions, and considerations that contributed to the further refinement of each alternative is presented in subsequent sections.

5.1 Alternative 1: Improved Management and Stewardship of Dover Existing Supplies

As presented in Section 4.2.2, Alternative 1 considers improvements to the existing Town-owned water infrastructure and the development of a new full time Town position. Simultaneously with the establishment of the new Town position, this alternative assumes the following actions will also be completed:

1. Engineering assessment of the Downtown infrastructure and Caryl Park Wellfield
2. Continue discussions with Aquarion to better understand system improvements and construction occurring Downtown, potential for system expansion, and ability to meet fire flow capacities identified through the Engineering Assessment
3. Policy decisions must be made to determine the fate of the Downtown system and Caryl Park Wellfield

Alternative 1 should implemented in the immediate future and should include all aforementioned actions, given the nature of Dover's water concerns and the need to improve Stewardship and coordination among user groups.

Further detail on the new full time Town position is provided below:

- A suggested title for the recommended position is Environmental & Regulatory Coordinator or Environmental Compliance Coordinator. Typically, these positions in Massachusetts municipalities fall under the Department of Public Works, Water and Sewer Departments or Engineering Departments.

- Key qualifications are a knowledge of and/or experience in meeting MassDEP drinking water guidelines for Public Water Systems, water conservation and drought management, as well as Massachusetts water supply protection regulations. Knowledge in applicable areas within MassDEP guidelines include: Guidelines for Public Water Systems; Chapter 6: Chemical Application, Chapter 7: Pumping Facilities, Chapter 9: Distribution System Piping & Appurtenances, and Chapter 10: Water Management Act Requirements; as well as the Massachusetts Drought Management Plan.

- One of the duties of this position would be to work with the Town Superintendent of Building Maintenance to support the Town's compliance with MassDEP regulations on the required maintenance of Dover's existing water assets, as defined in ANSI/AWWA G200-09 Standard for Distribution Systems Operation and Management. This person could also assist the Water Department in the preparation of the Water Annual Statistical Report, submitted annually to MassDEP.

- Another of the key responsibilities of this role would be to update and maintain the Town's website covering the Dover Water Resources Information and be the point person for citizens to communicate with on water conservation related matters. As well as to post the groundwater water monitoring well data, which is collected by Dover Water Department.

- The person filling this position would ideally be, or being willing to become, an active participant in state and regional water works associations, such as Massachusetts Water Works Association (MWWA) and New England Water Works Association (NEWWA). These associations provide a platform for municipalities to share knowledge on best practices and provide educational resources for water works professionals. Further, the person serving in this role would be a liaison to other active committees within the Town with interest in Dover's water conservation activities.

- It is recommended that the new Environmental Compliance Coordinator role, be the leader in promoting Dover's culture of conservation and tailor Dover's actions to what makes the most sense for the community of Dover. The person in this new role would work with other Town staff and committee members to develop conservation measures that best suit the needs of Dover. The Executive Office of Energy and Environmental Affairs (EOEEA) and the Massachusetts Emergency Management Agency (MEMA) released the updated Massachusetts Drought Management Plan in December 2023, that has guidelines for determining drought levels and responses. Section 8 provides guidelines for communities to develop conservation programs and Water Supply Drought Management Plans. Although the new Coordinator can recommend and perform outreach on conservation measures it is important to note that enforcement of such measures will require the rule making and enforcement authority of the Dover governing bodies, the Public Works and other town officials.

5.2 Alternative 2: Supplemental Water Supply Through Connection to the Natick Water System (Non-MWRA Supplied Community)

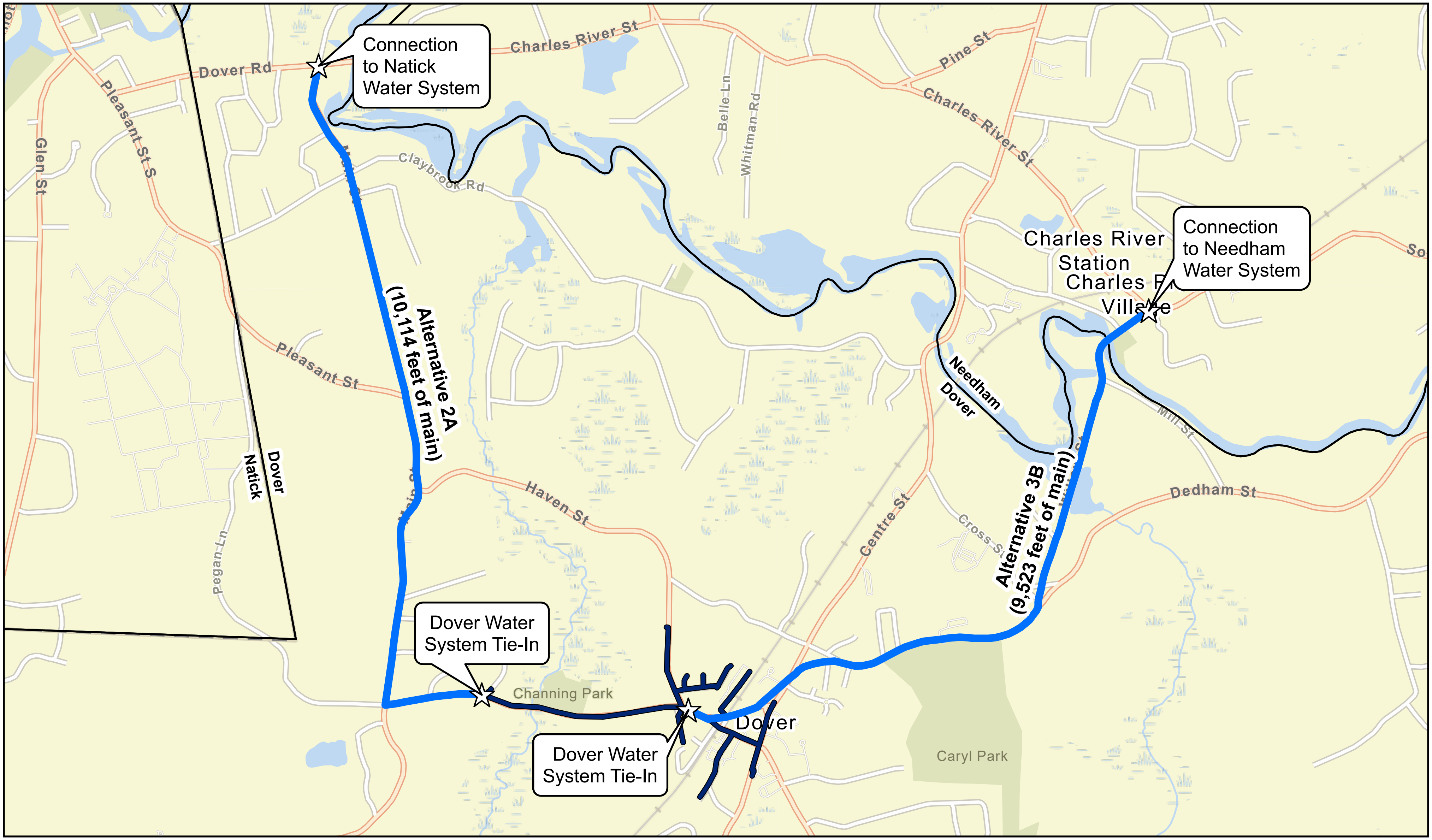
For the reasons outlined in Section 4.2.3, the Town of Natick was selected as the optimal non-MWRA-supplied water system that could offer Dover the most sustainable solution. This sub-alternative was identified in **Table 4-1** and is referred to herein as Alternative 2A. As such, a map of the current Natick water system was prepared as part of this work to assess the existing infrastructure and the feasibility of connecting the two systems. This map is included as **Figure 5-1**.

The map provides existing system water main locations, sizes, and valving information. Through a review of the map, any mains that were less than 12-inches in diameter were ruled out as potential system connection points, to avoid capacity restrictions. Next, the existing system mains with a diameter of 12-inches or greater were reviewed based on their proximity to existing Dover water infrastructure.

The Natick main selected as the connection point for Alternative 2A is a 20-inch transmission main at the intersection of Main Street and Dover Road in Dover. Proposed routes that were considered assumed travel along existing public roads in Town. For the transmission main from Natick to Dover, the most direct route is south along Main Street to the intersection of Springdale Avenue, then east along Springdale Avenue to the intersection of Old Colony Drive where the new main would meet the existing Downtown water system infrastructure. This proposed route is shown in **Figure 5-2**, identified as Alternative 2A on the map.

Date: 2/28/2023
1:6,000
1" = 500'
0 250 500 1,000 1,500 2,000 Feet
Cartography by: Richard Ames, GISP
Path: G:\GIS Projects\2022\WATER SYSTEM LAYOUT.aprx

Figure 5-1. Natick Water System Near Dover



CDM Smith

N

0 1,000 2,000 Feet

New 12" DI Water Transmission Main

Dover Water System Mains

Natick & Needham Proposed Transmission Mains

Figure 5-2

5.3 Alternative 3: Supplemental Water Supply Through an Indirect Connection to the MWRA System

Through preliminary screening, three water systems were selected as neighboring communities with an active MWRA connection that Dover could consider purchasing MWRA water through. The Dedham-Westwood Water District (DWWD), Town of Needham water system, and Town of Wellesley water system were assessed as sub-alternatives under Alternative 3. Maps of the three existing water systems were collected as part of this work to assess the existing infrastructure and the feasibility of connecting the systems.

Upon initial review of the supplied maps and proximity to existing Downtown Dover water system infrastructure, it was determined that both the DWWD and Wellesley water system infrastructure were significantly further than Needham. A more detailed review of potential transmission main paths confirmed this initial determination, officially ruling out both water systems as optimal MWRA connection points. DWWD was ruled out because the closest available infrastructure was located on Dover Road in Westwood, which is over 3.5 miles away. Wellesley was ruled out because the closest available infrastructure was also greater than 3 miles away. Whereas for Needham, all potential connection points were 2.1 miles or less. As such, Needham was carried forward for further evaluation as outlined in the subsequent section.

5.3.1 Needham

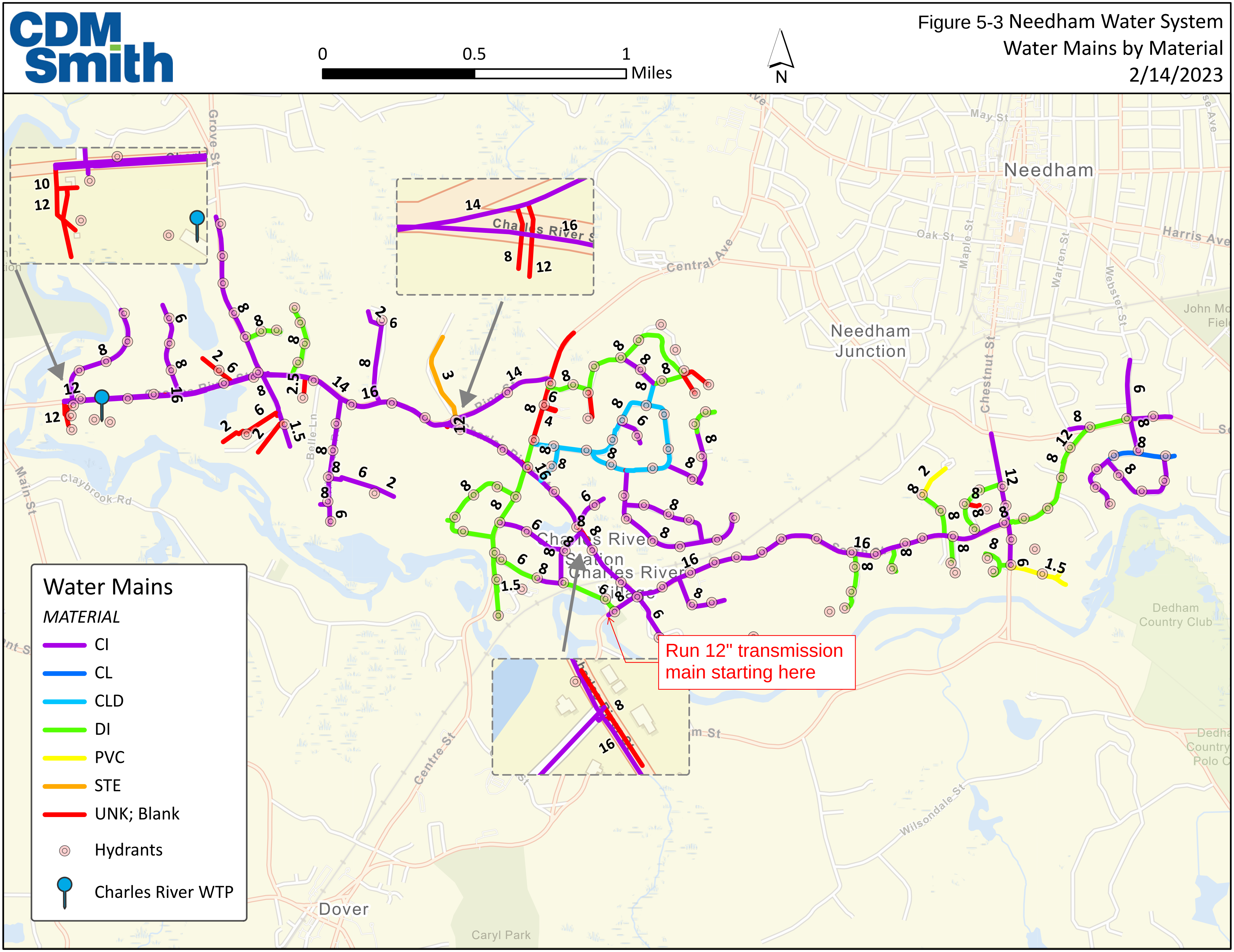
Three potential routes were selected to connect the Needham water system to the Downtown Dover water system infrastructure. A map of the Needham water system is included in **Figure 5-3**. These paths are summarized below and identified based on their connection point in Needham:

1. Transmission main path 1: Main Street
2. Transmission main path 2: Centre Street
3. Transmission main path 3: Willow Street

Similar to the Natick process, by reviewing the map of Needham any mains that were less than 12-inches in diameter were ruled out and existing system mains with a diameter of 12-inches or greater were evaluated based on their proximity to existing Dover water infrastructure. Based on a preliminary exercise estimating the total distance from the Downtown Dover infrastructure, path 1 was ruled out as it exceed 2 miles. Path's 2 and 3 were considered optimal routes for the proposed transmission main as they offered the shortest distance, both coming in at approximately 1.8 miles away from the Downtown Dover infrastructure. From there, the number of railroad and river crossings played a significant role in the selection process. The Centre Street path required two railroad crossings whereas the Willow Street path required one and the railroad itself was out of service. All three paths required one river crossing of the Charles River. For those reasons, Willow Street was selected as the most optimal transmission main connection point. The Needham transmission main selected as the connection point for Alternative 1 is at the intersection of South Street and Wilson Lane in Needham. The most direct route considered a path south along South Street until it transitions into Willow Street, and continuing along Willow

Street until the intersection of Cross Street where it transitions into Dedham Street for eventual connection to Springdale Avenue, where the main meets the existing Downtown water system infrastructure. This proposed path is shown in **Figure 5-2**, identified as Alternative 3B on the map. Assumptions made for this alternative and the proposed transmission main path at this preliminary stage are the same as outlined in Section 5.2.

Figure 5-3 Needham Water System
Water Mains by Material
2/14/2023



5.4 Transmission Main Routing Assumptions

Assumptions made for both selected alternatives and the proposed transmission main paths at this preliminary stage included the following:

- Water Main
  - Class 52 ductile iron water main, double-thickness cement-mortar lining
  - 12-inch in diameter
  - 5 feet of cover
  - Charles River crossing (Needham Alternative 3B only): 12" HDPE main, trenchless construction via horizontal directional drilling
- Connection – one tapping sleeve and valve
- Hydrant assemblies – one per 500 feet of main
- Mainline valves – one gate valve per 1,000 feet of main
- Side street connections – the side street intersections were quantified, and it was assumed that a tee would be located on the mainline with an 8-inch branch, an 8-inch gate valve, an 8-inch main (restrained joints) that is 25 feet in length, and an 8-inch cap would be provided. Costs were not included for the eventual extension of these side-street mains but these appurtenances were put in place for future expansion, if desired.
- Service connections – service connections were quantified based on a visual assessment of residential and business, church or municipal buildings along the proposed path. It was assumed that each building along the path would have a service connection from the main to the property line but that the connection from the property line to the building would be covered by the homeowner. All residential service connections were assumed to consist of a 1-inch diameter line with corporation, tubing and curb stop on the property lines. Buildings not identified as residential were assumed to have a 2-inch polyethylene service connection.
- Meter vault – an allowance was included to account for a meter vault
- Paving
  - Temporary paving during construction assumed to be trench paving. Permanent paving to be full width overlay
  - All paving will be on local roads as there are no state-maintained roads in Dover
- No provisions for rock removal or addressing contaminated soil or groundwater were included

- No provisions for a pump station nor storage tank were included, as hydraulic evaluations were not part of the scope of work for the project

5.5 Three Prioritized Alternatives

The three prioritized alternatives selected for progression into the financial evaluation phase of this work are summarized below:

1. Improved Management and Stewardship of Dover Existing Supplies
2. Supplemental Water Supply Through Connection to the Natick Water System (Non-MWRA Supplied Community)
3. Supplemental Water Supply Through an Indirect Connection to the MWRA System (Needham Water System)

The assumptions outlined herein were used as the basis for the conceptual cost analysis detailed further in Section 6.

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Section 6

Conceptual Cost Analysis and Financial Projections

6.1 Opinions of Probable Construction Cost

Based on the facilities information presented in Section 5, opinions of probable construction costs (OPCCs) were developed for two alternatives selected by the Dover Sustainability Report project steering committee (as described in Section 5) for the cost analysis are:

- Alternative 2A Supplemental water supply through connection to a neighboring community's water system (non-MWRA supplied community) via Natick, and
- Alternative 3B Indirect connection, new transmission main from neighboring community served by the MWRA system via Needham.

An OPCC was not developed for the other alternative selected by the steering committee (Alternative 1 Improved Management and Stewardship of Dover Existing Supplies) as this alternative does not include building of new infrastructure.

Factors that influence estimated construction costs include, but are not limited to, the following: cost of labor, materials, and equipment; services provided; schedules; contractor methods of determining prices; competitive bidding; and market or negotiating conditions. CDM Smith's planning level OPCCs include direct costs (materials and construction labor), indirect costs (permit fees, insurance and bonding costs), contractor general conditions, and contractor's overhead and profit. Additionally, construction contingencies and escalation due to inflation are included in the OPCCs presented.

These OPCCs do not include owner costs, finance or funding costs, legal fees, costs for land acquisitions or temporary/permanent easements, design engineering and permitting fees, construction oversight fees, change orders, operations, public participation costs or any other costs associated with the project that are not anticipated to be part of a bidding contractor's proposed scope of work.

6.1.1 Indirect Costs

The following indirect cost mark-ups are included in the Opinion of Probable Construction Costs for each alternative:

- 10% for General Conditions,
- 15% for Contractor Overhead and Profit,
- 0.4% for Permits,
- 0.65% for Insurance and Liability,
- 1.5% for Bonds,

- 25% Construction Contingency,
- An annual escalation rate of 5.0% to the midpoint of construction (May 2023 to October 2027)

6.1.2 Construction Contingency

Construction contingencies are costs added to estimates, usually as a percentage of direct costs, to account for elements of the project design or scope that are not yet fully defined and therefore cannot be accurately priced. Construction contingency is normally added based on how far advanced the design has proceeded, and the contingency is considered part of the construction cost. The construction contingency reflects any design development necessary based on the status and phase of the project.

At the preliminary stage of a planning study, carrying a 25% planning level contingency is CDM Smith's standard practice. This contingency has been applied to the unit cost per linear foot of pipeline.

6.1.3 Escalation to Midpoint of Construction

The OPCCs were developed in May 2023, and have been escalated to the midpoint of construction. For both alternatives, it is assumed that midpoint of construction will be October 2027, which equates to 24%.

The economic climate has changed dramatically in the last two to three years. The construction sector has been significantly impacted by recent global situations and events (such as the COVID-19 pandemic, natural disasters and international conflicts). Disruption of global supply chains have increasingly affected construction activities, with shortages of raw materials and other inputs, contractors and subcontractors, and workers. Key construction materials are experiencing price increases, shortages, and delivery delay.

The Engineering News-Record (ENR) 20-City Construction Cost Index (CCI) and Material Price Index (MPI) are cost indices that are used widely in the construction industry as a measurement of inflation. At the time that the OPCCs were developed, the CCI was 13,288 and the MPI was 5,817.

Table 6-1. Summary CCI and MPI Annual Percent Increases

CCI Annual Percent Increases	
2019-2020	1.75%
2020-2021	2.90%
2021-2022	7.36%
2022-2023	5.55%
MPI Annual Percent Increases	
2019-2020	3.21%
2020-2021	8.28%
2021-2022	30.94%
2022-2023	18.65%

Comparatively, the yearly percent increase for both the CCI and the MPI are much greater than the two prior years.

Due to the high inflation rates, supply chain issues, and materials cost volatility, the escalation rate being carried is 5.0% per year.

6.1.4 Cost Summary

The OPCC for Alternative 2A is $11,200,000, and the OPCC for Alternative 3B is $10,200,000.

On the basis described in the above subsections, this equates to $9,000,000 for Alternative 2A, and $8,200,000 for Alternative 3B in "today's dollars" (May 2023). The tables below summarize the total construction cost and cost per linear foot in comparison to "today's dollars" and prior to contingency. The overall cost per linear foot for Alternative 3B is higher than that for Alternative 2A due to trenchless river crossings that will be necessary to install the water main.

Table 6-2. Alternative 2A Estimated Construction Costs

Alternative 2A Supplemental Water Supply Through Connection to a Neighboring Community's Water System (non-MWRA supplied community) via Natick	
Estimated Distribution System Expansion (Linear Feet)	10,100
Estimated Construction Cost in "Today's Dollars" Prior to 25% Contingency	$7,200,000
Estimated Construction Cost in "Today's Dollars"	$9,000,000
Estimated Cost per Linear Foot of Distribution Main Prior to 25% Contingency	**$720**
Estimated Cost per Linear Foot of Distribution Main	**$890**
Opinion of Probable Construction Cost (Including Inflation)	**$11,200,000**

Table 6-3. Alternative 3B Estimated Construction Costs

Alternative 3B Supplemental Water Supply Through Connection to a Neighboring Community's Water System (MWRA-supplied community) via Needham	
Estimated Distribution System Expansion (Linear Feet)	8,800
Estimated Construction Cost in "Today's Dollars" Prior to 25% Contingency	$6,600,000
Estimated Construction Cost in "Today's Dollars"	$8,200,000
Estimated Cost per Linear Foot of Distribution Main Prior to 25% Contingency	**$750**
Estimated Cost per Linear Foot of Distribution Main	**$930**
Opinion of Probable Construction Cost (Including Inflation)	**$10,200,000**

The overall cost per linear foot of distribution main is higher than previous planning studies due to the high inflation observed recently and the contingency being carried for the construction costs.

6.2 Opinions of Probable Project Cost

Using the OPCC, a planning-level opinion of probable project cost (OPPC) was developed for each alternative. To calculate the OPPC, an allowance of 25% for Engineering and Implementation was added to the OPCC.

The OPPC for Alternative 2A is $14,000,000, and the OPPC for Alternative 3B is $12,750,000, as indicated in **Tables 6-4** and **6-5**.

Table 6-4. Alternative 2A Estimated Opinion of Probable Project Costs (OPPC)

Alternative 2A Supplemental Water Supply Through Connection to a Neighboring Community's Water System (non-MWRA-supplied community) via Natick	
Estimated Construction Cost (OPCC)	$11,200,000
Allowance for Engineering and Implementation (25%)	$2,800,000
Total OPPC	**$14,000,000**

Table 6-5. Alternative 3B Estimated Opinion of Probable Project Costs (OPPC)

Alternative 3B Supplemental Water Supply Through Connection to a Neighboring Community's Water System (MWRA-supplied community) via Needham	
Estimated Construction Cost (OPCC)	$10,200,000
Allowance for Engineering and Implementation (25%)	$2,550,000
Total OPPC	**$12,750,000**

6.3 Financial Projections

The purpose of this section is to evaluate two sets of alternative approaches to providing potable water to some or all of Dover.

1. The first set focuses on providing water to just the “Town-owned” system that is currently operated and maintained by Aquarion Water, including the provision of potable water to that service area. There are approximately 70 connections in the Town-owned system. This alternative assumes that the Town develops the infrastructure to connect to a third-party water system and then purchases potable water. Two alternatives are evaluated. One alternative assumes water is provided by the Massachusetts Water Resources Authority through a connection constructed to Needham. The second alternative is to build a connection to Natick, to purchase water from Natick.

2. The second set focuses on developing a Town-wide water system and assumes that the entire Town would be served from a single source. This requires both the physical connections described above but also the development of a Town-wide distribution network to allow all parcels to access the water supply.

This evaluation projects the total expenses for each alternative as well as the impact in terms of typical household bills. In developing these projections, the following assumptions were used for alternatives:

- The costs of purchased water for the MWRA-supplied options are based on the Authority's published ten-year projections, with those increased at a 3.5 percent annual rate thereafter. It's also assumed that Dover would pay Needham a ten percent wheeling charge. A wheeling charge is a fee assessed by one entity for the use of its system to move a commodity (in this case water) from a supplier to other users. For the Natick alternative, the costs are based on Natick's currently published rates and assume that Dover is charged a rate equal to 90 percent of the retail rate. Consistent with Natick's published rates, it is assumed that the water rate increases at a 5 percent annual rate.
- Capital costs are assumed to be financed with general obligation bonds, 20-year term and 5 percent average annual rate.
- An allowance for operations and maintenance costs was developed based on scaling from similar comparable communities.
- Non-water operation and maintenance costs are projected to increase at an annual rate of 4 percent.
- Water demands assume 194 gallons per day per connection based on the population projects and water demands presented in Section 3.

Subsequent sections will discuss the assumptions specific to the alternatives.

6.3.1 Town-Owned System

In this alternative, the Town would focus on providing water just to the core Town-Owned system. The water infrastructure in this area of the Town is owned by the Town, and water and operations and maintenance services are provided under contract through Aquarion (formerly Colonial Water). When Aquarion acquired the Colonial system and franchise, the existing agreement between the Town and Colonial carried over to Aquarion.

Under this alternative, the Town would terminate the Aquarion contract and negotiate water purchase agreements with Natick or the MWRA, as well as a contract with Needham to wheel water through Needham's system. It is assumed that the Town would obtain an operator or operating company to operate and maintain this system.

MWRA Alternative

Under this alternative, Dover would become an MWRA member and would receive water through a connection constructed to Needham. It is assumed that the connection would be available in fiscal year (FY) 2027. Additional key assumptions are as follows:

- Capital costs for the MWRA alternative, including contingencies and inflation, are estimated to be $12.8 million, as noted in **Section 6.2**, with the connection being made in Needham.
- Dover is assumed to be granted entrance to the MWRA with the buy-in fee being waived. In September 2022, the MWRA Board of Directors approved a proposal, as recommended by the MWRA Advisory Board, to waive for five years the Entrance Fee for new communities meeting certain criteria. As approved, the waiver extends through calendar year 2027, for a total of up to 20 million gallons per day (MGD) being sought by new communities. To

qualify for this Entrance Fee waiver, a new community must be approved by the MWRA Board of Directors for admission on or before December 31, 2027 and meet certain criteria, unless the maximum amount of water approved under this waiver (20 MGD) has been reached prior to this date. As a member, it will pay the MWRA-published rate plus a ten percent wheeling charge paid to Needham for moving water to Dover through the Needham system.

- As noted earlier, an allowance has been developed for estimating the operation and maintenance costs of this system.

Table 6-6 summarizes the projected costs associated with this alternative.

Table 6-6. MWRA Supply, Town-Owned Alternative, Projected Revenue Requirements and Annual Customer Bills

Year	Debt Service	O & M	Water Purchase	Total	Rate per 1,000 gallons	Annual Cost per Typical Resident
2027	$1,023,093	$100,000	$27,777	$1,150,870	$232	$17,388
2028	$1,023,093	$104,000	$29,027	$1,156,120	$233	$17,468
2029	$1,023,093	$108,160	$30,333	$1,161,586	$234	$17,550
2030	$1,023,093	$112,486	$31,698	$1,167,278	$235	$17,636
2031	$1,023,093	$116,986	$33,125	$1,173,203	$236	$17,726
2032	$1,023,093	$121,665	$34,615	$1,179,374	$238	$17,819

The annual costs are projected to increase from $1.15 million in FY 2027 to $1.18 million in FY 2032. The bulk of the cost is associated with the debt service from the infrastructure required to connect Dover into the MWRA system through Needham.

The resulting rates from this alternative are extremely high (more than 20 times higher) as compared to typical water rates in the Commonwealth of Massachusetts. The rate per $1,000 gallons is approximately $230/1,000 gallons. Typical water rates in Massachusetts are less than $10/1,000 gallons. As can be seen by the last line of **Table 6-6**, the typical annual cost per connection is projected to exceed $17,000. This compares to the average within the MWRA service area of approximately $800 per year. Additionally, one can compare these rates to the rates estimated for Dover residents currently supplied by Aquarion, which would be approximately $1,660 per year based on a 72,000 gallon usage.

Non-MWRA Alternative

Under this alternative, Dover would negotiate a wholesale bulk agreement with Natick and connect to the Natick system. It should be noted that direct discussions have not been held with Natick, as such this assessment serves to illustrative this potential alternative. The key assumption is that Natick has sufficient supply and would be willing to sell water to Dover. For these purposes, it has been assumed that Dover would pay at a rate equal to 90 percent of the Natick retail rate. The connection is assumed to be available in FY 2027. Additional key assumptions are as follows:

- Capital costs for this alternative, including contingencies and inflation, are estimated to be $14 million, as noted in **Section 6.2**.
- As noted earlier, an allowance has been developed for estimating the operation and maintenance costs of this system.

Table 6-7 summarizes the projected costs associated with this alternative.

Table 6-7. Non-MWRA Supply, Town-Owned Alternative, Projected Revenue Requirements and Annual Customer Bills

Year	Debt Service	O & M	Water Purchase	Total	Rate per 1,000 gallons	Annual Cost per Typical Resident
2027	$1,123,396	$100,000	$47,000	$1,270,396	$256	$19,194
2028	$1,123,396	$104,000	$49,115	$1,276,511	$257	$19,287
2029	$1,123,396	$108,160	$51,325	$1,282,881	$258	$19,383
2030	$1,123,396	$112,486	$53,635	$1,289,517	$260	$19,483
2031	$1,123,396	$116,986	$56,048	$1,296,430	$261	$19,587
2032	$1,123,396	$121,665	$58,571	$1,303,632	$263	$19,696

The annual costs are projected to increase from $1.27 million in FY 2027 to $1.30 million in FY 2032. The bulk of the cost is associated with the debt service from the infrastructure required to connect Dover into the MWRA system through Needham.

Similar to the MWRA alternative, the resulting rates from this alternative are also extremely high (more than 25 times higher) as compared to typical water rates in the Commonwealth of Massachusetts. The rate per $1,000 gallons is approximately $260/1,000 gallons. Typical water rates in Massachusetts are less than $10/1,000 gallons. As can be seen by the last line of **Table 6-7**, the typical annual cost per connection is projected to exceed $19,000. This compares to the average within the MWRA service area of approximately $800 per year. Additionally, one can compare these rates to the rates estimated for Dover residents currently supplied by Aquarion, which would be approximately $1,660 per year based on a 72,000 gallon usage.

6.3.2 Town-Wide System

In this alternative, the Town would focus on providing water to the entire Town, a potential of 2,600 connections and average day demand of approximately 0.5 mgd. Key assumptions for the Town-wide distribution system expansion for both alternatives are identified below.

- 12” main: $890/LF
- 8” main: $760/LF
- Portion of 12” main: assumed to be 1/3 of the total Town-wide expansion length
- Portion of 8” main: assumed to be 2/3 of the total Town-wide expansion length

An estimate of the Town-wide distribution system expansion was developed based on the total miles of roadway in Dover (44.4 miles), less the length of the transmission main within the Dover bounds for either alternative. This is planning-level estimate is summarized below in **Table 6-8**.

Table 6-8. Town-wide Distribution System Expansion for Proposed Alternatives

Cost to expand distribution system Town-wide	Natick (2A)	Needham (3B)
Estimated distribution system expansion (linear feet)	224,498	225,698
Estimated distribution system expansion (miles)	43	43
Assumed portion of distribution system with 12" diameter pipeline (linear feet)	74,833	75,233
Assumed portion of distribution system with 12" diameter pipeline (miles)	14	14
Assumed portion of distribution system with 8" diameter pipeline (linear feet)	149,665	150,465
Assumed portion of distribution system with 8" diameter pipeline (miles)	28	28
12" cost per linear foot	$890	$890
8" cost per linear foot	$760	$760
Estimated distribution system expansion cost	**$180,000,000**	**$181,000,000**

Under this alternative, the Town would assume the franchise rights from Aquarion and negotiate water purchase agreements with Natick or the MWRA. It is assumed that the Town would obtain an operator or operating company to operate and maintain this system.

The key assumptions specific to this alternative are as follows:

- For purposes of this assessment, no costs for the purchase of the franchise area have been assumed and included.
- The capital costs for constructing a Town-wide distribution system are estimated to be approximately $225 million (2028 dollars). This includes the capital costs related to the connecting the Dover system to either the Natick system or the MWRA system through the Needham system. This alternative assumes that the Town can issue approximately $12 million per year in debt for 20 years to fund the construction of the distribution system.
- It is assumed that the distribution system and resulting connections are implemented over a 20-year period. Capital costs for the project are approximately $11 million/year (2028 dollars) and are inflated at 3.5 percent per year over the 20-year implementation period.
- An allowance for operations and maintenance has been built in using the same approach as for the preceding alternatives; however, the costs in this alternative reflect the larger-sized systems. In addition, purchased water costs reflect the higher water volume.

MWRA Alternative

This alternative uses similar MWRA specific assumptions as set forth in **Section 6.3.1**. The most significant changes are the costs and time to construct the distribution system which is assumed to commence in FY 2028 and be spread over 20 years.

- Dover is assumed to be granted entrance to the MWRA with the buy in fee being waived. As a member it will pay the MWRA published rate plus a ten percent wheeling charge paid to Needham for moving water to Dover through the Needham system. MWRA rates are assumed to increase at an average annual rate of 3.5 percent following the end of the MWRA's published projections (2033).
- As noted earlier, an allowance has been developed for estimating the operation and maintenance costs of this system.

Table 6-9 summarizes the results.

Table 6-9. MWRA Supply, Town-wide Alternative, Projected Revenue Requirements and Annual Customer Bills

Year	Debt Service	O&M	Water Purchase	Total	Rate per 1,000 Gallons	Annual Cost per Typical Resident
2028	$818,474	$59,957	$43,778	$922,209	$ 111	$7,882
2029	$1,663,549	$123,511	$90,941	$1,878,002	$ 113	$8,026
2030	$2,536,089	$190,825	$141,750	$2,868,664	$ 115	$8,173
2031	$3,436,986	$262,067	$196,423	$3,895,475	$ 118	$8,324
2032	$4,367,163	$337,411	$255,114	$4,959,687	$ 120	$8,478
2033	$5,327,570	$417,040	$318,119	$6,062,728	$ 122	$8,636
2034	$6,319,190	$501,143	$384,128	$7,204,461	$ 124	$8,797
2035	$7,343,038	$589,916	$454,369	$8,387,324	$ 127	$8,961
2036	$8,400,161	$683,566	$529,056	$9,612,783	$ 129	$9,129
2037	$9,491,641	$782,303	$608,414	$10,882,358	$ 131	$9,301
2038	$10,618,594	$886,349	$692,680	$12,197,623	$ 134	$9,478
2039	$11,782,172	$995,934	$782,098	$13,560,205	$ 136	$9,658
2040	$12,983,567	$1,111,296	$876,928	$14,971,792	$ 139	$9,843
2041	$14,224,008	$1,232,684	$977,437	$16,434,129	$ 142	$10,033
2042	$15,504,762	$1,360,355	$1,083,908	$17,949,026	$ 144	$10,227
2043	$16,827,142	$1,494,577	$1,196,634	$19,518,353	$ 147	$10,426
2044	$18,192,498	$1,635,627	$1,315,924	$21,144,050	$ 150	$10,630
2045	$19,602,229	$1,783,796	$1,442,098	$22,828,123	$ 153	$10,840
2046	$21,057,776	$1,939,383	$1,575,492	$24,572,650	$ 156	$11,054
2047	$22,560,628	$2,102,699	$1,716,457	$26,379,784	$ 159	$11,293
2048	$21,742,153	$2,165,780	$1,776,533	$25,684,466	$ 155	$10,995

Total expenses are projected to increase from approximately $1.0 million in FY 2028 to $12.2 million in 2038 to nearly $26 million by 2048, with total costs decreasing slightly in the last year of the projection period. This is because year 2048 is the first year no new debt is being issued under the implementation period and debt service from year 2028 has been paid off. Since the system is assumed to be increasing connections each year as the distribution system is expanded, the impact on the retail rate is not as dramatic. User rates are projected to increase from $111/1,000 gallons in 2028 to $139/1,000 gallons in 2038 to approximately $155/1,000 gallons in 2048. Typical annual customer bills are projected to increase from $7,900 in 2028 to $8,100 in 2038 to $9,300 by 2048. While the larger assumed customer base reduces the projected rates and retail bills from the Town-owned system, the resulting rates and bills are exorbitant.

Non-MWRA Alternative

This alternative uses similar non-MWRA specific assumptions as set forth in **Section 6.3.2**. The most significant changes are the costs and time to construct the distribution system which is assumed to commence in FY 2028 and be spread over 20 years.

- Dover is assumed to purchase a larger volume of water from Natick under the same general terms and conditions. This alternative assumes that Natick has the capacity and willingness to sell Dover the required volumes.
- As noted earlier, an allowance has been developed for estimating the operation and maintenance costs of this system.

Table 6-10 summarizes the results.

Table 6-10. MWRA Supply, Town-wide Alternative, Projected Revenue Requirements and Annual Customer Bills

Year	Debt Service	O & M	Water Purchase	Total	Rate per 1,000 gallons	Annual Cost per Typical Resident
2028	$898,717	$59,957	$88,607	$1,047,281	$126	$8,951
2029	$1,826,642	$123,511	$182,531	$2,132,684	$129	$9,114
2030	$2,784,725	$190,825	$282,010	$3,257,560	$131	$9,281
2031	$3,773,946	$262,067	$387,294	$4,423,306	$133	$9,452
2032	$4,795,316	$337,411	$498,641	$5,631,367	$136	$9,626
2033	$5,849,881	$417,040	$616,320	$6,883,240	$138	$9,805
2034	$6,938,719	$501,143	$740,611	$8,180,472	$141	$9,988
2035	$8,062,944	$589,916	$871,805	$9,524,665	$144	$10,176
2036	$9,223,707	$683,566	$1,010,204	$10,917,476	$146	$10,368
2037	$10,422,194	$782,303	$1,156,123	$12,360,620	$149	$10,565
2038	$11,659,632	$886,349	$1,309,887	$13,855,868	$152	$10,766
2039	$12,937,287	$995,934	$1,471,836	$15,405,058	$155	$10,972
2040	$14,256,466	$1,111,296	$1,642,324	$17,010,087	$158	$11,183
2041	$15,618,518	$1,232,684	$1,821,717	$18,672,919	$161	$11,400
2042	$17,024,837	$1,360,355	$2,010,394	$20,395,587	$164	$11,621
2043	$18,476,861	$1,494,577	$2,208,753	$22,180,191	$167	$11,848

CDM Smith

Year	Debt Service	O & M	Water Purchase	Total	Rate per 1,000 gallons	Annual Cost per Typical Resident
2044	$19,976,076	$1,635,627	$2,417,204	$24,028,908	$171	$12,081
2045	$21,524,016	$1,783,796	$2,636,175	$25,943,987	$174	$12,319
2046	$23,122,263	$1,939,383	$2,866,108	$27,927,754	$177	$12,563
2047	$24,772,454	$2,102,699	$3,107,464	$29,982,617	$181	$12,813
2048	$23,873,737	$2,165,780	$3,200,688	$29,240,205	$176	$12,496

Total expenses are projected to increase from approximately $1.0 million in FY 2028 to $13.9 million in 2038 to over $29 million by 2048. Since the system is assumed to be increasing connections each year as the distribution system is expanded, the impact on the retail rate is not as dramatic. User rates are projected to increase from $126/1,000 gallons in 2028 to $152/1,000 gallons in 2038 to approximately $15,577/1,000 gallons in 2048. Typical annual customer bills are projected to increase from $8,900 in 2028 to $10,800 in 2038 to $12,500 by 2048. While the larger assumed customer base reduces the projected rates and retail bills from the Town-owned system, the resulting rates and bills are exorbitant.

6.3.3 Conclusions

Dover faces significant financial and affordability challenges to implement the alternatives evaluated herein. The Town's customer base is not large enough to support the anticipated level of capital investment. To move forward would require a significant infusion of grant or similar funding to offset the capital costs and remove that burden from the customer base.

Alternative 1 which includes an improved management and stewardship program for Dover's existing supplies, and is detailed in Section 4, considers improvements to the existing Town-owned water infrastructure and the development of a new full time Town position. This alternative appears to be the most economically feasible when compared to Alternatives 2A and 3B. The roles and responsibilities of this new Town position should include coordination of continued aquifer level monitoring. It is recommended that Dover implement Alternative 1 as soon as possible to facilitate organized water sustainability stewardship and maintain regulatory compliance with the Town infrastructure and water supply. Implementing Alternative 1 would support any future long-term solution to the water sustainability concerns and offer a single point of contact for residents and stakeholders to receive information.

CDM Smith is currently completing a technical assessment to evaluate the potential future risks of over reliance on the aquifer which supplies groundwater to the wells in Dover. The assessment aims at conceptually identifying the aquifer's ability to withstand future climate and demand changes. A technical memorandum will be generated summarizing the findings of the aquifer resilience work.

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Appendix A

Memorandum

To: Christopher Dwelley, Town Administrator
From: Michaela Bogosh, P.E. and Joe Ridge, CDM Smith
Date: July 21, 2020 (Final Updated August 5, 2020)

Subject: Evaluation of Option for Dover, MA to Turn Water Infrastructure Over to Colonial Water Company

The Town of Dover (the "Town") operates and maintains the water supply infrastructure that supplies water to approximately 70 connections in town, including four municipal buildings. As described in Task 1.1, water is supplied by Colonial Water Company (CWC) through a water supply Agreement.

The Town has requested that CDM Smith review the existing Town-owned infrastructure and develop a conceptual evaluation of infrastructure costs. Additionally, a discussion of selling the water infrastructure to CWC as well as other potential operational and maintenance (O&M) options are presented.

Overview of Town-Owned Infrastructure

The components of the Town-owned water infrastructure including pipe size and material as well as the number of valves grouped by size is presented in **Table 1**.

Table 1 – Summary of Town-Owned Water Supply Pipes and Valves

Pipe/Valve Size (inches)	Pipe Material	Approximate Total Length (feet)	Total Number of Valves
4	Cast Iron	440	2
6	Cast Iron	2470	10
8	Cast Iron	2630	9
4	Ductile Iron	940	4
6	Ductile Iron	620	2
12	Ductile Iron	2420	6

The oldest main is a 6-inch cast iron (CI) line located on Church Street which was installed in the 1950s. The majority of the other mains were installed between the 1950s and 1970s, with the exception of the 6-inch ductile iron (DI) main on Meeting House Hill Road which was installed in 1986 and the 12-inch DI main on Springdale Avenue which was installed in 1989.

In addition to the infrastructure summarized above, the Town also owns 13 fire hydrants, five (5) of which were replaced in 2015, and two (2) meter vaults. The third meter vault in Town, located by the fire station on Centre Street is owned by CWC. In recent discussions with the Town's Superintendent of Building Maintenance, Karl Warnick, it was determined that all of the existing fire hydrants are currently turned off, as there is not adequate water supply for fire fighting needs. It should be noted that the Agreement between the Town and CWC states that CWC will not provide water for general fire protection but only for refilling the Fire Department's tanker trucks following a fire. The pressure in the system is reportedly around 55 pounds per square inch (psi) which is adequate to supply customers under normal operation.

The Town also owns approximately 70 water service connections which includes the length of pipe from the main to the curb stop. Approximately 90% of the water service lines are thought to be copper, while the remaining 10% have been replaced by high density polyethylene (HDPE). The majority of water service lines are 1-inch in diameter while the four (4) that supply municipal buildings are 4-inch cast iron lines.

In discussion with Town staff, it was stated that the only record of a water main issue in recent history is a small break that occurred on Church Street in the spring of 2020. A leak was encountered in an area of the pipe that was supported by a wooden block. The crack in the pipe appeared to have been caused by the presence of the wooden block. A coupling was installed around the crack and no issues have been reported since.

Based on discussions with Town staff, it would appear that the existing infrastructure is fulfilling the current need and no significant upgrades are required, should the system supply need remain unchanged.

CDM Smith performed a high-level review of the 2017 and 2018 Massachusetts Department of Environmental Protection (MassDEP) Annual Statistical Reports (ASRs). Several inconsistencies were identified within the Town of Dover's ASRs and CWC's ASRs, including water system class, number of service connections, assets and chemical additions. CDM Smith recommends that a more detailed review of the ASRs be performed and corrected accordingly for the 2020 reporting year submittal.

Assessment of the Existing Infrastructure Costs

CDM Smith performed an assessment of the depreciated value of the Town-owned water infrastructure presented above using a standard public utilities approach. Generally, Public Utility Commissions (PUCs) only allow private utilities to recover through the rate base the Original Cost less Accumulated Depreciation. That establishes a likely price for the sale of water systems to a private utility.

Depreciation calculations are based on the following:

- Installation year: Approximate installation year of the infrastructure based on historical records and discussion with Town staff;
- Age of the infrastructure: The base year of 2019 minus the approximate installation year;
- Replacement costs: Based on costs provided by CDM Smith construction estimators;

- Engineering News-Record (ENR) index from the year of the install year;
- Original Cost: Calculation which estimates the original cost of the asset at the year of install by using the replacement cost and ENR indices to deflate back to the time of install;
- Estimated Useful Life: An estimate by asset class.
- Accumulated Depreciation: Calculation based on original cost, age, and estimated useful life. This has been calculated using straight line depreciation (i.e. if an asset is assumed to have a 30-year useful life, it loses 1/30 of its value each year). Therefore, if the asset is almost 70 years old, it will need to have an estimated useful life greater than 70 years in order to be considered having remaining value for these purposes.
- Original Cost Less Depreciation (OCLD): The calculated remaining value of the asset.

Given the age of the system overall, and the assumptions on estimated useful life, a large portion of the system is considered fully depreciated, including the 4-inch through 8-inch CI pipe and valves, 4-inch DI pipe and valves, all of the hydrants installed prior to 2015 and meters vaults, as well as all copper and CI water services. **Table 2** provides a summary of the depreciation assessment. The assets with remaining value include the 6-inch and 12-inch DI pipe and valves installed in 1986 and 1989 respectively, the hydrants installed in 2015 and the 1-inch HDPE water services, which amount to a total of approximately $57,000.

Water Infrastructure Ownership and Operational Options

Dover has had a water purchase agreement with CWC and its predecessor utility dating back approximately 26 years. That contract has minimal requirements regarding the operation and maintenance of the infrastructure owned by the Town. That contract has expired, but CDM Smith understands that the Town and CWC have agreed to a six-month extension. The Town must determine what to do to meet the needs of the water customers in town, including in the Town offices. The range of options include:

- The Town enters into an agreement with a different water purveyor;
- Extend the existing agreement with CWC under similar terms and conditions;
- Extend the existing agreement but with additional requirements to have CWC (or a comparable company) operate and maintain the system; or
- Sell the town infrastructure to some third-party that will have full responsibility for the Town- owned infrastructure.

Given the small size of the Town's existing water system, CDM Smith does not believe there are tangible advantages of the Town assuming complete responsibility of the water infrastructure and entering into a water purchase agreement with CWC or another nearby municipality. The economies of scale are such that the costs for operation and maintenance would be significant even with a part-time staff. CDM Smith suspects that this option will not be economical for the Town.

Should the Town want to maintain ownership of the infrastructure, an option could be to enter into an O&M contract with a contract operator, which would include performance standards, while also obtaining a water purchase agreement from CWC or another nearby municipality. This option would provide a way to ensure the integrity of the system and include some assurances that the infrastructure is being maintained appropriately. An assessment would need to be performed to gauge the interest of local contract operators. Another option could be for the Town to work with another nearby municipality who has water operators on staff to operate and maintain the Town's system. Similarly, an assessment would need to be performed to further investigate this option.

Some advantages of having CWC assume complete ownership of the Town's water infrastructure include the following:

- CWC is already providing water and has interconnections between other water systems and the Town's system should additional supply be desired in the future;
- If the Town customers become part of CWC's rate base, the maintenance and replacement of the existing infrastructure would be part of a larger rate base and the cost incurred by Town residents would likely be less;
- The level of ongoing maintenance would likely improve since it would be part of the service requirements for CWC under the Department of Public Utilities (DPU) regulations. The DPU process does provide a vehicle to enforce the maintenance requirements against CWC. Have CWC being subject to DPU regulations would be an advantage for the Town, especially given the recent issues concerning the presence of bacteria in the Town's distribution system and the subsequent Boil Order issued by MassDEP.

cc: Karl Warnick, Dover, MA

David Young, CDM Smith

Table 2 – Summary of Asset Value of Town-Owned Water Supply Pipes and Valves

Asset		Material	Approx. Install Year	Age (yrs)	Replacement Cost ($)	ENR Index	Original Cost ($)	Estimated Useful Life (yrs)	Accumulated Depreciation ($)	OCLD ($)
Pipe Size (inches)	4	Cast Iron	1950	69	$82,000	510	$3,700	35	$3,700	$0
	6	Cast Iron	1950	69	$510,000	510	$23,000	35	$23,000	$0
	8	Cast Iron	1950	69	$584,000	510	$26,000	35	$26,000	$0
	4	Ductile Iron	1970	49	$171,000	1381	$21,000	35	$21,000	$0
	6	Ductile Iron	1986	33	$113,000	4295	$43,000	35	$40,500	$2,500
	12	Ductile Iron	1989	30	$590,000	4615	$241,000	35	$207,000	$34,000
Valve Size (inches)	4	Cast Iron	1950	69	$4,200	510	$200	35	$200	$0
	6	Cast Iron	1950	69	$28,000	510	$1,300	35	$1,300	$0
	8	Cast Iron	1950	69	$38,000	510	$1,700	35	$1,700	$0
	4	Ductile Iron	1970	49	$7,300	1381	$900	35	$900	$0
	6	Ductile Iron	1986	33	$4,900	4295	$1,900	35	$1,800	$110
	12	Ductile Iron	1989	30	$41,000	4615	$16,800	35	$14,400	$2,400
Hydrants	-	-	1950	69	$39,000	510	$1,800	40	$1,800	$0
	-	-	1970	49	$20,000	1381	$2,400	40	$2,400	$0
	-	-	2015	4	$22,000	10035	$19,600	40	$2,000	$17,600
Meter Vaults	-	-	1970	49	$10,000	1381	$1,200	40	$1,200	$0
Water Services (inches)	1	Copper	1950	69	$51,000	510	$2,300	30	$2,300	$0
	1	Copper	1970	49	$2,000	1381	$240	30	$240	$0
	1	HDPE	1990	29	$7,000	4732	$2,900	30	$2,800	$100
	1.5	Copper	1950	69	$3,000	510	$140	30	$140	$0
	4	Cast Iron	1950	69	$22,000	510	$990	30	$990	$0
TOTAL					**$2,300,000**		**$412,100**		**$355,400**	**$56,700**

Note: Base year - 2019 (ENR Index = 11281)

Appendix B

Memorandum

To: *Chris Dwelley, Town Administrator*

From: *Al LeBlanc, PE*
Michaela Bogosh, PE
Lisa Gove, PE

Date: *September 9, 2022*

Subject: *Site Visit at Caryl Park Wellfield Field Notes*

The following memorandum serves to document the observations and findings of the field visit at the Caryl Park Wellfield, performed by Al LeBlanc, on Wednesday August 24, 2022. Al LeBlanc met with Karl L. Warnick, Superintendent of Building Maintenance who provided information about the wellfield prior to the site visit and accompanied Mr. LeBlanc during the visit. Field observations, summary of information as well as considerations for potential next steps for the Town of Dover are presented below.

Caryl Park Wellfield

The Caryl Park Wellfield serves three points of use:

1) Chickering School (elementary school)
2) Parks & Recreation Department – "Snap Valve" (flip-open cover, 1-inch hose connection)
3) Town-owned historical building, in which a resident caretaker lives (Caryl Farm Historic Site)

- Daily usage is on the order of 3,000 to 4,000 gallons per day (gpd).
- Zone I: 117-feet radius, includes Tennis Courts, Parking, Kids Play Area.
- Zone II: 413-feet radius, includes Dedham Street and a compost pile in the woods.
- Five (5) wellheads, nominal capacities: one is 35 gallons per minute (gpm) (off-line at present), the other four are 65 gpm each (on-line and available at present).
- Amongst the wellheads, there is a monitoring well across the dirt path from the soda ash building, also present on the site.

- The wells are 2-1/2-inch in diameter with screens at a depth of approximately 25-feet below ground surface.
- Water in wells have been observed at 18-feet from top of well at present. The wells have never gone dry at this site.
- Karl has observed groundwater has dropped ~2 feet in the July/August 2022 timeframe, which is evidence of drought in the region.

Soda Ash Building and Water Quality

- The building and system were designed by Tata & Howard, in the 2001-2002 timeframe.
- The structure is a precast concrete building and sits directly on gravel. There is no frost wall foundation system beneath.
- The facility cost approximately $100,000 to build originally.
- There has been no history of vandalism at site.
- Karl notes that the building is painted green, which provides "camouflage" and does not attract attention from public or passersby. It was noted that poison ivy vines are climbing up the building and is abound around the building. Karl notes herbicides can't be used given nearby water supply wells.
- Soda ash is used to increase pH. No other chemicals are dosed into this water typically.
- A zinc orthophosphate system (dedicated tank) was provided in the building but has never been used.
- The 100-ft Caryl Park Well sample tap runs back into this building.
- The Town has no volatile organic compound (VOC) waiver. As such, testing is performed for VOCs, inorganic chemicals (IOCs), and synthetic organic compounds (SOCs) as required.
- Karl has noticed that concentrations of sodium in the water are high in spring, but decrease by fall, annually. He attributes this to sanding and salting of the nearby road.
- Karl reported that concentrations of per- and polyfluoroalkyl substances (PFAS) have been detected at 6.4 parts per trillion (ppt) versus 20 ppt for PFAS6 in Massachusetts.

Vacuum System, Pressure Tank, Pumps, and Underground Vault

- Power
    - 3-phase 480-volt exists at site.

  - A portable generator is available and brought to this site when needed. Connection location is unknown but may be at the soda ash building.

- Pumps
  - Two 5-horsepower centrifugal pumps.
  - Pumps can deliver over 100 gpm.
  - Maximum Pressure = 60 psi.

- Tanks
  - 1,000-gallon tank receives water from wells, prior to delivery into the 5,000 gallon pressure tank,
  - 5,000-gallon pressure tank holds water and delivers to points of use. Karl adds air manually to this tank, as needed.

- Operational challenges
  - Mercury switches occasionally fail and pumps don't come on. Mercury switches are being replaced with electric switches. Karl is currently addressing this.
  - The data recorder is not sufficient for alarming. For instance, occasionally the town will sample, climb down in hole, and forget to turn the pumps back on. The town plans to install a cellular communications system to achieve better alarming and response time. Karl is currently addressing this as well.
  - Underground Vault houses pump/tank/electrical systems (1950s vintage) - system is accessed by descending into a manhole and climbing down manhole rungs, as seen in **Photo 1**. At the bottom is a small room with two tanks protruding into the room (mostly buried), substantial piping, pumps, electrical gear, dehumidifier, and more as seen in **Photos 2** though **4**. This is a confined space that requires confined space entry precautions operationally.

- The house at the Caryl Farm Historic Site is served with a 1-inch PVC pipeline

- The school is served with 8-inch ductile iron (DI) piping, which transitions down to 4-inch at the school. Karl indicated he helped install that piping in the year 2000.

Chickering School

- The Chickering School is at a higher elevation and receives water at approximately 45 psi.

- The school has booster pumps inside the building.

- The school has an approximately 90,000-gallon tank on site for fire water supply. Karl indicated that the school is aware that the water supply is finite and that the fire department must bring additional water on site if that supply is used up in the case of a large fire.

Other Observations and Resources

- Karl noted that another water source exists in town but it is off-line. The Church Street wells experienced a VOC and/or MtBE hit some number of years ago. The Town of Dover elected to take that source off-line upon discovering such constituents.
- Aquarion Water will be treating for PFAS at two nearby locations – Chickering (15 customers) and Springdale Farms (40 customers).
- Dover's Parks and Recreation Department has its own well in the woods, and they use it to fill an approximately 20,000-gallon tank in the summer (usually through August) to water athletic and recreation fields, which are called Chickering Fields per the signage on site. It is unclear if this other well's use affects the five wells that serve the Caryl Park Wellfield.

Facility Drawings

CDM Smith did not have access to facility drawings as part of this site visit effort, but did inquire with Dover as to whether as-built plans or facility mapping are available for the Caryl Park Wellfield and water facilities as such information is always helpful in any subsequent engineering phases should the Town of Dover move forward with any facility improvements. Karl shared that the following drawings would be available to his knowledge:

- MassDEP mapping for wellfield
- Plans of the soda ash building, designed by Tata & Howard
- Plans of the 8-inch water main, circa 2000, designer unknown.

CDM Smith recommends that in particular, an electronically scanned copy of the 1950 as-built or design drawings of the vault and pumping station would be helpful documents if Dover would like to proceed with any further study/investigation of facility improvements.

Possible Future Improvements and Considerations

Overall, the 70-plus year old wellfield and pumping facilities are performing, yet with several recent maintenance repairs that required fixing by Dover staff. Instrumentation and communication deficiencies have been identified and Dover staff are working to address such with the limited Dover water system annual operating budget. Additionally, the service and maintenance of the facility is challenging within the confined space conditions of the underground vault.

In CDM Smith's experience and as is typical in the water industry, mechanical (pump) systems are designed and built with a 25-to-30-year life expectancy and although they can be maintained to operate longer, such systems are much less reliable after that period. Conditions assessment of the facility for Dover would help the town to have a better understanding of what funds the town will need to have available to continue to operate/repair the current system; an estimate as to what types of funds may be required to replace such as system should spare parts no longer be available could be prepared. In a conditions assessment, electrical systems, instrumentation systems and mechanical systems are assessed by a professional engineer in those respective fields. Dover's system is years beyond a period of reliability, therefore, it may be more practical to perform a concept plan for a new replacement facility for improved reliability and long-term use, instead of investing funds to contract for a detailed condition assessment of 70^{+} year equipment and considering the challenges of the sub-grade vault.

Concept Plan for an Upgraded Well Pump Facility

A concept plan for Well Pump Replacement would include services to provide a concept for reconfiguring the wells for supplying a new above-ground pump station, which would eliminate the use of the underground vault and associated equipment. A new pumping station would be constructed in its place, which could house the pumps and tanks, allowing for safer and easier operation, maintenance, and access by Dover staff. The plan would include an opinion of probable project cost for Dover's use in planning for water system needs. A detailed recommendation on the configuration of the wellfield and pumping system would be performed in a future preliminary and design effort.

One option that might be helpful to include in a concept plan evaluation would be to determine the engineering requirements and feasibility of feeding water to this school system from an extension of the water main on Dedham Street. If such a supply was feasible it would eliminate the need for the town to maintain the well and the pumping facilities. Such as option might also be considered in the event that future well samples ever exceed the PFAS regulatory limits. Alternatively, it may be possible to install a small PFAS system in such case (similar to what Aquarion is planning to install at their nearby Chickering system supply). Given the small amount of supply needed for the area, a water main extension option may be feasible. Such a connection would require discussion between Dover and Aquarion Water with regard to water availability and any potential limits on the local system.

cc: Karl Warnick, Town of Dover
Jeff Diercks, CDM Smith

Photo 1 - Access manhole to underground vault

Photo 2 – Pumps located un underground vault

Photo 3 – Piping located in underground vault

Photo 4 – Electrical panels located in underground vault

Appendix C

CDM Smith

Technical Memorandum

To: *Town of Dover, Massachusetts*

From: *Kirk Westphal, PE and Zoë Schmitt, PE*

Date: *March 22, 2024*

Subject: *Technical Assessment of Aquifer Resilience to Future Condition*
Amendment #1 to CDM Smith Project Number 275685

Executive Summary

Future potential changes in precipitation and temperature from 2050 to 2100 were applied to the Town of Dover's groundwater aquifer using two independent approaches. Results were used to evaluate the resilience of Dover's aquifer in the face of a plausible range of future climate conditions. This study uses historic data from the USGS monitoring gage near the center of town. Findings are intended to indicate town-wide average conditions, and do not reflect localized changes to groundwater levels (e.g. due to increased extraction pumping at a specific site). In other words, results in this report can be interpreted as average changes in groundwater levels across the entire town.

Key Findings:

- Neither approach found a long-term downward trend in groundwater levels.
- Both approaches found lower summertime water levels of 0.3 to 0.5 feet on average. Periods of extended summertime drawdown are short-lived (1-2 months).
- Under extreme conditions, low annual groundwater levels could be approximately 1 - 2 feet below the historical low point (an average change across the entire area of the town).
- Annual high groundwater levels in the non-summer months could be approximately 0.5 – 1.5 feet higher than historical annual high levels.
- Climate variables (precipitation and temperature) had a larger impact on groundwater levels than changes in demand. Demand sensitivity analysis found that an experimental doubling of town-wide demand would reduce average groundwater levels by less than 1 additional inch, (again, averaged across the entire town area). This analysis **does not preclude** site-specific impacts due to increased extraction pumping at a given location.

Recommendations:

- The aquifer in Dover appears to be resilient over the long-term, with unlikely potential for long-term downward trends in water levels. We recommend continued monitoring, and revisitation if any year-over-year downward trends begin to emerge over a 5-10 year period, for example.

- We recommend further discussion with the Town to identify any potentially concerning groundwater levels.
- We recommend continuation of conservation efforts to reduce localized issues in groundwater supply.
- The results presented in this report should be interpreted as averages across the Town area. Detailed site-specific evaluations to understand localized impacts of any new or increased withdrawals are strongly encouraged.

1.0 Background and Purpose

As authorized under an Amendment to the Sustainability Water Study, CDM Smith reviewed existing and historical groundwater data and reports including the 2020 Town of Dover Hydrology Study, (Kleinfelder, 2020). The 2020 study was initiated by the Town Board of Health, who was concerned that 134 private wells (at the time) had been drilled deeper, decommissioned, or modified to increase yield, suggesting uncertainty in the long-term sustainability of the Town's groundwater supply. The 2020 study focused on public and private well usage from shallow sand and gravel aquifers throughout the town to supply nearly all residents and businesses, and reviewed approximately twelve years of demand data and two years of monitoring well data (2018-2019). The 2020 study recommended continuing well monitoring (ongoing), as well as exploration of drought management and conservation policies.

In July of 2022, the Town authorized CDM Smith to initiate work on a Water System Sustainability Assessment, whereby different water supply alternatives would be analyzed from both the short term and long term perspectives. The intent of the study is to provide water recommendations that address all Dover residents, including existing public water systems (PWS), private well systems, and other small and/or private water systems in Dover. During the initial phases of work, CDM Smith conducted multiple stakeholder meetings to gather information from Town committees and officials, to gain insight into each group's priorities when it comes to sustainable water supply for Dover. Evaluation criteria were developed and used to rank the different alternatives being considered, which include improved management and stewardship of Dover's existing supplies, supplemental water supply though neighboring water systems, supplemental supply through the Massachusetts Water Resources Authority (MWRA), supplemental supply through a new Town-owner municipal water source and also combining the existing Aquarion and the Town-owned systems. The top alternatives were carried forward to the cost estimating phase, in which opinions of probable construction costs were developed for a supplemental supply through the Town of Natick and an indirect connection to the MWRA through the Town of Needham. The alternative to improve management and stewardship for Dover's existing supplies proved to be much more economically feasible than the aforementioned water supply alternatives, and the alternative that CDM Smith recommends that Town work to implement in the immediate future. The CDM Smith report will be referenced in this Technical Memorandum.

This **Appendix C** Memorandum summarizes CDM Smith's Technical Assessment of Aquifer Resilience to Future Conditions specifically aimed at addressing the question of future resilience of Dover's existing groundwater supplies in response to uncertain climate change patterns in the region. Through the collection of nearly 55 years of historic data, application of state-of-the-art climate models (General Circulation Models, or GCMs), and two independent forms of hydrologic analysis of plausible future water table dynamics, CDM Smith evaluated potential trends and stability of the Dover area aquifers beyond 2050, relative to observed fluctuations since 1965.

Fundamentally, the questions addressed in this study are:

- What are the current trends in year-to-year groundwater dynamics in Dover?
- Are future climate scenarios likely to create a long-term downward trend in groundwater levels that would render the resource unsustainable?
- Even if there are no long-term depletion trends, what trends or changes are likely or expected on an annual basis with respect to drawdown and recovery?

2.0 Historical Observations of Groundwater Levels

The 2020 study reviewed 2018 and 2019 local groundwater monitoring data while CDM Smith helped characterize future risks by using an extended record of drawdown and recovery in the shallow aquifer, including times of severe regional drought. The shallow aquifers are principally coarse stratified deposits and thin till. The USGS has maintained a monitoring well in Dover since 1965, and this includes water level responses to the major droughts of the 1960s, 1980/1981, 2001/2002, and 2016 (USGS 421438071165601 MA-DVW 10R DOVER, MA). **Figure 2.1** illustrates this long-term record by plotting measured groundwater elevations between January 1965 and April 2022.

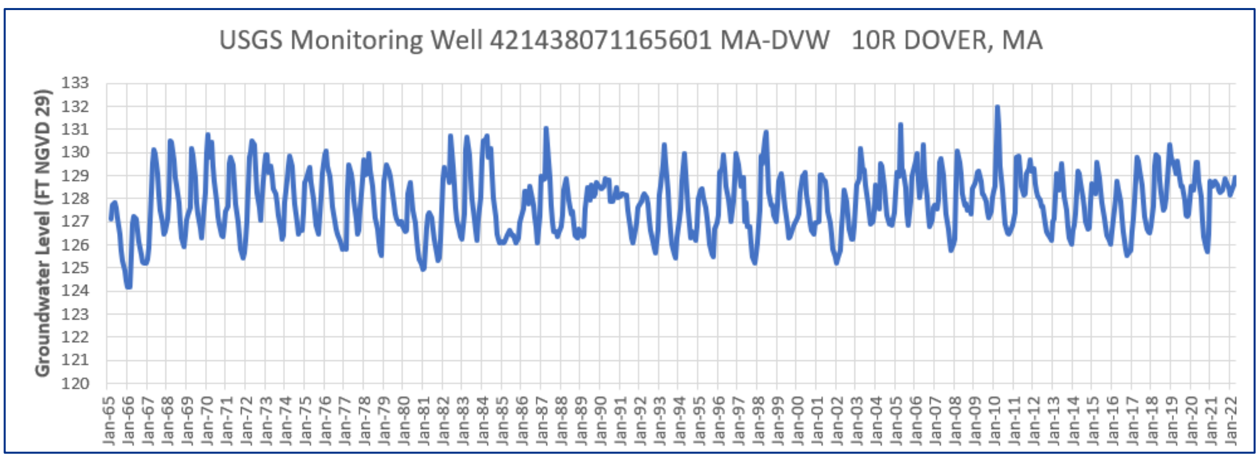

Figure 2.1 Long Term USGS Monitoring Well Data in Dover

While the USGS long-term record is enlightening, it could only be used for future decision-making if it can be shown to be reasonably representative of the collective groundwater patterns throughout Dover. **Figure 2.2** shows the location of the long-term USGS well in relationship to other wells in Dover, and **Figure 2.3** compares the observed water levels from late 2019 through late 2023.

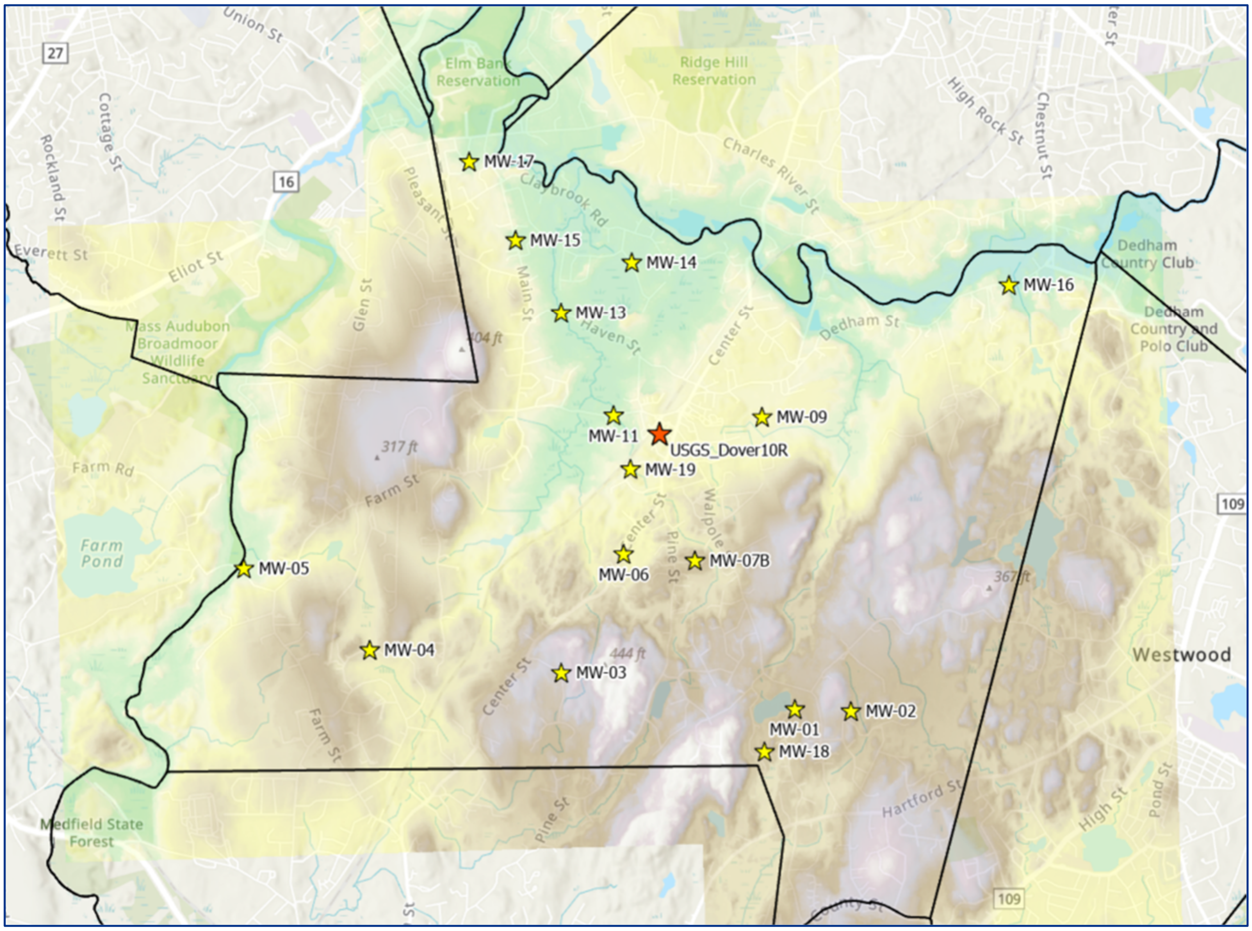

Figure 2.2 Comparative Locations of Long-Term USGS Well to Other Dover Wells

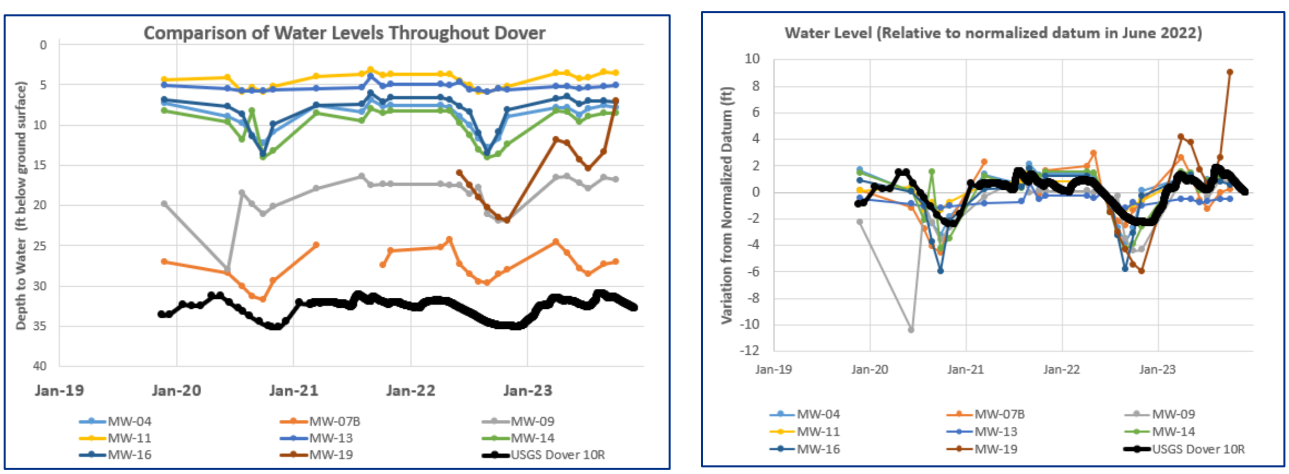

Figure 2.3 Comparative Water Levels Throughout Dover

Figure 2.2 illustrates that the long-term USGS well is approximately in the center of town geographically, representing somewhat of a spatial average of the rest of the wells. Figure 2.3 suggests that groundwater elevations at the long-term USGS well do exhibit similar trends to the other wells: They all draw down noticeably in 2020 and again in 2022, and recover within similar time periods (available data were limited to this time period). Some wells draw down less, some more, but in general the patterns are similar enough that the USGS well can be considered a useful representative indicator of groundwater rise and fall patterns in Dover.

3.0 Approach

Because climate change is an inherently uncertain phenomenon, even using state of the art climate projection models cannot be considered a failsafe means of future forecasting. To help boost confidence in results when examining the impacts of potential climate change scenarios on specific water supply systems, it is useful to develop more than one analytical approach, each independent from each other, and determine the extent to which they corroborate results. For this study, two independent methods were developed and employed: The correlation between groundwater elevation and climate variables (precipitation and temperature, along with demand), and a water balance model of rainfall, evapotranspiration, infiltration, and withdrawal. The presumption was that if the two methods produce similar projections of future groundwater trends, we can apply them confidently for planning. This is illustrated in Figure 3.1.

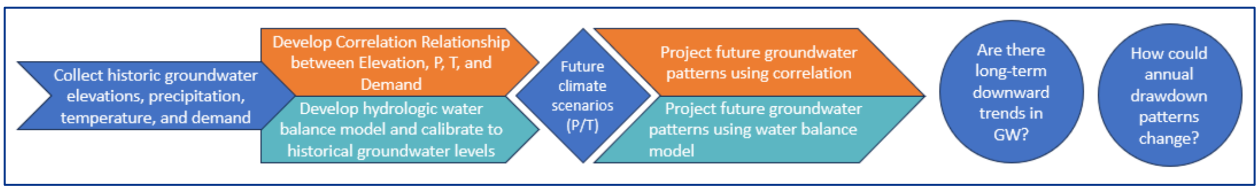

Figure 3.1 Analytical Approach Diagram

Three-dimensional groundwater modeling was not included in the amendment scope of work because a three-dimension model is not readily available and would require a much higher cost of services to produce than was contracted. Dover and CDM Smith staff discussed how the simpler (non-three-dimensional) model methods employed for this study do have appropriate resolution and detail with respect to the key aquifer questions of:

- Are future climate scenarios likely to create a long-term downward trend in groundwater levels that would render the resource unsustainable?
- Even if there are no long-term depletion trends, what trends or changes are likely or expected on an annual basis with respect to drawdown and recovery?

4.0 Data Sources

Information for this study was gathered from the sources identified in **Table 4.1**.

Table 4.1 Data Sources

Type of Information	Data Source	Notes
Historic Water Demand	Town of Dover Hydrologic Study, (Kleinfelder 2020), Water System Sustainability Study (CDM Smith 2024)	Demand data is not included explicitly in these noted reports. Assumptions on historic and future demand are discussed in Section 5.0.
Demand Projections	Water System Sustainability Study (CDM Smith 2024)	
Historic Groundwater Levels	US Geological Survey (Waterdata Website)[1]	See link 1 below.[1]
Historic Precipitation and Temp	NOAA US Historical Climate Network	Precipitation from nearby West Medway, site 199316. See link 2 below.[2]
Future Climate Projections	Bureau of Reclamation, CMIP3 and CMIP5 Data Portal[3]	Daily temperature and precipitation projections representative of a high emission scenario (RCP8.5). See link 3 below.[3]

Notes:
1. *https://nwis.waterdata.usgs.gov/nwis/gwlevels?site_no=421438071165601&agency_cd=USGS&format=rdb*
2. *U.S. Historical Climatology Network (USHCN) | National Centers for Environmental Information (NCEI) (noaa.gov)*
3. *https://gdo-dcp.ucllnl.org/downscaled_cmip_projections/dcpInterface.html#Projections:%20Subset%20Request*

5.0 Water Demand Assumptions

Historic and future water demands were estimated in this study through the blending of available information. Current demand presented in the 2020 report was scaled back to 1965 with a linear relationship to reported decadal population. Given that demand forecasts for 2030 are actually lower than 2020 (from the CDM Smith Report), future demand beyond 2050 was assumed to stay relatively constant at 2030 levels as a reasonable estimate. Total seasonal water use was extracted from the 2020 report for public water suppliers, and scaled to include estimated additional demand of private well users, for a total town-wide average use of 0.47 mgd as reported in CDM Smith's report (Section 3). **Figure 5.1** illustrates the synthesized demand pattern for future projections, and this pattern was scaled to historic population reports for historic model setup and calibration.

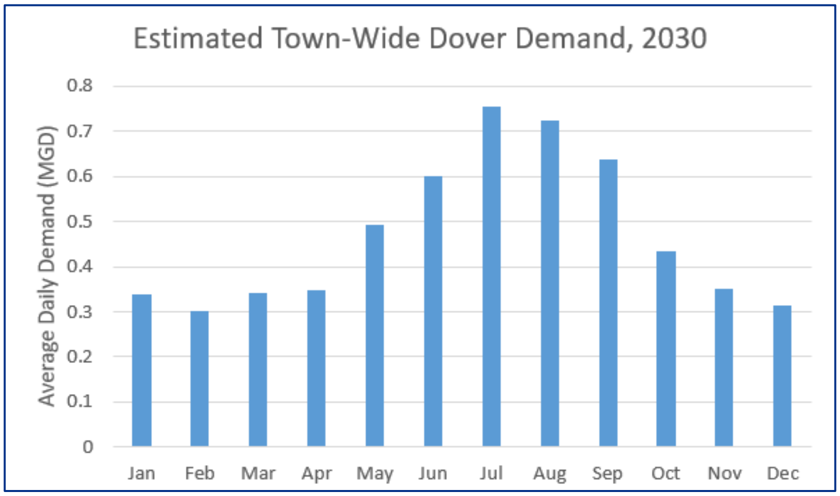

Figure 5.1 Estimated Average Town-Wide Demand Pattern for 2030

6.0 Two Independent Analytical Frameworks

As discussed in **Section 3.0**, because climate change is an inherently uncertain phenomenon, two independent analytical methods were employed to help estimate future groundwater patterns. For this study, the two independent methods were:

- **Multivariate Regression Model**: The correlation between groundwater elevation and climate variables (precipitation and temperature, along with demand)
- **Hydrologic Water Balance Model**: Water balance of rainfall, evapotranspiration, infiltration, and withdrawal.

The presumption was that if the two methods produce similar projections of historical groundwater trends, we can apply them confidently for planning. If they differ significantly, especially with respect to general trends, they may be useful in casting the results over a range of plausible future patterns.

The criteria used to evaluate the two approaches were based on visual inspection of the results and apparent trends. The following dynamics were evaluated for both methods:

Model Evaluation Criteria:

- Timing of drawdown and recovery.
- Magnitude of drawdown (lowest level each year).
- Variability of drawdown (year-to-year changes in the difference between minimum and maximum levels, and the annual minimum values themselves).
- Sustained multi-year patterns of high, low, or trending peaks and valleys.

Some notes on the application of the two methods:

- Results before 1980 are less certain – this may be due to different demand patterns (less summertime irrigation, for example), land use changes, and other undocumented factors affecting the supply system. However, since many of the low points in groundwater levels during this period were represented with reasonable year-to-year regularity. Hence, the results from this period are included in the overall assessment.

- Some droughts show less simulated drawdown than observed, and this may be due to historically higher demand rates during droughts (prior to active conservation strategies).
- One method utilized data relative to the NAVD88 datum, while the other utilized data relative to the NVDG29 datum. This is not a concern since the study results are framed simply in terms of differences between past and present (using one method at a time), but the absolute values of the model results should not be compared directly to one another.
- In both cases, the methods were compared to historical measurements. For future trend analysis, in order to compare evenly, simulated future groundwater patterns were compared to simulated historic groundwater patterns (knowing that the simulations were adequate representations of observed phenomena, but allowing an "apples-to-apples" comparison between past and future trends).

6.1 Multivariate Regression Model

Historic values of monthly precipitation, temperature, and estimated town-wide demand were tested as "predictors" of historical groundwater elevations. Using multivariate regression, and testing 1, 2, 3, 6, and 12-month averages of these variables, a regression model was developed to fit the historical data. The prior 6-month total precipitation in centimeters ($P_{sum\text{-}6}$), prior 6-month average temperature in degrees Kelvin ($T_{avg\text{-}6}$), and current average monthly demand in million gallons per day (D) scaled to population for a given monthly prediction proved to be better suited than other combinations of variables at reproducing the historical groundwater trends.

The fitted equation for Groundwater Elevation (GW ELEV), displayed visually in **Figure 6.1** in comparison to historical values, is represented as:

$$GW\ ELEV = 12.73(P_{sum\text{-}6})^{0.137} + 1303(T_{avg\text{-}6})^{-0.475} + 16.09(D)^{0.045}$$

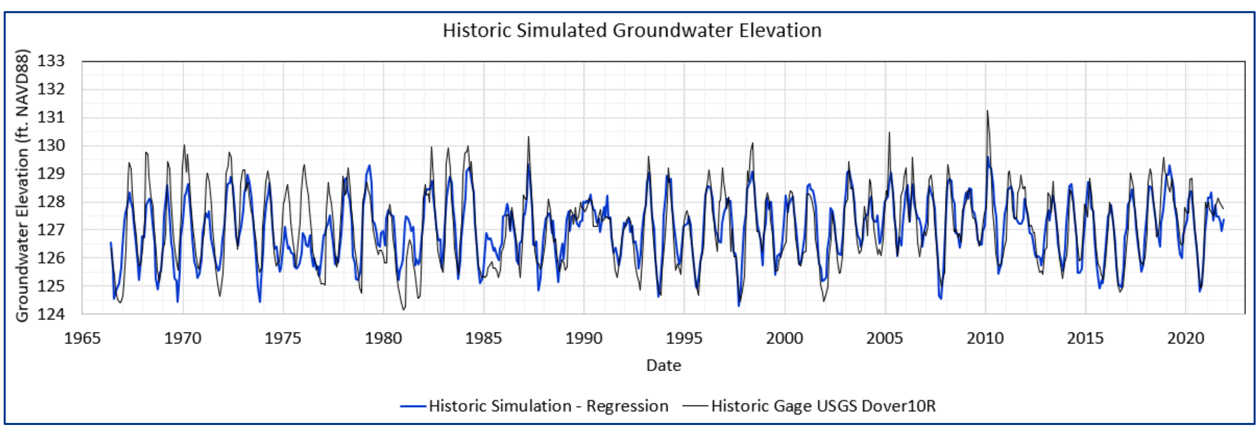

Figure 6.1 Multivariate Regression Using Historic Precipitation, Temperature, and Demand to Reproduce Historic Groundwater Elevation.

In this representation, the 6-month average precipitation was found to explain approximately 62% of monthly groundwater fluctuation, the 6-month average temperature was found to explain approximately 36% of monthly groundwater fluctuation, and varying monthly demand was found to explain approximately 2% of the monthly groundwater fluctuation.

While the performance of the model prior to 1980 is less useful than it is for the years after 1980, the majority of the multivariate regression model representation satisfies the evaluation criteria discussed earlier in this section:

- Timing of drawdown and recovery matches very well within each year.
- Magnitude of drawdown is generally consistent with historical observations, especially with respect to minimum and maximum levels each year.
- Variability of drawdown clearly matches historical ranges – after 1980, years with 4-5 feet of historic fluctuation are represented well by the model, as are years with 2-3 feet of fluctuation. Also, year-to-year variations in annual minimum levels are well-captured by the model.
- Sustained multi-year patterns of high, low, or trending patterns – Several examples are discussed below:
  - The regression model represents the nearly 3-year period from 1989-1992 in which groundwater was consistently high, with very accurate values.
  - The regression model reproduces the gradually decreasing, then increasing, and then decreasing minimum and maximum annual values over the period 2015-2021.
  - The model matches many of the lowest observed points in the historic observation, such as in 1993, 1995, 1997, 2007, 2016, and 2020.

The regression model is therefore a useful tool in relating precipitation, temperature, and demand to groundwater elevations historically, and can therefore be used to simulate groundwater response to future values of these variables for projection purposes.

6.2 Hydrologic Water Balance Model

A second method to test the response of groundwater levels to future climate variables is a simple water balance model. The *"abcd"* model is often employed as a 4-parameter model (7-parameters when including snow accumulation, melting, and soil porosity, as was done here) for rainfall/runoff/infiltration simulation that evaluates surface water flow and generalized groundwater storage in response to timeseries of precipitation and temperature (for backcround and equations, see "*Improved methods for national water assessment, water resources contract WR15249270", by Harold A. Thomas Jr., 1981, prepared for the United States Geological Survey:* https://doi.org/10.3133/70046351). The semi-physically based parameters represent hydrologic response functions and two state variables that are pertinent to this study; shallow soil moisture and shallow groundwater that can create baseflow in streams. Four of the parameters, "a, b, c, and d" represent the ability of the soil to absorb rainwater (a, and b), the ratio of to water running off quickly from soil moisture to the water infiltrating to shallow groundwater beneath the upper soils (c), and the percentage of total water in the ground lost to streams or bedrock in each timestep (d). The additional parameters of e (snow melt rate), Tb (temperature above which any accumulated snow melts at rate *e*), and P (the porosity of the soil, used in this case to convert total groundwater into equivalent vertical elevations) are included in this application of the abcd model to account for the snowy climate, and the need to distribute water vertically in the groundwater.

The model has been shown to work particularly well in largely impervious watersheds or regions. The principal model parameters and functions are illustrated in **Figure 6.2**, and explained in **Table 6.1**, which also includes the final calibrated parameter values for Dover. The model was developed with a monthly timestep.

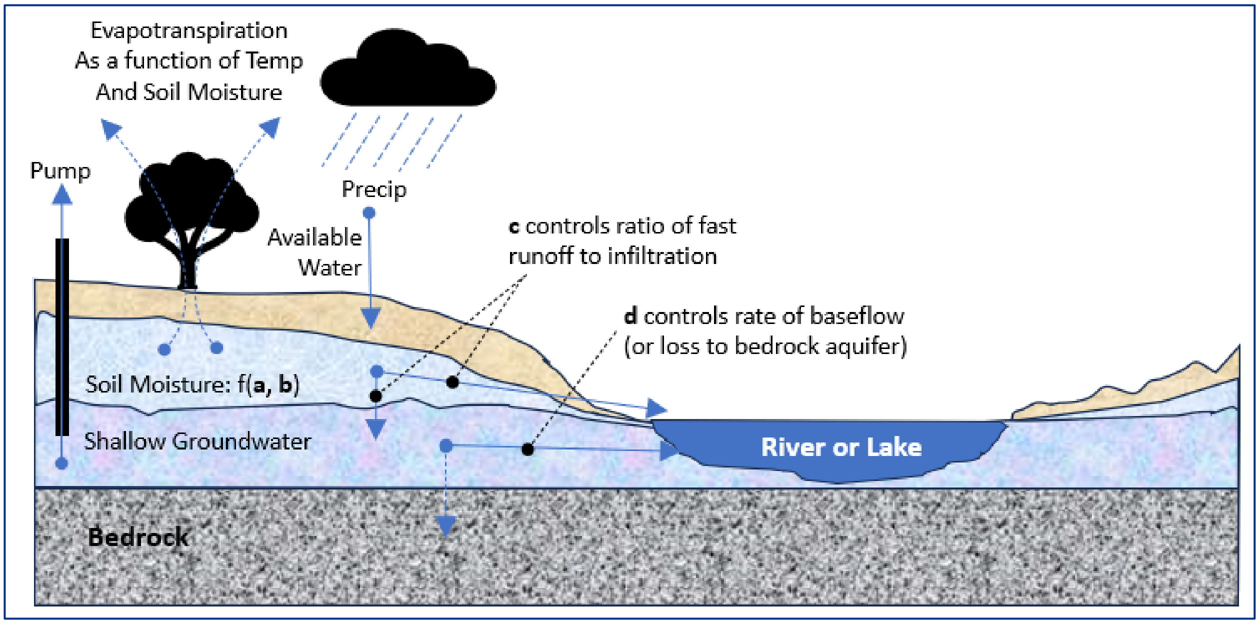

Figure 6.2 Conceptual Diagram of Water Flow and Storage Simulated in the abcd Model

Table 6.1 Parameters in the abcd Model

Parameter	Description	Plausible Values	Calibrated Value
a	Controls the amount of runoff and recharge that can occur when soils are undersaturated.	0-1: Close to 1 in flat areas, less than 1 in hilly areas	**0.988**
b	Saturation level of the soils, in equivalent inches of water	0 - ~45	**31.42**
c	Ratio of groundwater recharge to surface runoff. Note that for watersheds that are very flat and not highly impervious, this value tends to be at or near 1 (meaning that most or all water that infiltrates into the upper soil will infiltrate deeper rather than run off directly)	0 = all runoff 1 = all recharge Anything in between divides water proportionally	**1.00**
d	Rate of groundwater discharge as a percentage of total groundwater storage in each timestep	0 - 1	**0.29**
e	Snow melt rate: Effectively, the number of millimeters per degree above the melt temperature (Tb) to melt in a timestep	Varies based on the length of timestep	**30.65**
Tb	Melt Temperature: Effectively, the degrees Celcius above which snow will melt.	Near zero	**-1.89**
P	Soil porosity, to convert total inches of water in the ground to actual relative depth in soil.	~0.1 – ~0.5	**0.39**

The calibrated abcd Model for Groundwater Elevation is displayed visually in **Figure 6.3** in comparison to historical values.

Like the regression model discussed in Section 6.1, while the performance of the Water Balance model prior to 1980 is less useful than it is for the years after 1980, the majority of its representation satisfies the evaluation criteria listed above:

- Timing of drawdown and recovery matches very well within each year
- Magnitude of drawdown is generally consistent with historical observations, especially with respect to minimum and maximum levels each year.
- Variability of drawdown clearly matches historical ranges – after 1980, many years with 4-5 feet of historic fluctuation are represented well by the model, as are years with 2-3 feet of fluctuation. The variability of the minimum groundwater level from year to year is also captured well. The regression model seems to capture these dynamics with more accuracy than the water balance model.
- Sustained multi-year patterns of high, low, or trending patterns – Several examples are discussed below:
  - The water balance model represents the nearly 3-year period from 1989-1992 in which groundwater was consistently high.
  - The regression model reproduces the gradually decreasing, then increasing, and then decreasing minimum and maximum annual values over the period 2012-2021.
  - The model matches many of the lowest observed points in the historic observation reasonably well, (though not quite as well as the regression model), such as in 1995, 2007, 2016, and 2020.

While the regression model demonstrates an overall better match to historical data, the water balance model satisfies the general criteria and is a useful tool in relating precipitation, temperature, and demand to groundwater elevations historically. It can therefore be used to simulate groundwater response to future values of these variables for projection purposes and for corroboration with the regression model.

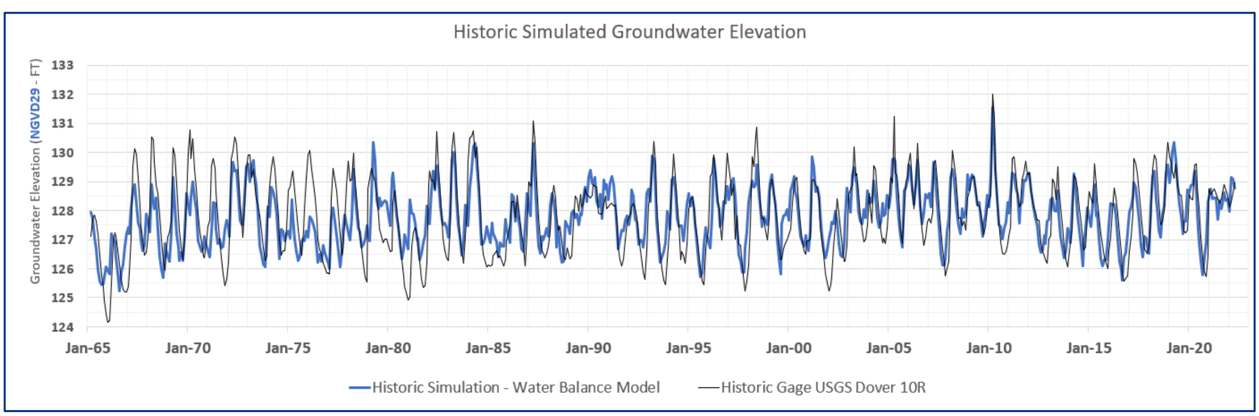

Figure 6.3 Water Balance Model Using Historic Precipitation, Temperature, and Demand to Reproduce Historic Groundwater Elevation

7.0 Climate Projection Process and Results

Climate projections are used to simulate and evaluate potential changes in groundwater levels for the second half of the century (2050-2100), a time horizon relevant to assess groundwater aquifer sustainability. Climate projections used herein, are derived from general circulation models (GCMs), which simulate major climatological processes on a global scale, including atmospheric and ocean circulation, aerosol impacts, and the carbon cycle. GCM output is used to simulate the climate under current and future emissions scenarios for the project area. These models are updated approximately every seven years, and this analysis used the currently available models, referred to as the Coupled Model Intercomparison Project, Phase 5 (CMIP5) models. Phase 6 models were released in 2023, and while they account for more complex processes, their accuracy is currently under debate. CMIP5, developed in the 2014 timeframe and broadly used in climate studies around the world today, were employed for Dover.

This study uses statistically[1] downscaled monthly temperature and rainfall projections, which are made available online through a collaboration of multiple agencies including the United States Bureau of Reclamation (USBR, or BoR), the US Geological Survey (USGS) and the National Center for Atmospheric Research (NCAR), Climate Analytics Group, Climate Central, Lawrence Livermore National Laboratory, Santa Clara University, Scripps Institution of Oceanography, US Army Corps of Engineers, National Center for Atmospheric Research, and Cooperative Institute for Research in Environmental Sciences[2]. Climate projections (and hindcasts) are available from 1950 through 2099 for a range of GCMs from different modeling centers around the world in a gridded format. To capture some of the uncertainty GCMs inherently contain, the climate adaptation community suggests the use of multiple GCMs, as this practice provides additional and more reliable information than any single GCM. Additionally, GCM diversity is considered a healthy aspect in the climate modeling community and the "multimodel" approach is a standard technique used by climate scientists to assess projections of a specific climate variable[3,4] (*Intergovernmental Panel on Climate Change 2014*). Thus, CDM Smith used all available GCMs in this study.

Further, climate model simulations from a variety of GCMs have generated output that varies depending on the emissions scenario and time being considered. The models are forced by anthropogenic emissions of greenhouse gases which represent different possible future trajectories of population, economic growth, land use changes and other factors. These emission scenarios are updated on regular basis (~7 years) to capture changes to demographics, technology, and socioeconomic conditions. A high-

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[1] Downscaling is the translation of low spatial resolution climate model output to higher spatial resolution output using additional physical information about the specific region of interest.
[2] Bureau of Reclamation Data Portal: https://gdo-dcp.ucllnl.org/downscaled_cmip_projections/dcpInterface.html
[3] Knutti, R., & Sedláček, J. (2013). Robustness and uncertainties in the new CMIP5 climate model projections. Nature Climate Change, 3(4), 369–373. https://doi.org/10.1038/nclimate1716.
[4] IPCC, 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.

end emission scenario was used for this study to reflect plausible worst-case scenarios on aquifer sustainability.

How the climate projections are used in the regression analysis and water balance model is further explained below.

7.1 Precipitation Deficit Trend Analysis

Examination of monthly projections of rainfall from all 32 GCMs in comparison to historic monthly precipitation records nearby (Bedford, Blue Hills, Plymouth, New Bedford, and Taunton) suggests that future droughts, as indicated by cumulative monthly deficits in precipitation, are not generally expected to worsen in terms of deficit magnitude, frequency, or duration. In fact, GCM data compared to all five weather stations above suggest generally wetter years on average through the 21st century. This observation should be used cautiously, however, for systems with regular and pronounced drawdown and recovery patterns within each year, as is the case with the Dover shallow aquifers. GCM results suggest higher concentrations of more precipitation in the winter, spring, and fall, and smaller changes in the summer, which would couple with higher temperatures and expose more water to evapotranspiration. Hence, the monthly analysis of future climate scenarios is necessary and useful, even with the understanding that precipitation may generally increase on an annual level in the Dover region.

7.2 Projections for Future Precipitation and Temperature

7.2.1 Climate Change Scenarios: Methods

Observed monthly precipitation and temperature records were used as a baseline on which changes in monthly precipitation and temperature between the historic period and future period are superimposed. To do so, for each GCM, cumulative distributions are calculated on a monthly basis for each climate variable (e.g., monthly precipitation and temperature) and for the modeled future periods, modeled past period and observed time periods. For each percentile value, delta values are calculated between model future and modeled past (from the distributions) and applied to the historic record of the corresponding percentile. The time series is generated in sequential fashion, whereby each record in an observed historical climate timeseries (usually monthly) is adjusted based on its relative rank on the distribution. This is done for each of the 32 models individually. As illustrated in **Figure 7.1** below, the climate adjusted synthetic time series are then used in the water balance and regression model to simulate future groundwater levels.

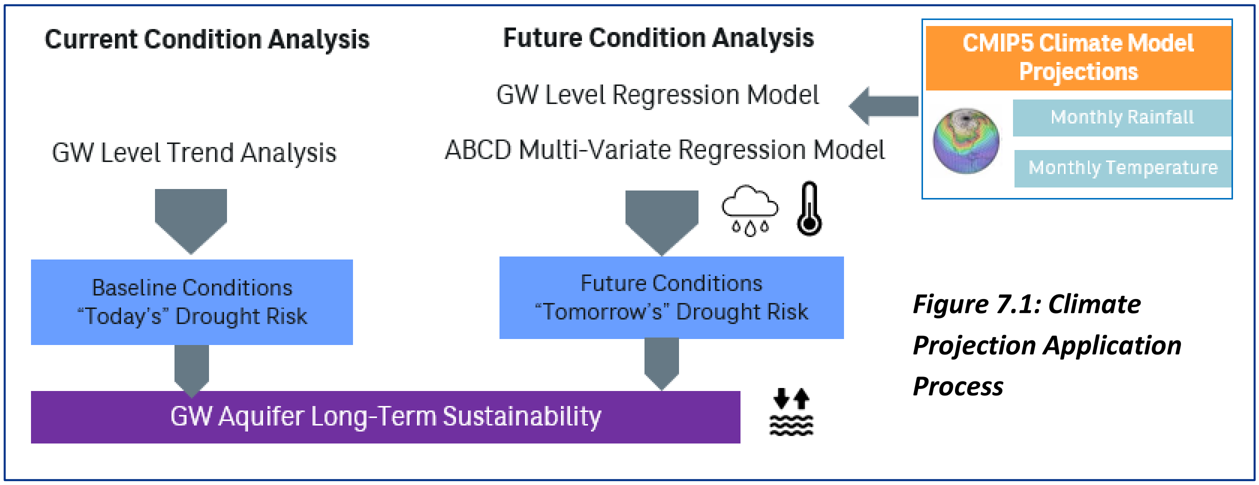

Figure 7.1 Application of Climate Change Projections to the Dover Aquifer Resilience Analysis

An important factor in understanding the simulation scenario results that are presented later in this report is the concept of superposition, in which we superimpose future climate conditions and future demand levels over long-term periods of historic hydrology (1965-2020). In doing so, we avoid the complexities of both demand and hydrology changing in specific sequences at the same time, and instead formulate questions of the form: "What would happen if the climate in 2050 to 2100 were superimposed over the historic hydrologic record?" In such simulations, the historic hydrology retains its sequence but is adjusted up or down each month based on climate projections, and demand is held constant. The results, while presented as timeseries, are more accurately interpreted as characterizing the probability of water availability and aquifer levels for the end of this century (2050 to 2100). The resulting future simulation time series are superimposed over the historic hydrologic record to produce the results and figures presented in **Section 8.0**.

7.2.2 Climate Change Scenarios: Results Summary

The general findings from the GCMs and their projections for precipitation and temperature trends from 2050-2100 are presented in this section. **Figure 7.2** illustrates that all 32 GCMs project higher mean air temperatures for every month of the year, with values that could increase by more than 10 degrees F in some cases. These higher temperatures, especially in the summer months, can lead to more evapotranspiration through the upper saturated soil.

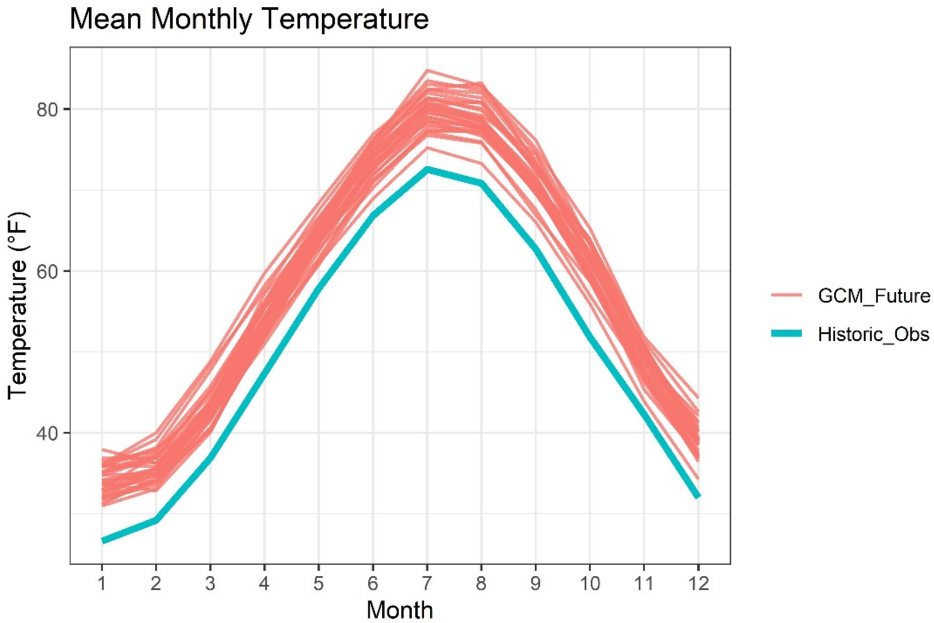

Figure 7.2 Mean Monthly Temperature of Future Climate Models Compared with Historical Data

Figures 7.3 and 7.4 illustrate a general tendency for precipitation to increase in the future scenarios. **Figure 7.3** compares all values of monthly precipitation from all GCMs against all monthly historical precipitation records (the graph on the right shows the full vertical scale, and the graph on the left zooms in on the vertical scale). Key statistics (median, 25th percentile, and 75th percentile) along with many outliers, are all higher in the GCM projections than in historical records. **Figure 7.4** compares the average historical monthly precipitation, as a single value, to the average monthly precipitation in each of the 32 GCMs (one value each, for 32 values). Again, the results suggest a clear upward trend in monthly precipitation in future climate scenarios. However, **Figure 7.5** demonstrates that these increases in precipitation are far more likely to be concentrated in the early and late parts of future calendar years, and much less so in the summer months. It will ultimately be the balance between future rainfall and future evapotranspiration that will define groundwater dynamics throughout each year, and this is analyzed and discussed in **Section 8.0**.

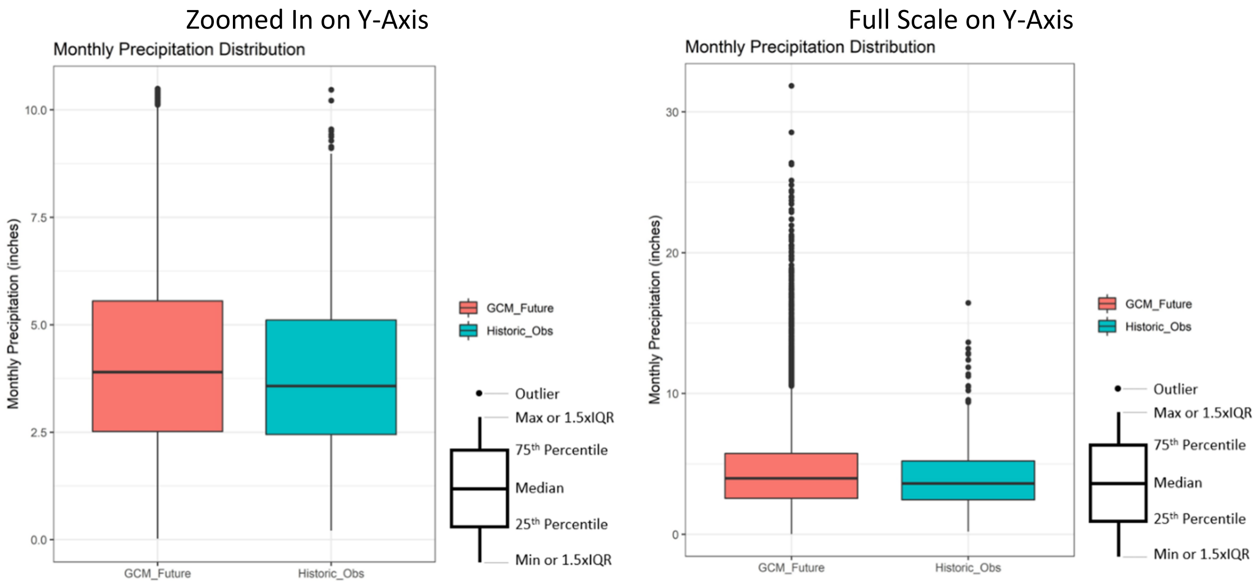

Figure 7.3 Monthly Variability of Precipitation in Climate Models vs. Historical Data

Note: Interquartile range (IQR) is the 75th percentile minus the 25th percentile. The line extending from the bottom of the box plot shows the 25th percentile to the minimum value, or to 1.5 times the IQR (whichever is smallest). Similarly, the line extending from the top of the box plot shows the 75th percentile to the maximum value, or 1.5 times the IQR.

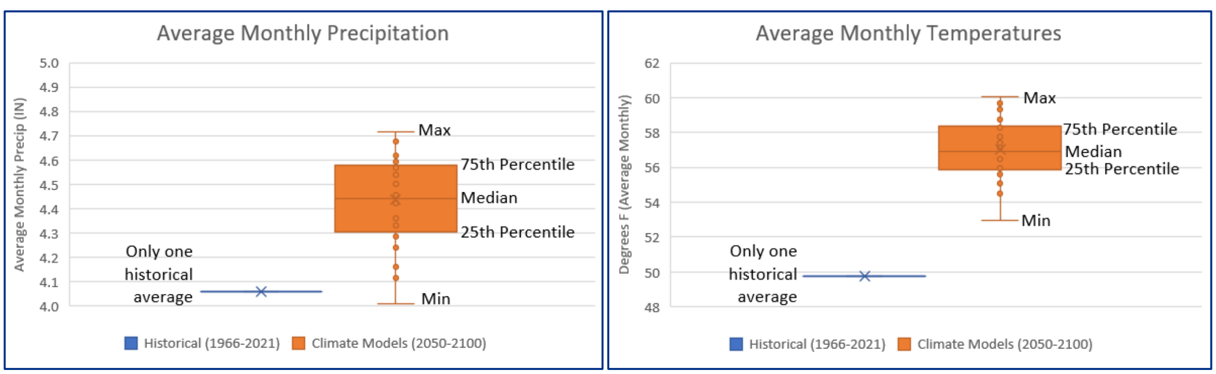

Figure 7.4 Long Term Monthly Average Precipitation and Temperature

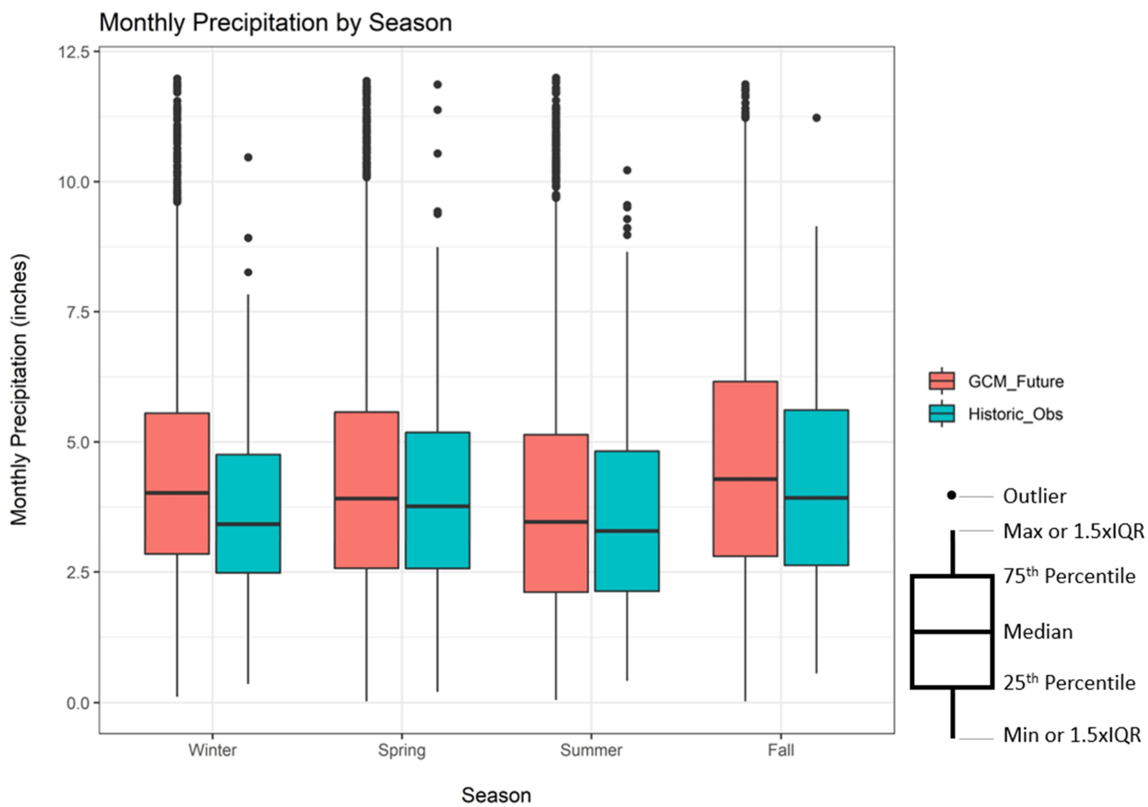

Figure 7.5 Seasonal Distribution of Future Precipitation Trends
Note: plot excludes some extreme outliers of future precipitation.

The analysis of this climate data can be summarized with some key observations:

- The GCMs project that annual precipitation will increase.
- The GCMs suggest that most of the annual increases in precipitation will occur in winter and fall, and the least pronounced will occur in summer.
- All GCMs suggest that temperatures will increase.

This suggests that while water may be plentiful in the future on an annual basis, the distribution of rainfall could result in changes in aquifer dynamics. Coupled with rising temperatures that can significantly increase evapotranspiration in the summer, where any increases in rainfall are likely to be very modest if anything, regular short-term summer stress on the groundwater could potentially increase. The analysis in the next several sections explores the plausible impacts of these projected changes in climate on Dover's groundwater.

8.0 Results

8.1 Projections of Climate-Affected Aquifer Dynamics

The projections for future precipitation and air temperature from all 32 GCMs were applied (in pairs from the same GCM) to the regression model and water balance model of the Dover aquifer**.** The results of each GCM were considered equally plausible, and hence equally likely – together, they create a range of plausible future climate conditions that could affect Dover's aquifer. Results are presented in this context of ranges.

Important to the interpretation of the results described in this memorandum is the acknowledgement that climate projections are not the same thing as forecasts, nor do they purport to represent *all* potential future climate conditions. Rather, each GCM computes a plausible condition in response to assumptions about future carbon emissions scenarios, and in aggregate, help to construct reasonable ranges with which to test natural system responses. Additionally, while actual future climate trends may occur beyond the range of the projections in this study, the projections can be useful in identifying potential trends and risks.

Figures 8.1-8.3 illustrate the range of potential aquifer patterns using the regression model from **Section 6.1** with all 32 GCMs. Future simulations are superimposed over the historic hydrologic record, as described in **Section 7.2.1**. **Figures 8.4-8.6** illustrate the same patterns using the water balance model from **Section 6.2**. Interpretations of these results are discussed in **Section 9.0**.

One limitation of this analysis is that the regression model is inherently limited in its ability to project long-term gradual downward trends in the water table because it projects actual water table levels rather than discrete changes in the water table level (this was attempted, without useable results). However, because the regression model clearly demonstrates a tendency for groundwater to recover even more robustly than it has historically, we can conclude that a downward long-term trend is not likely. This is corroborated by the water balance model, which *does* have the ability to simulate long-term trends, but also suggest that this is unlikely. This conclusion is further supported by the preponderance of GCM projections that suggest wetter years post 2050 than in the historical record used for this study.

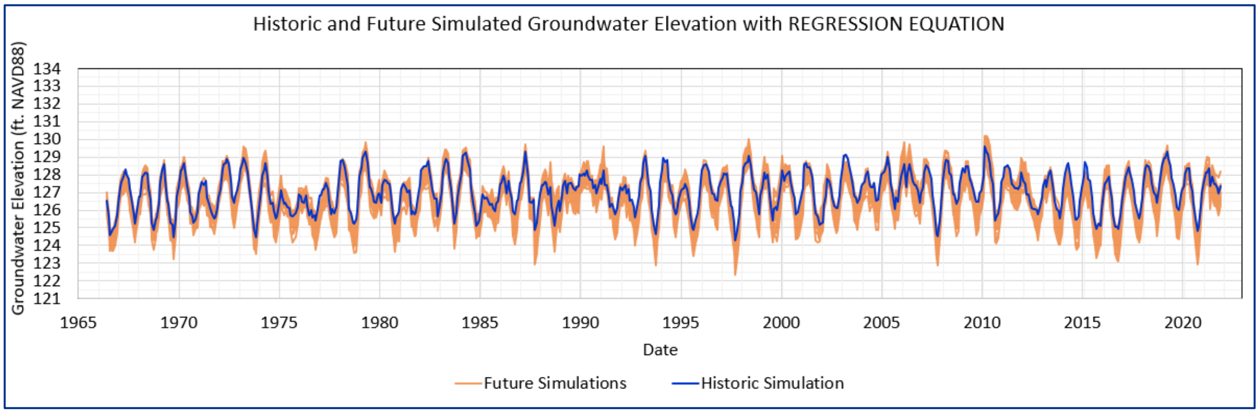

Figure 8.1 Future Projections of Groundwater Compared to Historic Simulation Using REGRESSION

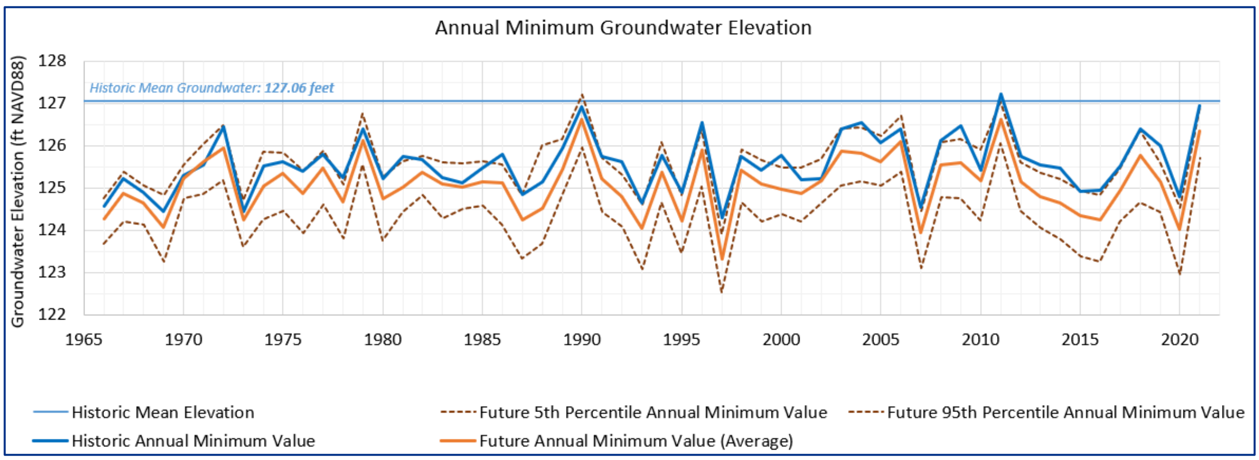

Figure 8.2 Range of Climate Model Projections for Lowest Annual Groundwater Compared to Historic Simulation Using REGRESSION

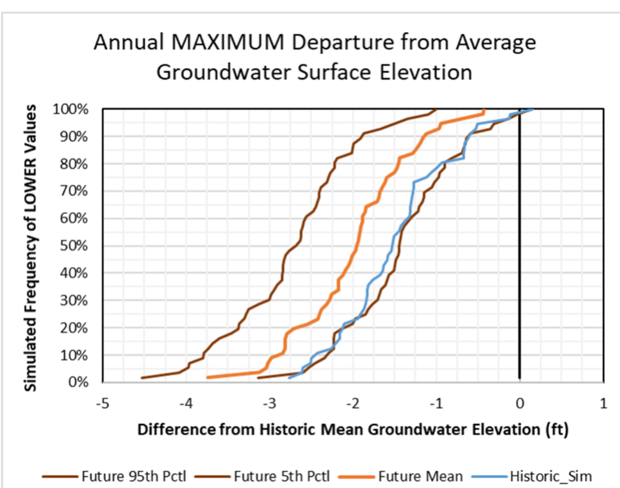

Figure 8.3 Frequency of Future Groundwater Changes Compared to Historic Simulation Using REGRESSION

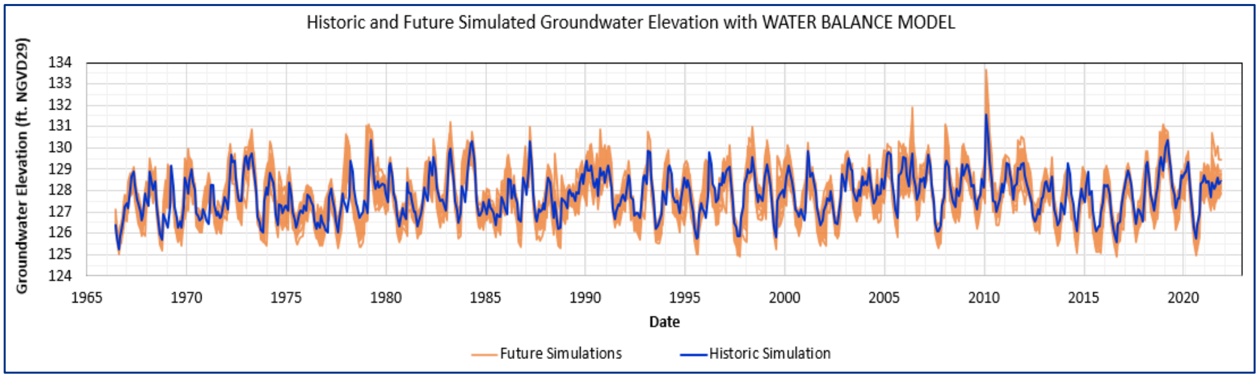

Figure 8.4 Future Projections of Groundwater Compared to Historic Simulation Using WATER BALANCE

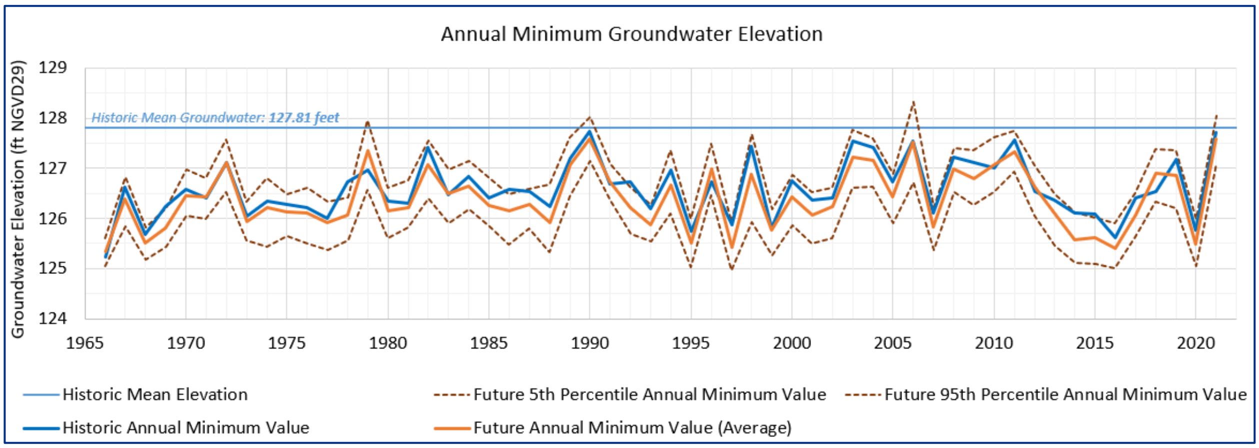

Figure 8.5 Range of Climate Model Projections for Lowest Annual Groundwater Compared to Historic Simulation Using WATER BALANCE

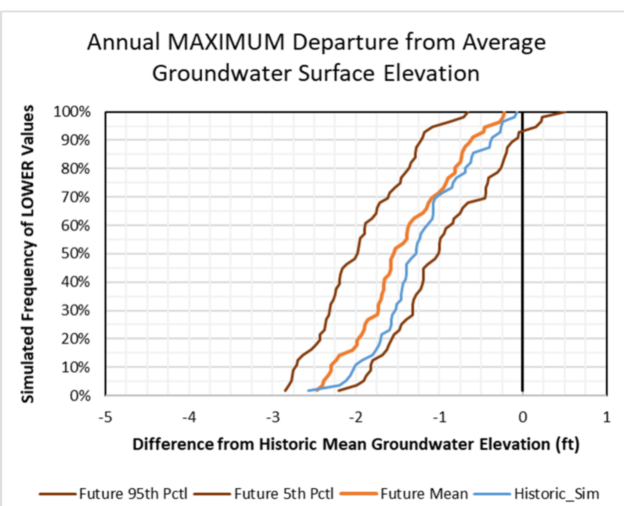

Figure 8.6 Frequency of Future Groundwater Changes Compared to Historic Simulation Using WATER BALANCE

8.2 Demand Sensitivity Analysis and Discussion

The primary focus of this study is to assess potential impacts of future climate variables on groundwater levels. Both analytical approaches included average monthly town-wide demand as a model input. Available town-wide demand information is limited; however, a seasonal pattern was applied to the climate projections to improve the robustness of the analysis (see **Section 5.0**). As described in **Section 6.1**, demand accounted for a small portion of the annual fluctuation in groundwater levels from the regression analysis. The water balance approach also found demand to be a comparatively minor factor when measured against the impacts of annual fluctuations in temperature and rainfall.

Between 1960 and 2020, the population in Dover has more than doubled. The town's aquifer has been able to absorb the impact of increasing populations (and with it, increasing demand) as evident by the water levels recovering year after year, without a long-term downward trend of aquifer depletion. Conservation efforts within the Town and the larger region may have mitigated the effect of increased population by lowering per capita usage. This historic record provides additional evidence that, as a whole, the aquifer is resilient to changes in demand.

To better quantify the town-wide impact, the water balance model was run with **two times** the estimated 2030 demand. In this scenario, the simulation of annual average withdrawals increased from 0.47 mgd to 0.94 mgd. The simulation results showed an average reduction in groundwater level of 0.05 feet (0.6 inches) due to this doubled demand.

This analysis is representative of the conditions of the USGS monitoring well, which for the purpose of this study, is a proxy of town-wide average conditions. However, the resolution of this work does is not fine enough to quantify site specific impacts, such asnegative localized impacts due to increased withdrawal pumping.. In other words, this is an average value distributed evenly across the entire town area, and local impacts may be much more significant. One recommendation of this study is to conduct site specific groundwater impact assessments at any location of new or proposed significantly increased pumping.

9.0 Interpretation and Limitations

While neither future condition analysis (groundwater level Regression model or mass balance modeling) indicate potential for a long-term downward trend in the water table, they both agree on the plausibility of lower summertime water tables due to increased evapotranspiration and changes in the distribution of precipitation beyond 2050. **Figures 8.2, 8.3**, **8.5**, and **8.6** suggest that in general, the average annual excursion of the water table below the historic annual low values could be expected to be approximately 0.3 - 0.5 feet (lower), but that under extreme conditions could be approximately 1 - 2 feet below the observed historical annual low points year-to-year (not compared to the single lowest recorded value). These annual summer minimum values are generally short-lived (as shown in **Figure 8.1 and 8.4**), and are a function of climate trends and seasonal demand variability. They are frequently accompanied in the results by rapid replenishment above average groundwater levels and higher water levels than historically observed in the early and later parts of many years.

It is reasonable to conclude from this analysis that while the aquifer does not appear to be at risk of long-term gradual depletion, the amplitude of its annual oscillation could increase, bringing lower short-term water table levels in the summer on a regular basis (for 1-2 months), and frequently higher levels in other parts of the year.

Study Result Limitations:

- Recall that the projected groundwater levels in this study are representative of the location of the USGS long-term monitoring well, and amplitudes are likely to be higher and lower in other locations in Dover, as illustrated in Figure 2.3.
- This study does not consider other threats to the aquifer such as groundwater contamination from Per- and Polyfluoroalkyl Substances (PFAS), leaky underground storage tanks, salt, etc.
- This study is conducted on a monthly average time frame and may not consider potential reduction in recharge due to increased precipitation intensity or decreased ground permeability on an event basis, or due to land cover changes.
- This study addresses the surficial groundwater aquifer only and does not provide information on the deeper bedrock aquifer.

Instead of building a time-intensive, three-dimensional numerical model, which would be more expensive and still carry uncertainties, this study employed two simpler corroborating models paired with GCMs to do this analysis. Fundamentally, the greatest uncertainty in any climate change analysis is the assumptions and representation of future emissions scenarios and their actual impacts. Despite some limitations, simpler tools can be applied as confidently as more complex tools to meet the objectives of this study, which are to identify the potential for long-term trends and year-to-year variations from historical groundwater levels. Presenting results as plausible ranges helps to reduce the uncertainty associated with an absolute prediction.

10.0 Conclusions

Since 1965, the long-term USGS gage in the approximate geographic center of Dover has measured annual oscillations in groundwater levels on the order of 2-4 feet each year from highest to lowest levels. In almost all years, the aquifer replenishes whatever is lost to evapotranspiration, well pumping, and transmission of water to streams or deeper aquifers. The results from the study do not indicate a noticeable trend upward or downward in historical average groundwater levels, and the shallow aquifers in Dover can be characterized as having been relatively stable over time. However, as discussed below, they may drop below historical annual minimum values modestly, but regularly in the future.

The results of this climate impact analysis suggest that groundwater levels are likely to continue to be relatively stable into the future. Higher expected annual levels of precipitation concentrated in the non-summer months is predicted to lead to higher groundwater levels than historically observed in those months, and correspondingly lower levels in the summer months. Key findings are listed here:

Key Findings

- Neither method of analysis projected any long-term downward trend in average groundwater levels, and from this perspective, the groundwater in Dover can be considered stable.
- Both methods suggested that ***on average***, low annual groundwater levels in the summer could be 0.3-0.5 feet lower than historical annual low levels (at the USGS monitoring gage near the center of town), though these periods are simulated as short-lived (1-2 months).
- Under extreme conditions, low annual groundwater levels could be approximately 1 - 2 feet below the historical low point at the USGS monitoring gage (other gages historically have fluctuated more dramatically as measured from the surface, as discussed in **Section 2.0**).
- Annual drawdown is likely to be followed by sufficient recovery to above average conditions, as high annual groundwater levels in the non-summer months could be approximately 0.5 – 1.5 feet higher than historical annual high levels at the USGS monitoring gage.
- The changes in future groundwater fluctuations appear to be driven predominantly by changing climate patterns, and less sot by demand. This was observed in both models and is confirmed by a sensitivity analysis where groundwater levels are minimally impacted (0.6 inches lower) by an experimental doubling of withdrawals.

In summary, no downward trend of the aquifer is expected as these results are interpreted, suggesting that the groundwater in Dover is likely sustainable volumetrically with current and projected water use patterns. Within-year oscillations are likely to increase in amplitude, and Dover may wish to assess whether regular conditions of slightly lower drawdown would pose any risks to water accessibility. Referencing the quantitative conditions (groundwater levels) that prompted the 2020 study may assist with this.

Next Steps

These results are based on currently accepted climate models for this type of analysis. However, climate change is inherently uncertain, and the results should not be considered to be forecasts, but plausible ranges of future conditions based on assumptions about future emissions levels, simplification of complex natural systems, and assumptions about future water use. Rather than examining the results in the context of what is most likely, it may be more useful to examine the results and ask “Do any of the plausible conditions represented pose a risk that should be mitigated?” Addressing this question can help Dover make informed decisions about the resilience of its aquifers.

Specifically, understanding the groundwater conditions that led to the initial motivation for the 2020 study (drilling of deeper wells, etc.) could help translate the results of this study into appropriate planning guidance. If groundwater levels in 2015 and 2016 (among the lowest on record, but not the lowest) caused concern or problems with well functionality, this study suggests that such conditions could occur more frequently and with more severity, though these changes would likely be small or moderate (in accordance with the numbers in the Key Findings above), and short-lived (See **Figure 10.1**). CDM Smith recommends a discussion with the Town to identify potentially concerning groundwater levels from past observations, and use the results of this study to collectively understand and address the risk of any adverse conditions recurring or worsening.

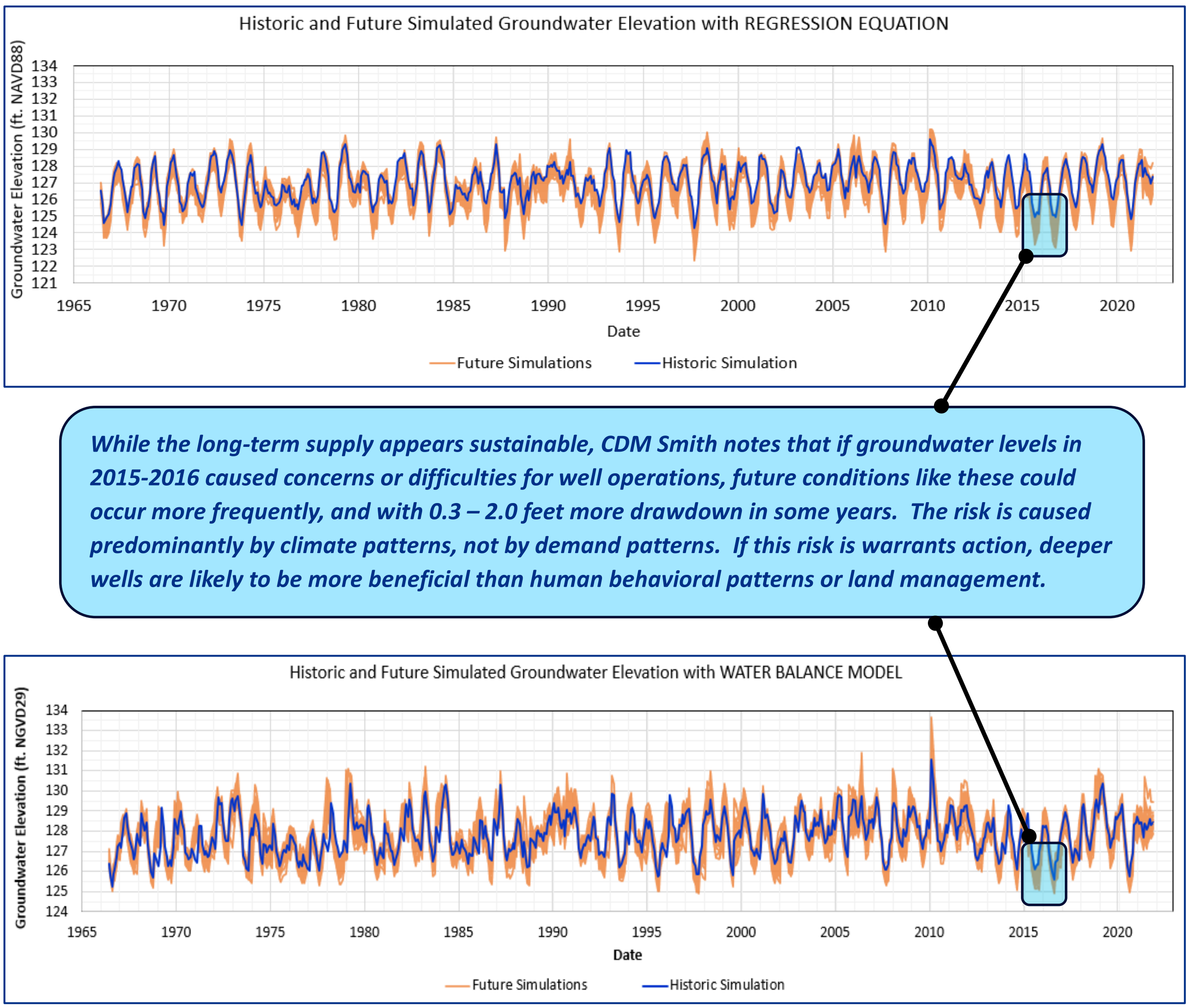

Figure 10.1 Projected Lower Drawdown Compared with 2015-2016 Low Water Levels

Specific Recommendations:

- The aquifer in Dover appears to be resilient over the long-term, with unlikely potential for long-term downward trends in water levels. We recommend continued monitoring, and revisitation if any year-over-year downward trends begin to emerge over a 5-10 year period, for example.
- We recommend further discussion with the Town to identify any potentially concerning groundwater levels in future projections.

- We recommend continuation of conservation efforts to reduce localized issues in groundwater supply.
- The impacts of demand on localized groundwater conditions (e.g. parcel- or pump-level) cannot be quantified by the generalized approaches used in this study. The study is intended to explain town-wide average conditions rather than fine resolution detail Detailed site-specific evaluations to understand localized impacts of any new or proposed increased withdrawals would be needed to estimate impacts of such.

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