CORRECTIVE ACTION PLAN

for the Millville Elementary School's drinking water system

PWSID 2188004

updated June 13, 2023
(previous versions December 21, 2022 and April 26, 2023)

This update of the Town of Millville's Corrective Action Plan provides new information regarding three topics:

- The use of purchased bulk water as an interim solution for reducing the level of disinfection byproducts (DBPs). That is being done at the request of the Blackstone-Millville Regional School District (BMRSD) during approximately the last five weeks of the school year in late May and early June 2023.
- Reporting of the successful removal of iron and manganese after replacement of the GreensandPlus filter media
- To additionally respond to water quality concerns regarding the levels of per- and polyfluoroalkyl substances (PFAS) detected with recent analytical monitoring, Millville reports here to the Massachusetts Department of Environmental Protection (MassDEP) on steps being taken to gather preliminary information to allow the consideration of possibly establishing a physical interconnection with a neighboring water system to provide a different water supply. If an interconnection was provided, then use of the current groundwater well with all of its water quality problems would be discontinued.

Conceptually, the remaining sections of this Corrective Action Plan are basically the same as in the two previous versions, with both water quality problems being solved at relatively low cost. The iron and manganese violation was successfully addressed in February 2023 by replacing the GreensandPlus media.

The DBP violation is planned to be addressed during the school recess in summer 2023 by discontinuing the use of chlorine as the pre-oxidant for the greensand filters and switching to permanganate. The required WS34 application is expected to be submitted to MassDEP in the near future subject to its completion by Northeast Water Solutions, Inc. (NWSI).

Introduction

This Corrective Action Plan is intended to provide the conceptual approach that the Town of Millville proposed to MassDEP to address the two October 15, 2022 Notices of

Noncompliance (NONs) for the drinking water system at the Millville Elementary School. The two NONs are related to the disinfection byproduct Maximum Contaminant Levels (MCLs) (ENF# NON-CE-19-5D00014118) and the treatment technique for iron and manganese (ENF# NON-CE-19-5D00014119). This corrective action plan outlines the specific short-term and long-term action measures that Millville is conducting to ensure the water supplied to consumers meets applicable standards, and includes timelines for the actions to be completed.

Problem Statement for Iron and Manganese

Iron and manganese were being removed quite well through early 2021, as shown in Figures 4 and 5, Then the greensand filters started to remove iron and manganese less effectively, and those times were correlated to relatively low levels of chlorine in the greensand filter effluent.

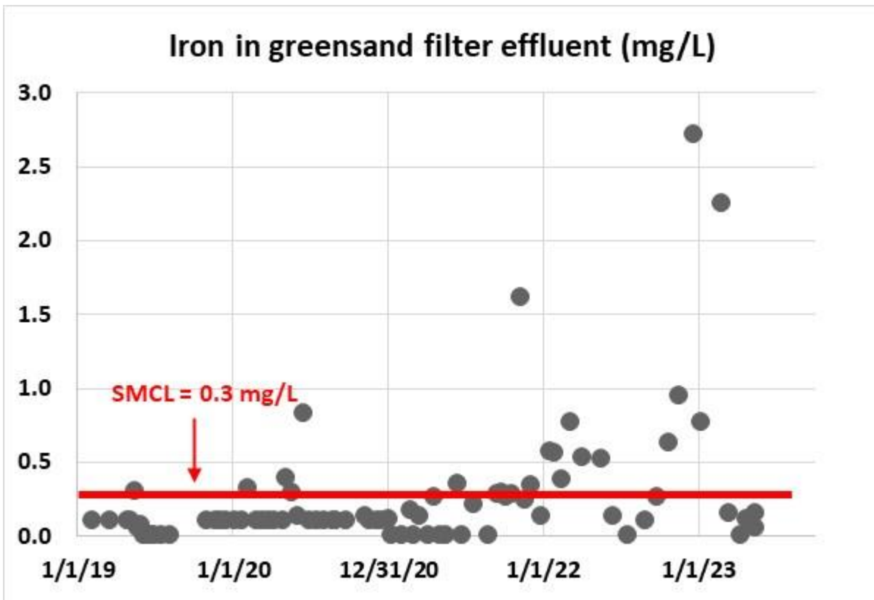

Figure 4. Iron in the GreensandPlus filter effluent

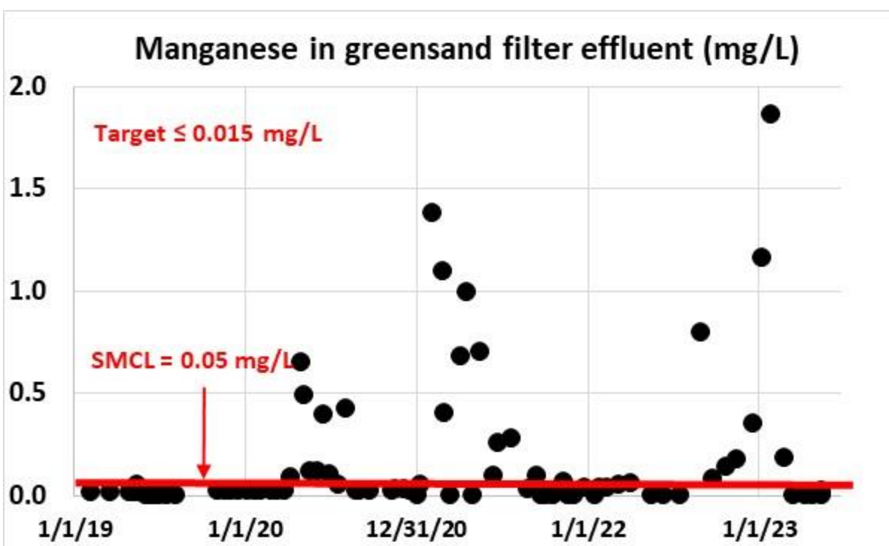

Figure 5. Manganese in the GreensandPlus filter effluent

Sufficient chlorine must be maintained in the greensand filter or it will lose its effectiveness for removing iron and manganese. There were several occasions in late 2020 through 2022 where the chlorine level was too low for too long, adversely affecting the capability of the greensand filters. The filter media was regenerated with chlorine in July 2022, but that did not work well enough to maintain the effluent iron and manganese concentrations below their respective Secondary Maximum Contaminant Levels (SMCLs).

Please note that values of 0.1 mg/L for iron and 0.01 mg/L or 0.02 mg/L for manganese from before 2021 in these plots are probably non-detect values (where the "<" sign was removed in the data provided to WCS). Starting in 2021, the non-detect data are shown as 0.0 mg/L.

Millville Successfully Implemented Solution for Iron and Manganese Removal

The GreensandPlus media was replaced by NWSI in February 2023, and that restored the effectiveness of the filters as shown by the data in Table 5 and in Figures 4 and 5. It took from several days to a few weeks for the media to fully activate for removal of dissolved portions of iron and manganese. Since then, manganese has been reduced mostly to non-detect levels, and iron has been consistently below the Secondary Maximum Contaminant Level (SMCL) of 0.3 mg/L (Table 5). There were no drawbacks to replacing the GreensandPlus media, other than the cost and system shutdown time.

Table 1. Impact of Replacing GreensandPlus Media on Iron and Manganese Removal

	Total Fe (mg/L)		Total Mn (mg/L)	
Date	**Well**	**Greensand filter effluent**	**Well**	**Greensand filter effluent**
1/10/23	13.2	0.77	1.23	1.16
1/30/23		13.5		1.86
2/22/23	replaced Greensand Plus media in both filters			
2/27/23	15.2	2.25	1.31	0.184
3/17/23	18.9	0.16	1.34	ND
4/13/23		ND		ND
4/27/23	17.9	0.11	1.25	ND
5/17/23		0.059		ND
5/18/23	27.1	0.157	1.19	0.023

Currently the chlorine residual target for the greensand filter effluent is 0.5 mg/L (+/- 0.3 mg/L). The varying iron levels in the raw water make maintaining a steady chlorine residual difficult, and the on/off nature of this treatment system also does not help. Based upon historic operating data, the treatment process operates for approximately 15 hours per week during the active school year, and less during vacation periods. Extended stagnant periods can potentially result in a loss of greensand media effectiveness, further emphasizing the need to maintain sufficient chlorine residual in the filter effluent.

Problem Statement for Disinfection Byproducts

Historical HAA5 results are plotted in Figures 1 and 2 for the two DBP monitoring locations, the Nurse's Station and the Teacher's Lounge. Compliance is based on the locational running annual average (LRAA) at each site. Most of Millville's DBP results have been fairly good. The majority of the quarters (76%, or 26 out of 34 quarters since 2014) had average haloacetic acid (HAA5) results below 60 ppb, the level of the MCL for the LRAA. However, relatively high HAA5 has been detected periodically in the water system, with several NONs resulting.

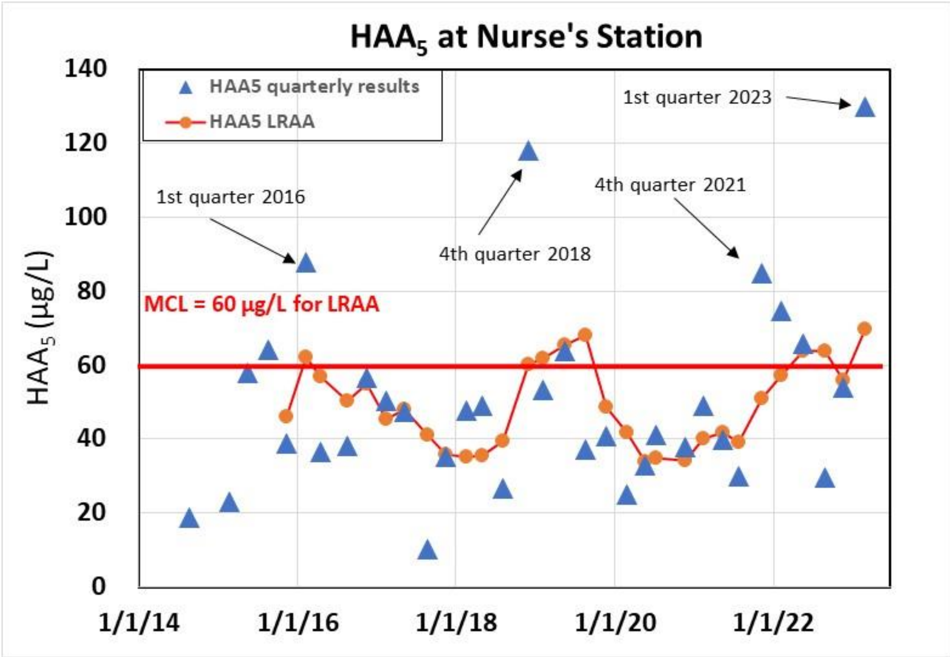

Figure 1. HAA5 at the Nurse's Station

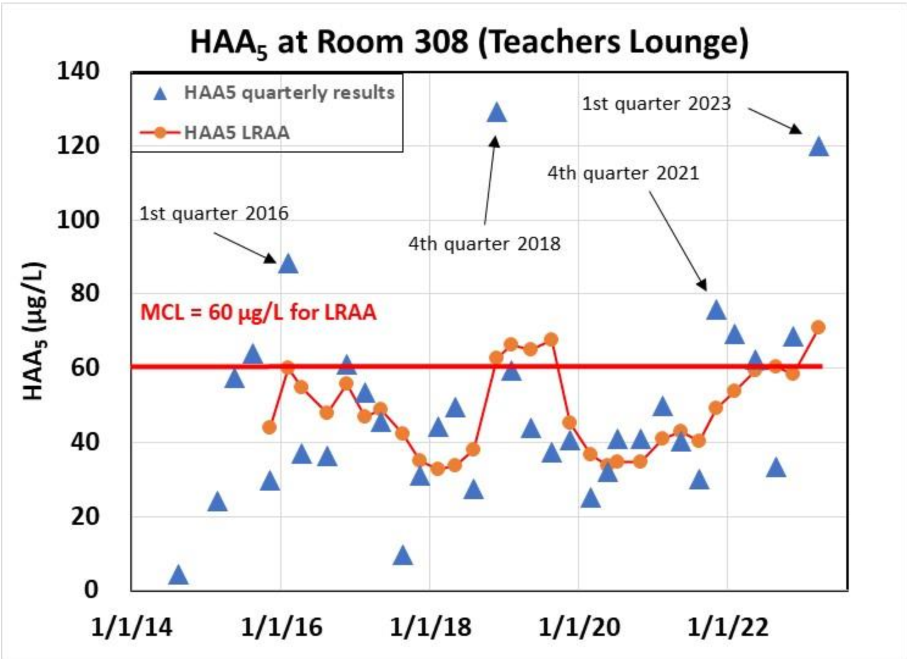

Figure 2. HAA5 at the Teachers Lounge

The HAA5 results from four individual quarters stand out as uncharacteristically high, as noted in Figures 1 and 2. In each of those four quarters the high HAA5 results were caused by sampling during short periods of just a few days when the greensand filter effluent chlorine residuals were relatively high and well above the target ranges. In each case the chlorine level then quickly decreased and returned to within the target range, and HAA5 decreased accordingly.

Given compliance is based on the locational running annual averages, a single high HAA5 value can result in regulatory violations for up to four (4) consecutive quarters. That happened with the high HAA5 result from 4^{th} quarter 2018 (Figures 1 and 2) when the operators overfed chlorine for a short period and compliance sampling occurred then. Four quarters of violations occurred because of that single result.

Another example is the uncharacteristically high result from first quarter of 2023. That was caused primarily by the result from a sample that was collected shortly after replacement of the GreensandPlus media on February 22, 2023. The effluent chlorine residual was held quite high for only about the first three days after installing the new media, averaging 2.9 mg/L, well above the normal target of 0.5 mg/L. But that’s the water that was sampled for DBP compliance, and the HAA5 result was 250 ppb, compared to only 23 ppb in January and 27 ppb in December. That February sample contributed greatly to the quarterly average result of 130 ppb, which caused a violation for that quarter and is sure to result in three more quarters of violations.

In summary, during the past nine years, HAA5 sample results collected during four isolated occurrences of high chlorine residuals – for just a few days each – have resulted in eight quarters of HAA5 MCL violations, with another three quarters of violations likely still to come in 2023 as a consequence (and regardless of the future results during those three quarters). That’s a total of 11 quarter violations from only four short-term increases in HAA5.

More recently, it appears that increasing levels of total organic carbon (TOC) are making it more difficult to meet the DBP limits, even when the chlorine residual levels are kept within the target range. The natural organic matter present in the water, quantified as TOC, serves as the precursors for formation of DBPs. Figure 3 shows the increasing trend for TOC in the raw well water, and a lesser but still increasing trend for TOC in the treated water. The treatment system (sediment filter plus greensand filter) averages about 35% removal of TOC.

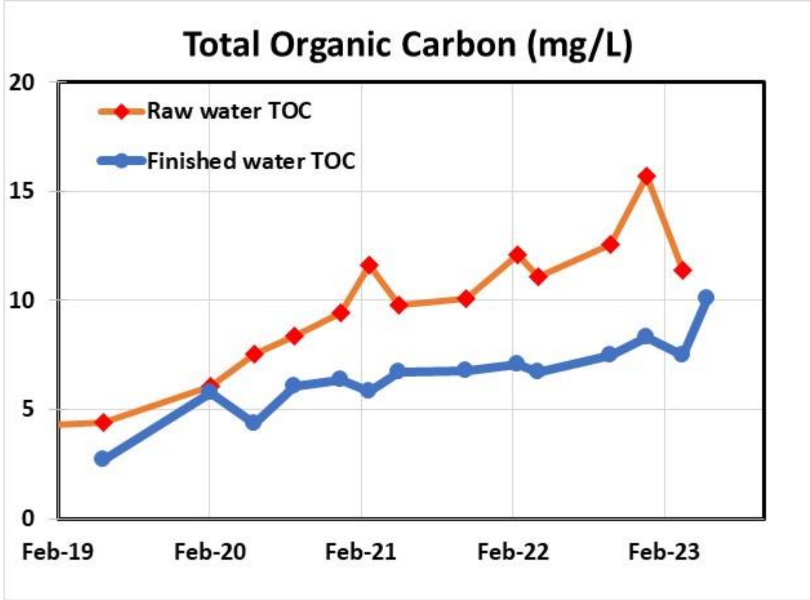

Figure 3. Total Organic Carbon

Interim Solution for Disinfection Byproducts (use of purchased bulk water)

The consumer, Blackstone-Millville Regional School District (BMRSD), has decided to purchase water for the remaining school year at the Millville Elementary School. Use of the bulk water will provide quality that meets all SDWA standards for treated drinking water. This is being done because of their concerns about the chlorinated disinfection byproducts that are the subject of part of this Corrective Action Plan. The use of purchased water started on May 19, 2023, currently continues, and is expected to continue through the end of the current school year which is scheduled for June 16.

The Town of Millville accepts this decision by the BMRSD, but does not believe it was necessary, especially given that the treated water is not being used at the school for drinking purposes and that the issues with water color have been eliminated.

Highlights regarding the use of purchased bulk water are as follows:

- Bulk water purchaser: Blackstone-Millville Regional School District
- Financial support: The Town of Millville Board of Selectmen authorized $15,000 for reimbursement to the BMRSD for their costs in purchasing the bulk water
- Bulk water supplier: Henshaw Farms, Chesterfield, MA, 413-531-7235
- Time frame: May 19, 2023 through mid-late June 2023
- MassDEP approval: NWSI submitted to MassDEP on May 18, 2023 a request for the use of bulk water and included a description of proposed procedures. MassDEP granted approval on May 19, 2023 with those procedures then considered as requirements. MassDEP's approval is valid for the period of May 19 through June 30, 2023.

- Connection: the water will be pumped into the 6,000-gallon storage tank. BMRSD staff, assisted by NWSI's Certified Operator, will ensure the connection from the truck to the MES water system is made properly.
- Water quality: the bulk water supplier is listed on MassDEP's list of authorized suppliers, and water quality information was supplied by NWSI to MassDEP.
- Treatment System: The groundwater pump, bag particle filter, and greensand filter operations have been shut down during use of the delivered bulk water, while the corrosion control chemical feeds (silica, phosphate, and soda ash) all continue.

Note that purchased bulk water was also previously used by BMRSD from February 9 to 22, 2023 while the GreensandPlus filter media was being replaced.

Solution for Disinfection Byproducts

To address the DBP issue, the preoxidant chemical for the greensand filters will be changed from chlorine to permanganate. Discontinuing the use of chlorine will completely and immediately eliminate the formation of chlorinated disinfection byproducts. Chlorine is currently used only as the pre-oxidant for the greensand, and not for the purpose of microbial disinfection (UV light treatment is currently used for disinfection). As such, no alternative disinfection system would need to be installed under the current conditions.

Permanganate (MnO_4^{-1}) is a stronger and faster oxidant than chlorine, and has been used for decades as a chemical oxidant for dissolved Mn^{2+} and is the traditional oxidant used with greensand filters. While chlorine is very effective for creating the manganese oxide surface of the filter media that removes dissolved manganese, it is not effective for direct oxidation of dissolved manganese at pH < 8 – 9 (Brandhuber et al., 2013, *Guidance for the Treatment of Manganese*). The faster oxidation resulting from the use of permanganate should improve oxidation of dissolved manganese and subsequent filtering of the resulting solids, while also maintaining the manganese oxide surface of the media to effectuate removal of dissolved manganese.

Potassium permanganate ($KMnO_4$) has been proposed by NWSI as the oxidant instead of sodium permanganate ($NaMnO_4$). Sodium permanganate is available in liquid form, but is more expensive. Potassium permanganate is a dry power that first must be mixed into solution prior to being pumped into the water stream, and poses additional safety considerations for the operators using it.

The primary potential drawback to the use of permanganate is that the water will turn pink or purple in color if the permanganate residual in the filter effluent is too high. To prevent this possibility, Millville will use a color monitor as an online measure for the filter effluent. Concentrations high enough to cause color will result in the permanganate feed decreasing or shutting off, and an alarm notification will be issued to the operators. Permanganate can also potentially form organically complexed manganese or colloidal manganese oxides, which could pass through the filter. Monitoring of total manganese will determine if this is a problem. That is not expected though, given the high TOC has not presented a problem for removal of iron or manganese in this system using chlorine.

Per MassDEP's request, Millville instructed NWSI to maintain the ability to feed shock doses of chlorine in the event that is necessary due to bacterial detections in the distribution system.

NWSI recently completed design details for the operational modification. While the potassium permanganate should be easy to procure, current supply chain issues could potentially impact the availability of the necessary permanganate monitoring instrumentation and computer components (including microchips).

NWSI is responsible for preparing the necessary application to MassDEP for the modification in treatment technique, and will also be responsible for implementing the changes. The application is anticipated to be submitted to MassDEP in June 2023.

As of now, the switchover from chlorine to permanganate is anticipated to be completed by NWSI during late summer 2023, barring any unanticipated delays. NWSI currently estimates it will require a minimum of four weeks, and potentially longer, to completely implement the switchover. That would allow sufficient time to effectuate the start-up, determine the desired permanganate dose, work any bugs out of the system, and confirm success for removal of iron and manganese with analytical testing.

Neither NWSI nor Water Compliance Solutions believe that a pilot study is necessary. Greensand with permanganate is a commonly used treatment technique for iron and manganese removal, and the start-up period effectively serves as a full-scale pilot system. This is a small treatment system, and a pilot study is not needed to generate data to scale the design up to full scale. An initial permanganate dose can be estimated based on stoichiometry between permanganate and the iron, manganese, and organic carbon loading present in the influent to the greensand filters, and the dose would then be adjusted as needed based on full-scale operating conditions.

Potential Alternatives to Address PFAS levels

The water supplied by the well at the Millville Elementary School is of poor quality for several important parameters. The raw water is extremely corrosive, but that problem was solved through the use of three corrosion control chemicals (silica, phosphate, and soda ash). Iron and manganese are high, but the greensand filters can remove that with continued maintenance of sufficient chlorine residual in the filter effluent (Figures 4 and 5). Increasing levels of total organic carbon (Figure 3) have made compliance with the Disinfectants/Disinfection Byproducts Rule more difficult (Figures 1 and 2).

Finally, the level of per- and polyfluoroalkyl substances (PFAS) in Millville's treated water is close to the current MassDEP MCL for PFAS-6, and is above the USEPA's proposed new PFAS limits. Millville's PFAS-6 levels currently average 15.3 ppt, which is 77 percent of the existing MCL of 20 ppt (Figure 6). For a general industry rule of thumb, it's time to take action if a contaminant approaches approximately 80 percent of the MCL. Accordingly, Millville would be prudent to investigate means to reduce PFAS levels even without consideration of the USEPA's new proposed stricter PFAS regulation. Any decision to implement an action to reduce PFAS under the existing (or future) regulation would be contingent on available funding.

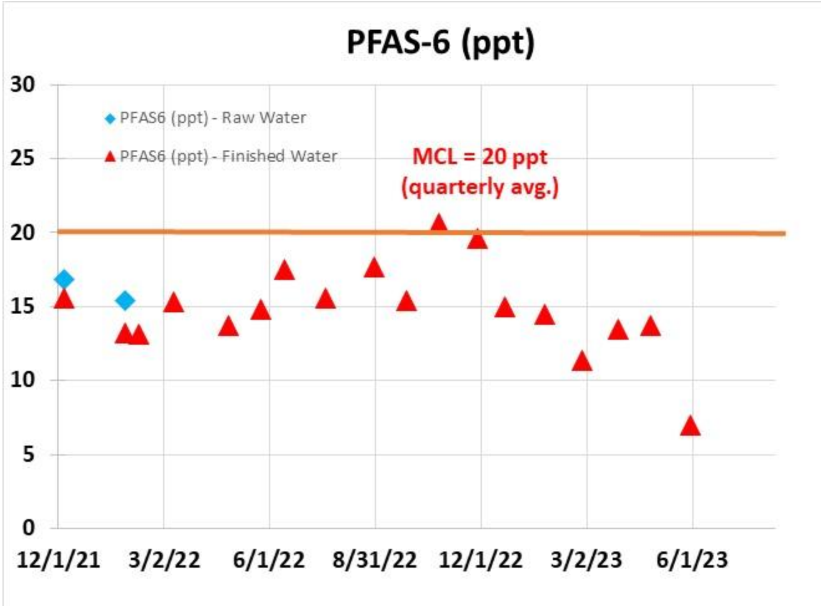

Figure 6. PFAS-6 in raw and treated water

The poor quality of Millville's water may render the standard treatment technologies typically used for PFAS to be ineffective. Removal of PFAS using activated carbon may be limited by interference from the high TOC. Nanofiltration may also be difficult due to particulate matter and the increasing TOC levels, and ion exchange may encounter excessive competing ionic species.

Given the current raw water quality and treatment challenges, and especially with the recent new pressures regarding current PFAS levels as well as the USEPA's new proposed PFAS regulation (which Millville's water would not meet), Millville has decided to consider pursuit of alternate water sources to supply the school's needs. Millville has also been encouraged by MassDEP to consider an interconnection with a neighboring water system. Such an endeavor would require significant engineering and construction work and substantial financial commitment.

The two possible nearby water systems that Millville could potentially connect to are Blackstone, MA and Uxbridge, MA. Millville is currently in the process of communicating with those communities to determine if either has both the needed water capacity and a willingness to sell water to Millville.

If that inquiry is successful, Millville is expected to solicit services from an engineering firm to conduct a feasibility study regarding the identified potential interconnection. Considerations of routing and geology will be especially important for practicality and project cost. Water quality considerations of the proposed new supply will also be evaluated. The Town of Millville Board of Selectman already approved allocation of $25,000 toward such an engineering study on May 15, 2023.

As an alternate solution for the reduction of PFAS, the above engineering study would also include evaluation of different treatment processes for removal of PFAS. That would include methods considered by the USEPA as best available technologies (BATs) for removal of PFAS including granular activated carbon, ion exchange, and nanofiltrations.

Millville is also in the process of identifying and considering potential outside funding sources for construction of an interconnection with another water system. Potential sources include loans through the State Revolving Fund (SRF), a grant from MassDEP, and the use of American Rescue Plan Act (ARPA) funds. A time schedule has not been set yet for the engineering study.

Necessary Provisions

Performance of this Corrective Action Plan is subject to adherence to federal, state, and local laws, bylaws, and regulations; legally authorized appropriation; and adequate funding availability.