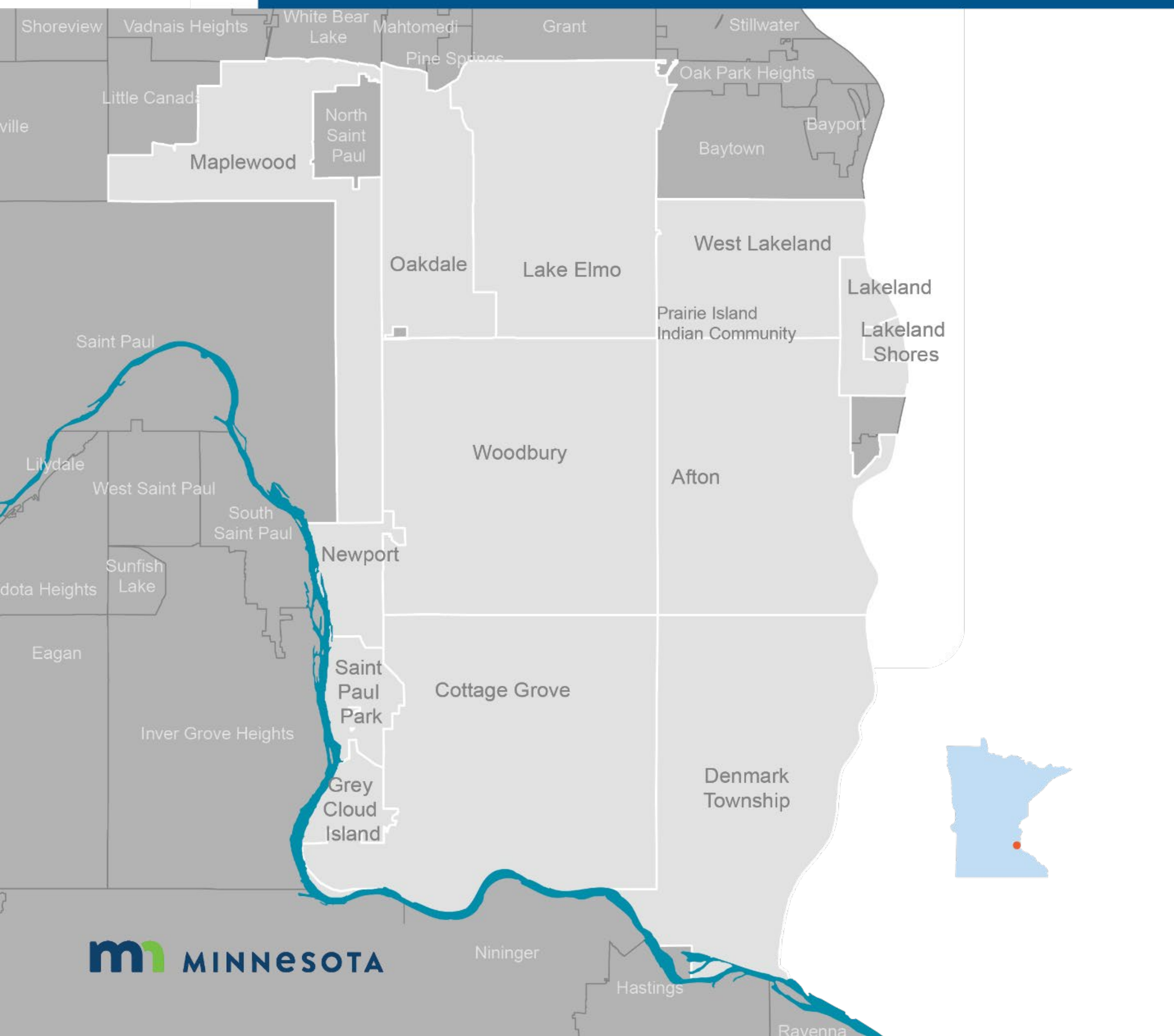
Conceptual Drinking Water Supply Plan

Long-term options for the East Metropolitan area.



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Contents

Glossary

3M Grant for Water Quality and Sustainability Fund (Grant) – Under terms of the Settlement, an $850 million Grant was provided by 3M to the State to be used to enhance the quality, quantity, and sustainability of the drinking water in the East Metropolitan Area; to restore and enhance natural resources and outdoor recreational opportunities; and to reimburse the State for certain other expenses.

2007 Consent Order – An agreement between 3M and the MPCA requiring 3M to investigate and take remedial actions to address releases and threatened releases of PFAS from the 3M Cottage Grove Site, the 3M Oakdale Disposal Site, and the 3M Woodbury Disposal Site; and to reimburse the Minnesota Pollution Control Agency (MPCA) for its costs to oversee the remediation actions taken under the Consent Order to help provide safe drinking water to affected homes and communities (e.g., installation of temporary or permanent treatment).

2018 Agreement and Order (Settlement) – An agreement to settle the State's Natural Resources Damage lawsuit against 3M for $850 million. Minnesota's Attorney General sued 3M in 2010, alleging that the company's disposal of PFAS had damaged and continues to damage drinking water and natural resources in the East Metropolitan Area. After legal and other expenses were paid, about $720 million is available to finance drinking water and natural resource projects in this region. The MPCA and the Minnesota Department of Natural Resources (DNR) are Co-Trustees of these funds.

Alignment – Location of water lines relative to other infrastructure, typically roadways.

Aquifer – An underground layer of water-bearing permeable rock; rock fractures; or loose, unpacked materials (gravel, sand, or silt). In a water-table (unconfined) aquifer, the water table (upper water surface) rises and falls with the amount of water in the aquifer. In a confined aquifer, layers of impermeable material both above and below cause the water to be under pressure, so that when the aquifer is penetrated by a well, the water will rise above the top of the aquifer (artesian condition).

Aquitard – An underground layer that has low permeability and limits, but does not completely prevent the flow of water to or from an adjacent aquifer.

Booster pump station – A pump station located within the water supply system that is designed to boost the pressure of water within a long pipeline.

Capital costs – One-time costs to build or rebuild infrastructure, including water treatment plants, wells, distribution systems, and other facilities.

Centralized system – A centralized water treatment approach for a given service that treats water at a single treatment facility in a central location and then distributes the water via a dedicated water distribution network across the service area.

Citizen-Business Group – One of three work groups to help the MPCA and the DNR identify and recommend priorities and projects for Settlement funding. This group is composed of the MPCA; the DNR; and about 15 citizen, business, and nongovernmental representatives who live or work in the East Metropolitan Area. One representative from the Government and 3M Working Group serves as a liaison to this group.

Conceptual Drinking Water Supply Plan (Conceptual Plan) – This plan, developed from a strategic planning effort as a step toward addressing the goal of Priority 1 of the Settlement, which is to ensure safe drinking water in sufficient supply to residents and businesses in the East Metropolitan Area to meet current and future needs. The Conceptual Plan presents a recommendation consisting of sets of conceptual projects (called scenarios) that, when combined, address drinking water quality and quantity issues for the 14 communities currently known to be affected by per- and polyfluoroalkyl substances (PFAS) contamination in the East Metropolitan Area. This Conceptual Plan will be used to guide the development and implementation of projects to be funded under the Grant.

Conceptual projects – Project ideas developed by the work groups, members of the public, and the Co-Trustees to address PFAS-related drinking water quality and quantity issues in the East Metropolitan Area. These conceptual projects are consistent with the water supply improvement options, but provide more detail, such as information on project location(s), project component(s), and PFAS treatment technologies.

Conceptual site model (CSM) – A simplified set of assumptions, data, and information that was used to develop a picture of how the groundwater system functions as the basis for developing the more detailed groundwater model.

Co-Trustees – The MPCA and DNR. Under the Minnesota Environmental Response and Liability Act (MERLA), the State on Minnesota (State) is the Trustee for all natural resources in the State, including air, water, and wildlife. The Governor's Executive Order 19-29 (inclusive of 11-09) designated the Commissioners of the MPCA and DNR as Co-Trustees for natural resources under MERLA and other laws.

Decentralized system – A decentralized water treatment approach that may rely on multiple treatment facilities at various locations to serve communities/neighborhoods in a given service area. Typically, these treatment facilities are far enough apart that it mitigates the cost and/or water quality concerns of a centralized treatment facility. On a much smaller scale, a decentralized system may also rely on point-of-entry treatment systems (POETSs) or point-of-use treatments (POUTs) that are installed at individual homes or businesses to achieve potable water.

Distribution line – A smaller diameter line, typically between 6 and 16 inches, that supplies water to consumers.

Distribution system – The portion of a water supply network that conveys potable water from transmission lines to water consumers and provides for residential, commercial, industrial, and fire-fighting water demand requirements. A distribution system can contain distribution lines, booster pump stations, pressure-reducing valves, and storage facilities such as water storage tanks or towers.

Drinking water distribution model – A comprehensive representation of the current and planned drinking water supply infrastructure in the East Metropolitan Area, used to support the evaluation of scenarios in this Conceptual Plan. The model includes information on drinking water supply infrastructure (e.g., connections, demand, water use, available water supply, system pressures, layouts and locations of infrastructure) as well as private and non-community public supply well data.

Drinking Water Supply Technical Subgroup (Subgroup 1) – One of the three work groups; composed of technical experts and formed to analyze options, deliver assessments, and provide advice for long-term options for drinking water supply and treatment to the Government and 3M Working Group, and the Citizen-Business Group.

East Metropolitan Area – Communities to the east of the Minneapolis/St. Paul Metropolitan Area that have been affected by PFAS releases from the 3M Company (3M) source areas. Currently includes the cities of Afton, Cottage Grove, Lake Elmo, Lakeland, Lakeland Shores, Maplewood, Newport, Oakdale, St. Paul Park, and Woodbury; the townships of Denmark, Grey Cloud Island, and West Lakeland; and the Prairie Island Indian Community.

EPA Health Advisory Levels (HALs) – Non-enforceable and non-regulatory technical guidance for state agencies and other public health officials on health effects, analytical methodologies, and treatment technologies associated with drinking water contamination. HALs are based on non-cancer health effects for different lengths of exposure (1 day, 10 days, or a lifetime). In 2016, the U.S. Environmental Protection Agency (EPA) released HALs for perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS).

Government and 3M Working Group – One of three work groups to help the Co-Trustees identify and recommend priorities and projects for Settlement funding. The formation of a working group consisting of representatives from the MPCA, the DNR, Washington County, the East Metropolitan Area communities, and 3M to identify and recommend projects was a requirement of the 2018 Agreement and Order (Settlement). One representative from the Citizen-Business Group serves as a liaison to this group.

Granular activated carbon (GAC) – GAC is made from raw organic materials (such as coconut shells or coal) that are high in carbon. Heat, in the absence of oxygen, is used to increase (activate) the surface area of the carbon, which is why these filters are sometimes referred to as “charcoal” filters. The activated carbon removes certain chemicals that are dissolved in water passing through a filter containing GAC, by trapping (adsorbing) the chemical onto the GAC.

Groundwater Management Area – A designation created by the Minnesota legislature as a tool for the DNR to address difficult groundwater-related resource challenges. Within these areas, the DNR may limit total annual water appropriations and uses to ensure sustainable use of groundwater that protects ecosystems, water quality, and the ability of future generations to meet their own needs. Washington County, along with Ramsey County and portions of Anoka and Hennepin Counties, falls within the North and East Metropolitan Groundwater Management Area.

Groundwater model – A numerical, three-dimensional representation of the groundwater aquifers in the East Metropolitan Area used to support the evaluation of scenarios in this Conceptual Plan. The purpose of the groundwater model is to provide insight into the current groundwater flow system, and predict impacts to flow paths and groundwater resources through the year 2040 from the proposed scenarios. These flow paths and quantity estimates are based on projected groundwater recharge/precipitation rates, surface water elevations, and pumping volumes of the proposed scenarios.

Health advisory – Notice from MDH that a drinking water supply has exceeded health-based guidance values developed by MDH.

Health-based value (HBV) – A health-based water guidance value developed by the Minnesota Department of Health (MDH) using the same scientific methods as health risk limits (HRLs), including peer review. Like an HRL, it is the concentration of a water contaminant, or a mixture of contaminants, that, based on current knowledge, can be consumed with little or no risk to health by the most exposed and sensitive individuals in a population. HBVs are developed to provide water guidance between rule-making cycles for chemicals that may have been recently detected in the water or for which new health information has become available.

Health risk index (HRI; health index, HI) – An indicator of the combined risk of exposure to PFAS compounds that cause the same health effects. It is determined by calculating the concentration of each PFAS compound divided by its HRL or HBV, and adding the resulting ratios. An HI equal to or greater than one indicates possible combined effects. The HRI is referred to interchangeably throughout the document as the health risk index, the health index, the HI, or the HRI. While HRI and HI are terms used for every chemical, the Conceptual Plan always uses them in reference to PFAS contamination. See the definition for PFAS for more information.

Health risk limit (HRL) – A health-based water guidance value developed by MDH that has been promulgated through the Minnesota rule-making process, which includes peer review and public input. It is the concentration of a groundwater contaminant, or a mixture of contaminants, that, based on current knowledge, can be consumed with little or no risk to health by the most exposed and sensitive individuals in a population.

High-service pumps – Pumps located at the water treatment facility that deliver large volumes of treated, potable water to the water supply system.

Horizontal directional drilling – A minimal impact trenchless method of installing underground utilities such as pipe, conduit, or cables in a relatively shallow arc or radius along a prescribed underground path using a surface-launched drilling rig.

Ion exchange (IX) – IX processes are reversible chemical reactions for removing dissolved ions from a solution and replacing them with other similarly charged ions. In water treatment, it is primarily used for softening, where calcium and magnesium ions are removed from water; however, it is being used more frequently for the removal of other dissolved ionic species.

Jack and bore – A method of horizontal boring construction for installing casing or steel pipes under roads or railways. Construction crews drill a hole underground horizontally between two points (the sending and receiving pits) without disturbing the surface in between. This is accomplished by using an auger boring machine that inserts casing pipe as it moves through the earth while simultaneously removing the soil from within the casing pipe.

Maximum contaminant level (MCL) – The maximum level of a contaminant allowed in water delivered from a public water supply. MCLs are set by EPA through a scientific process that evaluates the health impacts of the contaminant and the technology and cost required for prevention, monitoring, and/or treatment. States are allowed to enforce lower (i.e., stricter) standards than MCLs, but are not allowed to enforce higher (i.e., less strict) standards.

Metropolitan Council – The regional policy-making body, planning agency, and provider of essential services for the Twin Cities metropolitan region, including transportation, wastewater, water supply planning, growth planning, parks and trails, and affordable housing. The Minnesota Legislature established the Metropolitan Council in 1967; it has 17 members who are appointed by the Governor.

Municipal supply well – A drinking water well that serves as a source of water for a municipal water system.

Municipal water system – Refers to an existing municipality’s drinking or potable water treatment and distribution system.

Non-community public supply well – A well that provides water to the public in places other than their homes – where people work, gather, and play (e.g., schools, offices, factories, childcare centers, or parks) – and is part of a non-community public water system (see definition below).

Non-community public water system – A drinking water system that supplies water from private water supply well(s) on a year-round basis to:

- A residential development with six or more private residences (e.g., apartment buildings, private subdivisions, condominiums, townhouse complexes, mobile home parks), or
- A mobile home park or campground with six or more sites with a water service hookup.

Non-municipal well – A well that is considered non-municipal in this Conceptual Plan, and includes domestic, irrigation, commercial, and non-community public water supply wells.

Operations and maintenance (O&M) – All work activities necessary to operate and maintain all water treatment and supply facilities from the source of water through the distribution systems.

Per- and polyfluoroalkyl substances (PFAS) – A family of synthetic chemicals, initially developed by 3M, used to make products that resist heat, oil, stains, grease, and water. They are extremely resistant to breakdown in the environment, accumulate in humans and animals, and are "emerging contaminants" that are the focus of active research and study. Specific chemicals within the PFAS family include perfluorooctanoic acid (PFOA), perfluorooctane sulfonate (PFOS), perfluorohexane sulfonate (PFHxS), perfluorobutane sulfonate (PFBS), and perfluorobutanoic acid (PFBA).

Point-of-entry treatment system (POETS) – Water treatment system installed on the water line as it enters an individual home, business, school, or other building. These systems treat all the water entering the building.

Point-of-use treatment (POUT) – Water treatment system installed on the water line at the point of use, such as a faucet.

Pressure-reducing stations – Locations within the water supply system where a pressure-reducing valve has been installed.

Pressure-reducing valves – A valve fitted in a pipe system, which, in spite of varying pressures on the inlet side (inlet pressure), ensures that a certain pressure on the outlet side (outlet pressure) is not exceeded, thus protecting the components and equipment on the outlet side.

Priority 1 – The first priority of the Grant is to enhance the quality, quantity, and sustainability of drinking water in the East Metropolitan Area. The goal of this highest-priority work is to ensure safe drinking water in sufficient supply to residents and businesses in the East Metropolitan Area to meet their current and future water needs. Examples of projects in this first priority may include, but are not limited to, the development of alternative drinking water sources for municipalities and individual households (including, but not limited to, creation or relocation of municipal wells), the treatment of existing water supplies, water conservation and efficiency, open-space acquisition, and groundwater recharge (including projects that encourage, enhance, and assist groundwater recharge). For individual households, projects may include, but are not limited to, connecting those residences to municipal water supplies, providing individual treatment systems, or constructing new wells.

Priority 2 – The second priority of the Settlement is to restore and enhance aquatic resources, wildlife, habitat, fishing, resource improvement, and outdoor recreational opportunities in the East Metropolitan Area and in downstream areas of the Mississippi and St. Croix Rivers. The Co-Trustees have immediate access to $20 million in Settlement funds for projects in this priority category. After the safe drinking water goals of the first priority have been reasonably achieved, all remaining Settlement funds will then be available for natural resource restoration and enhancement projects.

Priority 3 – If funds remain after the first two priority goals have been met, the Grant can be used for statewide environmental improvement projects. Only projects in categories such as statewide water resources, habitat restoration, open space preservation, recreation improvements, or other sustainability projects would be eligible.

Private well – A domestic drinking water well that is not part of a public water system. The quality and safety of water from private wells are not regulated by the federal Safe Drinking Water Act, nor in most cases by state laws.

Public supply well – A drinking water well that serves as a source of water for a public water system.

Public water system – A regulatory term under the federal Safe Drinking Water Act for a drinking water supply system that serves at least 15 homes or 25 people for at least 60 days a year.

Recharge – Water added to the aquifer from the surface through the unsaturated (dry or vadose) zone in the uppermost soils through processes called infiltration and percolation following any precipitation (rain or snow) event.

Regional water supply system – A water system that supplies potable water to more than one community or water system.

Scenarios – Sets of conceptual projects that consider water supply, distribution, and demand, and are evaluated in this Conceptual Plan using drinking water distribution and groundwater models.

Small community water system – A private and voluntary water system that serves neighborhood-sized clusters of residences.

Special Well Boring and Construction Area (SWBCA) – A mechanism that provides for controls on the drilling or alteration of wells in an area where groundwater contamination has resulted or may result in risks to public health. The purposes of an SWBCA are to inform the public of potential health risks in areas of groundwater contamination, provide for the construction of safe water supplies, and prevent the spread of contamination due to the improper drilling of wells or borings.

Sustainability – Responsible interaction with the environment to provide, improve, and protect the drinking water for future generations by lessening environmental impacts, thoughtfully managing demands, and empowering conservation through education and targeted projects. Minnesota Statute § 103G.287, subd. 5, describes groundwater sustainability as the development and use of groundwater resources to meet current and future beneficial uses without causing unacceptable environmental or socioeconomic consequences.

Transmission line – A large-diameter pipeline designed to convey large volumes of water at higher pressures from a source (typically a water treatment facility) to a distribution system for use. Water transmission lines are typically larger in diameter (greater than 16 inches), and consumers are not typically placed on transmission lines because of their high velocities and pressures.

Watershed districts – Special government entities that monitor and regulate the use of water within certain watersheds in Minnesota, rather than within political boundaries, which were first authorized by the legislature in 1955.

Water storage tank – A water storage facility consisting of a cylindrical tank that has a base elevation at the existing ground surface. Storage facilities provide sufficient water volume to meet peak hour water demands.

Water storage tower – An elevated water storage facility (also referred to as a water tower) that supports a water storage tank with a base elevation above the existing ground surface to provide sufficient pressure to the water distribution system, and to provide emergency storage for fire protection.

Water supply improvement options – A reasonable range of options that could improve drinking water quality and quantity, including both centralized and decentralized systems, which are evaluated against a set of screening criteria in this Conceptual Plan to determine their relevance to the individual communities in the East Metropolitan Area.

Water supply system – A system for the treatment, transmission, storage, and distribution of water from source to consumers (e.g., homes, commercial establishments, industry, irrigation facilities, and public agencies for water).

Work groups – Three groups formed by the Co-Trustees to help identify and recommend priorities and projects for Settlement funding: the Government and 3M Working Group, the Citizen-Business Group, and the Drinking Water Supply Technical Subgroup.

Acronyms and abbreviations

AACE	Association for the Advancement of Cost Engineering
Abt	Abt Associates
ADD	average daily demand
CAD	computer-aided design
Conceptual Plan	Conceptual Drinking Water Supply Plan
CSM	conceptual site model
DNR	Minnesota Department of Natural Resources
EPA	United States Environmental Protection Agency
GAC	granular activated carbon
GIS	geographic information system
Grant	3M Grant for Water Quality and Sustainability Fund
GWTP	groundwater treatment plant
HAL	EPA Health Advisory Level
HBV	health-based value
HI	health index (used interchangeably with HRI)
HRI	health risk index (used interchangeably with HI)
HRL	health risk limit
IX	ion exchange
MCES	Metropolitan Council Environmental Services
MCL	maximum contaminant level
MDH	Minnesota Department of Health
MERLA	Minnesota Environmental Response and Liability Act
mgd	million gallons per day
MGS	Minnesota Geological Survey
MPCA	Minnesota Pollution Control Agency
N/A	not applicable
NPS	National Park Service
O&M	operations and maintenance
PFAS	per- and polyfluoroalkyl substances
PFBA	perfluorobutanoic acid
PFBS	perfluorobutane sulfonate
PFHxS	perfluorohexane sulfonate
PFOA	perfluorooctanoic acid
PFOS	perfluorooctane sulfonate
POETS	point-of-entry treatment system
POUT	point-of-use treatment
QA/QC	quality assurance/quality control
Settlement	2018 Agreement and Order
SPRWS	St. Paul Regional Water Services
State	State of Minnesota
Subgroup 1	Drinking Water Supply Technical Subgroup
SWBCA	Special Well Boring and Construction Area

SWTP	surface water treatment plant
3M	3M Company
2007 Consent Order	2007 Settlement Agreement and Consent Order
TCE	trichloroethylene
VOC	volatile organic compound
Wood	Wood Environment & Infrastructure Solutions, Inc.

Appendix E. Updated recommended options

E.1 Updated recommended options overview

This appendix provides the detailed modeling and costing results for the updated recommended Options 1, 2, and 3. After the Co-Trustees of the Settlement received feedback through the public comment period of September through December 2020 on the draft Conceptual Drinking Water Supply Plan (Conceptual Plan), modifications were made to the recommended options (Appendix H), and costs were updated. The updated recommended Options 1, 2, and 3 presented in this appendix have built upon the recommended Options 1, 2, and 3 discussed in Chapter 7 and in Appendix H in Section H.4, Recommended Options. Details of the updated recommended Options 1, 2, and 3 are provided in Sections E.2–E.4; the options are summarized as follows and in Table E.1:

- Recommended Option 1 – Community-specific improvements for a treatment threshold of Health index (HI) ≥ 0.5 (Section E.2)
- Recommended Option 2 – Community-specific improvements for a treatment threshold of HI ≥0.3 (Section E.3)
- Recommended Option 3 – Community-specific improvements different from Option 1 for the communities of Lake Elmo and Oakdale for a treatment threshold of HI ≥0.5 (Section E.4)

Table E.1. Recommended Options 1–3 summary.

Community served	Recommended Option 1 components (Section E.2)	Recommended Option 2 components (Section E.3)	Recommended Option 3 components (Section E.4)
Woodbury	1 WTP (11,600 gpm)	1 WTP (15,600 gpm)	1 WTP (11,600 gpm)
Lake Elmo	Capital for 2,700 gpm supplied by Woodbury; O&M for 2,000 gpm WTP in Lake Elmo	2,700 gpm to be supplied by Woodbury	Supplied by SPRWS via interconnects with Oakdale
Oakdale	1 WTP (expand existing), 2 new wells	1 WTP (expand existing), 2 new wells	Supplied by SPRWS
W. Lakeland – Municipal System	PWS for 80% Township, 2 wells, 1 WTP, 8" & 12" lines	PWS for 80% Township, 2 wells, 1 WTP, 8" & 12" lines	PWS for 80% Township, 2 wells, 1 WTP, 8" & 12" lines
W. Lakeland – POETSs	POETSs only	POETSs only	POETSs only
Cottage Grove	2 WTPs (7,100 gpm; 3,200 gpm), 1 new well	2 WTPs (8,600 gpm; 3,200 gpm), 1 new well	2 WTPs (7,100 gpm; 3,200 gpm), 1 new well
Newport	Interconnects with Woodbury and Cottage Grove	Interconnects with Woodbury and Cottage Grove	Interconnects with Woodbury and Cottage Grove
St. Paul Park	2,200 gpm WTP	2,100 gpm WTP	2,200 gpm WTP
Lakeland, Lakeland Shores, Lake St. Croix Beach	225 service connections	225 service connections	225 service connections
Prairie Island Indian Community	300 gpm WTP, PWS with 8" lines and tank	300 gpm WTP, PWS with 8" lines and tank	300 gpm WTP, PWS with 8" lines and tank

Community served	Recommended Option 1 components (Section E.2)	Recommended Option 2 components (Section E.3)	Recommended Option 3 components (Section E.4)
Maplewood	Water main extension for 35 connections	Water main extension for 35 connections	Water main extension for 35 connections
Grey Cloud Island	POETSs only	POETSs only	POETSs only
Denmark	POETSs only	POETSs only	POETSs only
Afton	POETSs only	POETSs only	POETSs only

Acronyms:
WTP = water treatment plant
gpm = gallon per minute
O&M + operation and maintenance
POETS = point-of-entry treatment system; plural is “POETSs”
PWS = public water system
SPRWS = Saint Paul Regional Water Service

E.1.1 List of figures

Table E.2 includes a list of figures to support the discussion of the three recommended options and will be referenced throughout this appendix.

Table E.2. List of figures accompanying Appendix E.

Figure name	Description
Figure E.1 Updated recommended Options 1 and 3 non-municipal well treatment map for HI ≥ 0.5	Regional map illustrating which non-municipal wells will receive a POETS or be connected to the distribution system according to the HI ≥ 0.5 threshold. Shows West Lakeland Township POETSs alternative.
Figure E.2a Updated recommended Option 1 municipal infrastructure improvements map for HI ≥ 0.5 (Lake Elmo interconnect)	Regional map illustrating municipal wells and infrastructure improvements according to the HI ≥ 0.5 threshold and showing Lake Elmo with an interconnect with Woodbury. Shows West Lakeland Township municipal system alternative.
Figure E.2b Updated recommended Option 1 municipal infrastructure improvements map for HI ≥ 0.5 (Lake Elmo autonomous)	Regional map illustrating municipal wells and infrastructure improvements according to the HI ≥ 0.5 threshold and showing Lake Elmo with an autonomous water supply. Shows West Lakeland Township municipal system alternative.
Figure E.3 Updated recommended Option 2 non-municipal well treatment map for HI ≥ 0.3	Regional map illustrating which non-municipal wells will receive a POETS or be connected to the distribution system according to the HI ≥ 0.3 threshold. Shows West Lakeland Township POETSs alternative.
Figure E.4a Updated recommended Option 2 municipal infrastructure improvements map for HI ≥ 0.3 (Lake Elmo interconnect)	Regional map illustrating municipal wells and infrastructure improvements according to the HI ≥ 0.3 threshold and showing Lake Elmo with an interconnect with Woodbury. Shows West Lakeland Township municipal system alternative.
Figure E.4b Updated recommended Option 2 municipal infrastructure improvements map for HI ≥ 0.3 (Lake Elmo autonomous)	Regional map illustrating municipal wells and infrastructure improvements according to the HI ≥ 0.3 threshold and showing Lake Elmo with an autonomous water supply. Shows West Lakeland Township municipal system alternative.
Figure E.5 Updated recommended Option 3 municipal infrastructure improvements map for HI ≥ 0.5	Regional map illustrating municipal wells and infrastructure improvements according to the HI ≥ 0.5 threshold, with SPRWS replacing the water supply for Lake Elmo and Oakdale. Shows West Lakeland Township municipal system alternative.

Figure name	Description
Figure E.6a Simulated drawdown for Iteration 1 (Lake Elmo interconnect) under dry conditions in the Prairie du Chien aquifer[1]	Regional map showing the groundwater model drawdown analysis results in the Prairie du Chien aquifer for Iteration 1 (Lake Elmo interconnect as described in Section E.2.5) under dry conditions.
Figure E.6b Simulated drawdown for Iteration 2 (Lake Elmo autonomous) under dry conditions in the Prairie du Chien aquifer[1]	Regional map showing the groundwater model drawdown analysis results in the Prairie du Chien aquifer for Iteration 2 (Lake Elmo autonomous as described in Section E.2.5) under dry conditions.
Figure E.6c Simulated drawdown for recommended Option 3 under dry conditions in the Prairie du Chien aquifer[1]	Regional map showing the groundwater model drawdown analysis results in the Prairie du Chien aquifer for recommended Option 3 (Lake Elmo and Oakdale served by SPRWS) under dry conditions.
Figure E.7a Simulated drawdown for Iteration 1 (Lake Elmo interconnect) under dry conditions in the Jordan Sandstone aquifer[1]	Regional map showing the groundwater model drawdown analysis results in the Jordan Sandstone aquifer for Iteration 1 (Lake Elmo interconnect as described in Section E.2.5) under dry conditions.
Figure E.7b Simulated drawdown for Iteration 2 (Lake Elmo autonomous) under dry conditions in the Jordan Sandstone aquifer[1]	Regional map showing the groundwater model drawdown analysis results in the Jordan Sandstone aquifer for Iteration 2 (Lake Elmo autonomous as described in Section E.2.5) under dry conditions.
Figure E.7c Simulated drawdown for recommended Option 3 under dry conditions in the Jordan Sandstone aquifer[1]	Regional map showing the groundwater model drawdown analysis results in the Jordan Sandstone aquifer for recommended Option 3 (Lake Elmo and Oakdale served by SPRWS) under dry conditions.
Figure E.8a Simulated drawdown for Iteration 1 (Lake Elmo interconnect) under wet conditions in the Prairie du Chien aquifer[1]	Regional map showing the groundwater model drawdown analysis results in the Prairie du Chien aquifer for Iteration 1 (Lake Elmo interconnect as described in Section E.2.5) under wet conditions.
Figure E.8b Simulated drawdown for Iteration 2 (Lake Elmo autonomous) under wet conditions in the Prairie du Chien aquifer[1]	Regional map showing the groundwater model drawdown analysis results in the Prairie du Chien aquifer for Iteration 2 (Lake Elmo autonomous as described in Section E.2.5) under wet conditions.
Figure E.8c Simulated drawdown for recommended Option 3 under wet conditions in the Prairie du Chien aquifer[1]	Regional map showing the groundwater model drawdown analysis results in the Prairie du Chien aquifer for recommended Option 3 (Lake Elmo and Oakdale served by SPRWS) under wet conditions.
Figure E.9a Simulated drawdown for Iteration 1 (Lake Elmo interconnect) under wet conditions in the Jordan Sandstone aquifer[1]	Regional map showing the groundwater model drawdown analysis results in the Jordan Sandstone aquifer for Iteration 1 (Lake Elmo interconnect as described in Section E.2.5) under wet conditions.
Figure E.9b Simulated drawdown for Iteration 2 (Lake Elmo autonomous) under wet conditions in the Jordan Sandstone aquifer[1]	Regional map showing the groundwater model drawdown analysis results in the Jordan Sandstone aquifer for Iteration 2 (Lake Elmo autonomous as described in Section E.2.5) under wet conditions.
Figure E.9c Simulated drawdown for recommended Option 3 under wet conditions in the Jordan Sandstone aquifer[1]	Regional map showing the groundwater model drawdown analysis results in the Jordan Sandstone aquifer for recommended Option 3 (Lake Elmo and Oakdale served by SPRWS) under wet conditions.

Figure name	Description
Figure E.10 Particle tracking for Iteration 1 under dry conditions[1]	Regional map showing the groundwater model particle tracking analysis results for Iteration 1 (Lake Elmo interconnect as described in Section E.2.5) under dry conditions.
Figure E.11 Particle tracking for Iteration 1 under wet conditions[1]	Regional map showing the groundwater model particle tracking analysis results for Iteration 1 (Lake Elmo interconnect as described in Section E.2.5) under wet conditions.

Note:

1. Figures E.6a/b–E.9a/b apply to both recommended Options 1 and 2, depending on which iteration is considered for Lake Elmo water supply. Figures E.6c–E.9c apply only to recommended Option 3. Note that the groundwater modeling drawdown analyses in Figures E.6a/b/c–E.9a/b/c are not tied to costs and are used to assess simulated groundwater conditions for conceptual planning purposes only.

E.1.2 Tables

Table E.3 below indicates the tables included in discussion of the recommended options in Section E.2–E.4. In addition, background tables are provided in the Section E.1 (Tables E.1–E.6). Section E.5 Table E.85 lists the municipal wells requiring treatment in updated recommended Options 1–3, and Section E.6 Table E.86 provides the total number of existing and proposed POETSs for each community.

Table E.3. List of tables accompanying Appendix E.

Section	Groundwater modeling pumping rates	Average Daily Demand (ADD)	Drawdown analyses	Base capital and O&M costs	Particle tracking capital and O&M costs	Pretreatment capital and O&M costs	Summary Table
Option 1:							
E.2.1 Afton	NA	NA	NA	Table E.7	Table E.8	NA	NA
E.2.2 Cottage Grove	Table E.9	Table E.10	Table E.11	Table E.12	Table E.13	Table E.14	NA
E.2.3 Denmark	NA	NA	NA	Table E.15	NA	NA	NA
E.2.4 Grey Cloud Island	NA	NA	NA	Table E.16	Table E.17	NA	NA
E.2.5.1 Lake Elmo/Woodbury interconnect	NA	Table E.18	Table E.19	Table E.20	Table E.21	NA	NA
E.2.5.2 Lake Elmo – autonomous	Table E.22	Table E.23	Table E.24	Table E.25	Table E.26	Table E.27	NA
E.2.6 Lakeland, Lakeland Shores, and Lake St. Croix Beach	Table E.28	NA	NA	Table E.30	Table E.31	NA	NA
E.2.7 Maplewood	NA	NA	NA	Table E.32	NA	NA	NA
E.2.8 Newport	Table E.33	NA	NA	Table E.34	Table E.35	NA	NA
E.2.9 Oakdale	Table E.36	Table E.37	Table E.38	Table E.39	Table E.40	Table E.41	NA
E.2.10 Prairie Island Indian Community	NA	Table E.42	Table E.43	Table E.44	NA	Table E.45	NA
E.2.11 St. Paul Park	Table E.46	NA	NA	Table E.47	Table E.48	Table E.49	NA

Section	Groundwater modeling pumping rates	Average Daily Demand (ADD)	Drawdown analyses	Base capital and O&M costs	Particle tracking capital and O&M costs	Pretreatment capital and O&M costs	Summary Table
E.2.12.1 West Lakeland – POETSs	NA	NA	NA	Table E.50	Table E.51	NA	NA
E.2.12.2 West Lakeland – Municipal System	NA	NA	Table E.52	Table E.53	Table E.54	Table E.55	NA
E.2.13 Woodbury	Table E.56	Table E.57/ Table E.59	Table E.58/ Table E.60	Table E.61	Table E.62	Table E.63	NA
E.2.14 Option 1 Summary	NA	NA	NA	NA	NA	NA	Table E.64
Option 2:							
E.3.–E.3.7 Cottage Grove	NA	NA	NA	Table E.65	Table E.69	Table E.72	NA
E.3.5–E.3.7 Woodbury	NA	NA	NA	Table E.66	Table E.70	Table E.73	NA
E.3.5–E.3.7 Lake Elmo – Woodbury interconnect	NA	NA	NA	Table E.67	Table E.71	Table E.74	NA
E.3.5–E.3.7 Lake Elmo – Autonomous	NA	NA	NA	Table E.68	Table E.71	Table E.75	NA
E.3.8 Option 2 Summary	NA	NA	NA	NA	NA	NA	Table E.76
Option 3:							
E.4.5 Oakdale/Lake Elmo – SPRWS	NA	Table E.77	NA	Table E.81	NA	NA	NA
E.4.5 Oakdale	NA	NA	NA	Table E.82	NA	NA	NA
E.4.5 Lake Elmo	NA	NA	NA	Table E.83	NA	NA	NA
E.4.8 Option 3 Summary	NA	NA	NA	NA	NA	NA	Table E.84

E.1.3 Assumptions/considerations

Any of the three recommended options would provide safe and sustainable drinking water across the East Metropolitan Area. The options consist of conceptual projects ideas submitted by the government units through the conceptual project submittal process (see the Conceptual Project list in Appendix D) and subsequent discussions with Co-Trustees. With a few exceptions, the water supply improvements (also referred to as improvements) described in Section E.2–E.4 are consistent with each community's existing long-term water supply plans and Conceptual Plan efforts.

E.1.3.1 Treatment thresholds

The updated recommended options costs were developed under two conditions used to identify impacted wells that would receive treatment – generally those with an HI value greater than or equal to (≥) 0.5 would receive treatment under Options 1 and 3, and those with an HI value greater than or equal to 0.3 would receive treatment under Option 2. As defined in Chapter 6, the current HI value calculation takes into account the five per- and polyfluoroalkyl substances (PFAS) constituents – perfluorobutane sulfonate (PFBS), perfluorobutanoic acid (PFBA), perfluorohexane sulfonate (PFHxS), perfluorooctanesulfonic acid (PFOS) and perfluorooctanoic acid (PFOA). The HI values used for private/non-municipal wells in the updated recommended options in Appendix E represent Minnesota Department of Health (MDH) private well sampling conducted as of October 2020. Municipal well HI values presented in Appendix E Section E.2 were used to determine the need for treatment and represent MDH municipal well sampling conducted through the first quarter of 2021. These values are rolling averages, which are calculated based on the last four quarters of sampling data each time MDH collects new data. Note that these HI values may differ from those presented in other parts of the Conceptual Plan depending on when those parts were completed during the Conceptual Plan development.

The thresholds of HI ≥ 0.5 and HI ≥ 0.3 were determined based on previous analyses completed and provided in Appendix H. In those analyses, it was determined that costs were optimized around an HI threshold of 0.5, and that a threshold of lower than 0.3 was more representative of treating nearly all wells with background levels of PFAS based on the current PFAS constituents that are considered in the calculation of the HI defined in Chapter 6, Section 6.1.5. Treatment for municipal and non-municipal wells is determined by the respective thresholds in the recommended options, except where otherwise noted in Sections E.2–E.4.

E.1.3.2 Modeling analyses

The viability of the water supply improvements, treatment, and distribution within each recommended option was analyzed, using the East Metropolitan Area regional three-dimensional numerical groundwater flow model, developed by the Minnesota Pollution Control Agency's consultant, Wood, and referred to as the East Metro Model (EMM), as well as a combined drinking water distribution (hydraulic) model, also developed for the Conceptual Plan. Chapter 2 includes assumptions regarding the development and calibration of the groundwater and hydraulic models specific to each community and their water demands. Results from these analyses are presented in the community-specific discussions of Sections E.2–E.4.

The models were used to estimate costs presented in this appendix by optimizing the number of wells, their locations, capacities, and depths (groundwater model); estimating areas of potential future PFAS contamination (groundwater model); estimating lengths and diameters of pipe (hydraulic model); and estimating the quantity and size of pumps and valves (hydraulic model). The treatment threshold HI is the primary difference between the three options, and affects which drinking water wells receive treatment. However, the municipal well pumping rates and potential future movement of PFAS are not affected by the HI threshold, and are assessed using the groundwater modeling analyses. The groundwater modeling does not change across the options for the most part, with the exception of Option 3 for Lake Elmo and Oakdale as described further in Section E.4. In contrast, the hydraulic modeling analyses were revised from one option to the next due to drinking water improvements determined based on the HI thresholds.

The following section provides further background information that is common throughout the groundwater modeling analyses discussed in Sections E.2–E.4 as a supplement to discussion in Chapter 2 and Appendix C. Hydraulic modeling analyses are described on a community-specific basis within Sections E.2–E.4; refer to Chapter 2 for the main details of the hydraulic modeling conducted.

E.1.3.2.1 Groundwater modeling analyses

The EMM was constructed using the MODFLOW-USG code developed and maintained by the United States Geological Survey. The EMM was calibrated to current conditions assuming steady state, and was then used in combination with the advective particle tracking code mod-PATH3DU to simulate and predict the potential groundwater quantity and (to a limited extent) quality changes associated with the Conceptual Plan projects, including assessment of the three recommended options. The simulated groundwater elevations from the calibration under current conditions served as a comparison for predictive simulations.. The PFAS transport using mod-PATH3DU is a simplistic and in some ways a conservative approach, assessing transport based on advective flow only, and not considering the many factors that can control the fate and transport of PFAS, such as sorption. The following describes how the EMM groundwater modeling analyses were used to assess the water supply improvements identified in the recommended options. Further description of the background hydrogeologic information as well as the numerical groundwater model development can be found in Appendices B and C, respectively.

Groundwater model: drawdown. Groundwater levels (quantity available) associated with increased pumping and the subsequent drawdown due to potential future community municipal water supply wells were evaluated under two different relative climate conditions: wet and dry. Figures E.6a–E.9c show the drawdown analyses results for the different pumping and climate conditions of the three recommended options.

Municipal well pumping conditions were simulated using the 2040 ADD of each community spread over their respective municipal wells proportionate to their respective pumping rates. (If an individual municipal well's maximum capacity made up 15% of a community's overall pumping capacity, that well would be assigned 15% of the overall ADD.) Note that the ADDs discussed in the groundwater modeling subsections of E.2 through E.4 are not the same as the maximum daily demands (MDDs) discussed in hydraulic modeling subsections.

The EMM was used to determine drawdown due to potential future pumping conditions as compared to the regulatory guidance threshold provided by the Department of Natural Resources (DNR), under forecasted increased municipal supply well demand and dry conditions. If pumping conditions do not exceed this threshold they are considered within safe yield (i.e., not projected to cause unacceptable effects on the aquifer, as described below).

Safe yield thresholds were provided by the DNR as written guidance for assessing the risk of municipal well yields exceeding aquifer capacity. A 50% available head threshold was designated by the DNR guidance as a warning check that drawdown needs to be assessed further. The available head is the difference between the "static" groundwater elevation (the average 2016–2018 simulated head from the calibrated steady-state groundwater flow model) and the top elevation of the aquifer. The threshold is applied to the formation in which the well is screened as well as confined overlying aquifers. (For example, a well producing from the Jordan Sandstone Aquifer requires a threshold assessment for the Jordan Sandstone Aquifer and the overlying Prairie du Chien Aquifer if present and confined.) If the simulated drawdown exceeds the 50% threshold, further analysis would be warranted.

The DNR guidance on safe yield thresholds was used as an indication of aquifer sustainability under projected future municipal water supply demands. This drawdown analysis was performed for the updated recommended options discussed herein. Using the numerical EMM under steady state, and the threshold guidance provided by the DNR, simulated head at the existing and proposed water supply well locations was evaluated to determine whether drawdown exceeds the conservative 50% threshold and whether proposed wells need further evaluation. However, this threshold was not exceeded for analyses presented in Appendix E.

The calibrated EMM used for the Conceptual Plan evaluation of drawdown impacts is based on current conditions. It represents a relatively wet set of climate conditions that are observed in Minnesota, including higher precipitation rates and warmer temperatures.[1] The currently modeled wet climate condition observed in Minnesota is predicted to continue over the next century, with intervening dry periods.[1] Since the calibrated steady-state model represents relatively wet conditions, model recharge and pumping rates at non-municipal wells were not modified for the drawdown evaluation under wet conditions. Simulated pumping rates were only adjusted at municipal wells to account for 2040 demands.

Model parameters were modified for the dry climate setting to evaluate potential future drought conditions as a worst-case scenario. Model recharge was reduced by 66% of the current recharge rate based on modeling by the DNR using the Soil Water Balance model over a drier time period of 2006 to 2009 that approaches drought-like conditions. Additionally, ADD rates for the municipal water supply wells were increased for the dry condition by multiplying the current condition water supply well rates by a percentage of approximately 15–30%, based on the ratio of maximum per capita demand for the water supply wells over average per capita demand from years 2005–2015. Pumping rates at irrigation wells were also increased for the dry condition simulations, by taking the maximum annual volume reported over a 20-year period (1988–2018).

The results for all options under dry conditions indicate that drawdown does not exceed the 50% available safe head yield threshold in the Jordan Sandstone nor the Prairie du Chien aquifers, where the aquifers are present and confined. The results indicated that no subsequent transient simulations were necessary to assess the maximum 75% safe yield threshold, and the recommended options were deemed acceptable from a water availability (quantity) perspective. The simulated drawdown as a percentage of available head for the Jordan aquifer ranges from 0 to 37%, and for the Prairie du Chien aquifer from 0 to 48%. The greatest potential impacts predicted by the model are associated with proposed new wells for Woodbury. Other simulated community wells (proposed or existing) show drawdown as a percentage of available head less than 25%.

Groundwater model: Particle tracking. Forward particle tracking using the EMM, as shown in Figures E.10 and E.11 for one iteration, was conducted for the updated recommended options to simulate water particle movement over time. The model simulation helped estimate future areas that may become impacted by PFAS contamination. This provided the basis for contingency funding from the Settlement to be set aside for the future as needed.

To perform the simulation, particles were placed at locations of known PFAS sources and areas where available groundwater sampling data indicates HI values are greater than one, which is the current value that triggers a drinking water health advisory from the MDH. The particles were then allowed to track forward in time to the year 2040 under dry and wet climate conditions based on advective flow from the flow model results. Simulated particles in the model followed the direction of groundwater flow, which is influenced by the different pumping rates of high-capacity supply wells including municipal supply wells, and changes in groundwater recharge rates for the different climate conditions. However, the

1. MDH, 2015. Minnesota Climate & Health Profile Report. Minnesota Department of Health. St. Paul, MN. February 2015. https://www.health.state.mn.us/communities/environment/climate/docs/mnprofile2015.pdf

model does not estimate PFAS *concentrations* in the future. Therefore, conservative assumptions were made in order to estimate costs associated with the future movement of PFAS, as discussed further in Section E.1.3.3.

In order to assign potential future costs, resulting particle tracks (lines) from the EMM for all three recommended options, pumping Iterations, and climate conditions were plotted on a map. Boundaries were then drawn to include the extent of all particle tracks. These boundaries are considered to be projected areas potentially impacted by PFAS by year 2040, as shown on Figures E.1–E.5, and are consistent across all three recommended options.

E.1.3.3 Updated recommended option cost considerations

Costs presented in this appendix include only those that are considered to be Settlement-eligible (i.e., PFAS-related) as described in Chapter 6 as well as Chapter 9, and do not include every aspect associated with each water supply improvement, as Settlement funds will not cover some costs. Costs for capital improvements or O&M that are not needed as a direct result of PFAS contamination are not covered.

The cost estimates also represent an approximation, or an early-stage opinion of the probable costs, that is consistent with a conceptual plan. The estimate includes uncertainty because only a percentage of the overall design effort has been completed. Uncertainty would be decreased in later stages of the design process. Given the level of engineering effort and the cost estimation methodology applied, the cost estimate should be considered as Association for the Advancement of Cost Engineering Class 5. Accuracy for a Class 5 cost estimate is application-specific but is considered to be within the range of +50% to -30% for the costs discussed herein.

There also may be regulatory or permitting requirements that were unknown or not included as part of the estimates, such as National Environmental Protection Act requirements. It is important to note that while some guidelines were used for general Settlement funding determination, case-by-case considerations were also taken into account.

Three sets of costs are presented for the updated recommended Options 1–3 in Sections E.2–E.4:

- **Base costs** include eligible capital and O&M costs. The calculation of these costs does not consider results of the groundwater model particle tracking analysis, which helped identify potentially impacted areas out to the year 2040 and is further described below. The base costs were used to establish minimum funding priorities as part of the Settlement fund allocations described in Chapters 8 and 9.
- **Particle tracking costs** include potential future costs associated with providing treatment or replacing private wells with a connection to the municipal distribution system, as well as treating municipal wells that are located within projected areas potentially impacted by PFAS by year 2040 as determined through the groundwater particle tracking analysis. Particle tracking analyses use the EMM estimated potential areas of groundwater movement over the next 20 years. Since a true fate and transport analysis has not been performed at this time, the concentration of PFAS in these areas is unknown. As a conservative approach, particle tracking costs were therefore assembled under the assumption that all wells designated for potable use that are located within these projected areas would exceed the respective HI treatment thresholds used under each recommended option. These particle tracking costs were developed separately from the base costs and are considered part of a contingency fund for future potential PFAS movement as part of the Settlement fund allocations described in Chapter 9. The specific potential particle tracking cost implications as they relate to each community are further discussed in Sections E.2–E.4.

- **Pretreatment costs** include potential additional costs associated with capital improvements and O&M for the pretreatment of metals, such as iron and manganese. These costs were not previously included in estimates in Appendix H. Information from the ion exchange (IX) treatment pilot study being conducted in Cottage Grove as part of the Settlement-funded projects indicated that iron and manganese concentrations in groundwater could present operational challenges with either granular activated carbon (GAC) or IX treatment, due to fouling of media. In systems with elevated iron and manganese, removing these constituents prior to the PFAS treatment can extend the life of the PFAS treatment media. Pretreatment costs were estimated for all communities where PFAS treatment is proposed. However, not all communities are anticipated to need to implement pretreatment as part of the Conceptual Plan, and pretreatment for either GAC or IX treatment systems should be evaluated against alternatives such as more-frequent PFAS treatment media change-outs. Therefore, this set of costs is considered contingent on a demonstrated cost benefit by way of additional testing and detailed and site-specific treatment designs and analyses. O&M costs for pretreatment are not included in the final Plan because pretreatment will be implemented only if it reduces O&M costs for PFAS treatment. Further discussion of how the pretreatment costs were calculated is provided in Appendix F, Section F.7, and Chapter 9 discusses the Conceptual Plan costs.

The cost estimates presented for the updated recommended Options 1–3 include several common elements of capital and O&M, as described in Chapter 8 and 9 and further below. Unit costs used in these estimates are presented in Appendix F, Section F.1.

Drinking water treatment and supply infrastructure costs include capital and O&M costs based on the communities' projected 2040 demands. Water treatment and supply infrastructure includes treatment facilities, distribution systems, home connections, and POETSs. A standard 25% contingency for engineering projects and 15% estimate for professional services, such as planning, permitting, design, and construction management, is applied to the total estimated capital costs. Elements of the drinking water infrastructure costs are described below, and those that were updated from the previous recommended options presented in Appendix H have been indicated in the description.

- **Water supply sources:** Under the updated recommended options, each community would remain autonomous and continue to be supplied by groundwater, with a few exceptions where the alternative – to establish interconnects, where potentially needed, between neighboring communities – was explored. Residents and businesses would be served by their local municipal water system where feasible, and those homes with private wells that could not feasibly connect to a municipal water system would continue to be served by their private groundwater wells, with treatment as determined by the treatment thresholds. However, there are a few communities that do not remain autonomous under some future and potential conditions. Newport (Options 1–3), Lake Elmo (Options 1–3), and Oakdale (Option 3) cost estimates include alternative water supplies from neighboring communities, as part of the updated recommended options described further in Sections E.2–E.4.
- **Ineligible distribution system infrastructure:** Costs for tanks, booster pump stations and pressure-reducing/sustaining valves (PRVs) were generally not included for those communities with existing distribution systems, as they had been previously in Appendix H, because they were either necessary to accommodate growth (i.e., not Settlement-eligible) or they would be covered by funds collected through city fees for connections to the existing distribution system. The implications of city fees and service lateral connections are discussed later in this section. Costs for these individual infrastructure components were included only in cases where a new

municipal water treatment facility and distribution system was proposed. These communities include Prairie Island Indian Community (PIIC) and West Lakeland Township.

- **Individual community considerations:** Additional considerations were made for the following communities that differ from the recommended options presented in Appendix H:
  - **West Lakeland:** Previously recommended options included costs to implement a new public drinking water supply system, and to seal private wells for West Lakeland Township residents that get connected to the new supply system. The updated recommended options include two sets of costs: one with costs to implement a new municipal drinking water supply system and seal private wells; and one with costs for residents to receive a POETS for their private drinking water wells where the treatment threshold applies. Each set of costs and related analyses is further described in Sections E.2-E.4.
  - **Newport:** Previously recommended options included costs for one interconnect for Newport in order to support their public water supply system in the future should it become necessary due to PFAS impacts. Should Newport need to rely on alternative methods for public water supply in the future, the city would prefer to seal their two municipal wells and receive water via one or both of these interconnects as opposed to implementing treatment. Further discussion between the city and the Co-Trustees led to the decision to also include costs for a second interconnect between Newport and Cottage Grove in order to provide resiliency and an alternative water supply for the city.
- **Neighborhood connections:** Changes were made to the number of connections to an existing municipal water supply system included in the Conceptual Plan between the initial recommended options (Appendix H) and updated recommended options (Appendix E). Since the draft Conceptual Plan release, a number of communities submitted requests, and received funding, for completing some of these connections in an expedited timeline (prior to the final Conceptual Plan). In addition, the previous overall number of connections also included homes in West Lakeland as part of the potential new public water system. As a result of some connections already being funded and the two alternatives for West Lakeland, a lower number of connections overall were considered for each option.

  Table E.4 summarizes the neighborhood and individual home connections considered in recommended Options 1, 2, and 3 for communities that have an existing municipal water supply system. The numbers of homes presented are estimates based on the Minnesota Well Index (MWI), and in some cases, aerial imagery that has not been field verified. For each neighborhood or individual home, the following data is presented:
  - Connection status: Whether the neighborhood has been approved under an expedited project to be connected (Expedited Project), is proposed to be connected under the recommended options (Yes), or has potential to be connected as a result of treatment thresholds as well as the groundwater particle tracking analysis and future sampling (TBD)
  - Number of existing homes with wells
  - Number of homes with wells that fall into the HI categories included
  - Number of existing homes/wells with a POETS currently installed
  - Number of homes/wells that are proposed to receive a POETS in each option

  Other factors considered for each neighborhood that are not shown in the table include the proximity to existing PFAS source areas and the neighborhood's proximity to the public water system, and the number of years before the cost of POETSs exceeds the cost of the connection. There are six whole neighborhoods with a "Yes" status, indicating they are to be connected as part of the three recommended options. These neighborhoods were selected based on feedback from the communities; sampling data; proximity to source areas where there would be more potential for additional homes to be impacted; and the capital costs to connect the neighborhood as compared to capital and O&M costs for POETSs over a period more than 20 years.

The following describes the guidelines used for selecting homes to be connected and/or homes that receive a POETS:

- **"Yes" neighborhoods are included in the base costs**. No additional whole neighborhood connections are included in any costs.
- **If a home has a line running in front of it and meets or exceeds the HI threshold**, the cost to connect that home is included in the base costs.
- If a home has a line running in front of it **and does not meet or exceed the HI threshold**, but is within the particle tracking areas, the cost to connect it is included in the particle tracking costs.
- Homes in neighborhoods that **do not already have lines running in front of them:**
    - include a POETS in base costs if their well meets the HI threshold, and
    - include a POETS in particle tracking costs if they are within a particle tracking area.

Costs for connecting a neighborhood would include the associated distribution lines, service laterals, and city connection fees, which will be discussed later in this section. For an individual home, the cost of the service lateral and city fee would be included. The numbers of homes included are estimates based on wells present in the MWI and MDH sampling data as of October 2020. None of the cost estimates included neighborhoods or individual homes approved for connection to the existing distribution system under expedited project funding.

Table E.4. Neighborhoods and individual homes considered for connection to municipal water distribution systems under the recommended options.

Neighborhoods or areas	Neighborhood or Individual Connection	Connection Status (Exp. Proj, Yes, TBD)[3]	No. of Existing Homes	No. of Existing Homes at HI values:		No. of Wells with POETSs	Options 1 and 3		Option 2	
				≥0.3, <0.5	≥0.5		No. of Wells receiving POETSs	No. of s Connected	No. of Wells receiving POETSs	No. of Wells Connected
Cottage Grove Neighborhoods and Individual Homes										
River Acres	Neighborhood	Expedited Project	123							
Granada Ave	Neighborhood	Expedited Project	36							
Goodview Ave	Neighborhood	Yes	43	7	18	4	0	43	0	43
Harkness Ave	Neighborhood	Yes	9	1	4	2	0	9	0	9
Point Douglas Rd	Neighborhood	Yes	15	0	11	10	0	15	0	15
Impacted Individual Homes	Individual	TBD	142	23	119	62	49	8	70	10
Lake Elmo Neighborhoods and Individual Homes										
Stonegate	Neighborhood	Expedited Project	65							
Hamlet on Sunfish Lake	Neighborhood	Expedited Project	41							
31st St	Neighborhood	Expedited Project	7							
Parkview Estates/ Cardinal Ridge and Cardinal View	Neighborhood	Expedited Project	62							
Whistling Valley	Neighborhood	Expedited Project	37							
38th & 39 St.	Neighborhood	Expedited Project	49							
Torre Pines	Neighborhood	Expedited Project	23							
Tapestry extension	Neighborhood	Expedited Project	1							
Homestead	Neighborhood	Yes	18	2	8	6	0	18	0	18
20th Circle	Neighborhood	Yes	4	0	4	4	0	4	0	4
Packard/Eden Park	Neighborhood	Yes	64	7	23	12	0	64	0	64
Impacted Individual Homes	Individual	TBD	63	24	39	10	18	11	35	18

Neighborhoods or areas	Neighborhood or Individual Connection	Connection Status (Exp. Proj, Yes, TBD)[3]	No. of Existing Homes	No. of Existing Homes at HI values:		No. of Wells with POETSs	Options 1 and 3		Option 2	
				≥0.3, <0.5	≥0.5		No. of Wells receiving POETSs	No. of s Connected	No. of Wells receiving POETSs	No. of Wells Connected
Woodbury Neighborhoods and Individual Homes										
Impacted Individual Homes	Individual	TBD	57	25	32	2	18	5	48	7
Lakeland Neighborhoods and Individual Homes										
Impacted Individual Homes	Individual	TBD	47	30	17	1	0	29	0	46
Oakdale Neighborhoods and Individual Homes										
Impacted Individual Homes	Individual	TBD	4	4	0	0	0	4	0	4
St. Paul Park Neighborhoods and Individual Homes										
Impacted Individual Homes	Individual	TBD	11	11	0	5	0	6	0	6
Newport Neighborhoods and Individual Homes										
Impacted Individual Homes	Individual	TBD	35	9	26	0	6	3	32	3

NS = Not sampled

ND = Non-detect

1. If a home was assumed to have a well but was not included in the MWI it was counted as a "Not Sampled" or "NS" well.
2. It is assumed that nonresidential wells will be replaced on a 1:1 basis with a connection; however, there may be instances where multiple wells would be replaced with one connection during implementation.
3. Neighborhoods approved to be connected under expedited projects were not included in the costs estimates for the recommended options; neighborhoods with a “Yes” were proposed to be connected under the recommended options and included in the cost estimates; and neighborhoods or individual homes with a “TBD” were included in the costs resulting from the particle tracking analysis.

- **PFAS treatment** costs accounted for under the recommended options include GAC PFAS treatment technology. Costs for ion exchange (IX) treatment technology were compared in the previous analyses presented in Appendix H. However, GAC costs were used for budgeting, since GAC was found to have higher capital and O&M costs than IX and is currently the only approved technology to treat PFAS in drinking water in Minnesota. A comparison of drinking water treatment technologies is presented in Appendix F, Section F.3; municipal system and treatment plant capacity calculations are discussed in Appendix F, Section F.4; and calculations for capital and O&M costs for PFAS treatment are described in Appendix F, Sections F.5–F.6.
- **Stormwater** management costs included estimates to construct permanent stormwater infrastructure in conjunction with the capital infrastructure as part of local and regional stormwater management requirements. Such infrastructure requirements vary greatly, depending on site and design conditions, ranging from no requirements to infiltration ponds and new curb and gutter. While not included as part of the previous cost estimates in Appendix H, ongoing projects within the East Metro Area highlighted the potential need for stormwater infrastructure as a result of implementing the improvements under the recommended options. Current regulatory drivers include local watershed district requirements, as well as state-administered National Pollution Discharge Elimination System and municipal separate storm sewer system (MS4) permit requirements. Given the time needed to design and implement these projects, a changing regulatory environment may also contribute to increased stormwater compliance costs beyond what is typically estimated.

  Work group technical representatives as well as watershed districts and state agency representatives provided input on the approach for estimating stormwater-related costs for the Conceptual Plan. Ultimately, a community-specific approach was reached to estimate the costs as a percentage of capital infrastructure projects that are most likely to trigger stormwater management requirements. This is necessary due to variability and uncertainty of costs associated with stormwater requirements for infrastructure projects across the East Metropolitan Area. Table E.5 provides the percentages applied to capital costs per community, as well as examples of capital cost components to which the percentages were applied, and examples of components to which percentages were not applied to account for stormwater management costs. The percentages were determined based on actual project cost data, provided by city staff of Cottage Grove, Lake Elmo, and Woodbury, that had stormwater management costs included. Those percentages were then used for other communities based on similar jurisdictional requirements. The resulting cost estimates are believed to be conservative, and so the funding set aside for these stormwater considerations is expected to be used only as needed.

Table E.5. Percentages applied to capital costs to account for anticipated stormwater management costs.

<table>
<tr><th>Community/Project</th><th>Stormwater %</th><th rowspan="10">Percent applied to specific capital costs, such as:
• WTPs
• Pretreatment
• Interconnects
• Pump stations
• Transmission mains
• Distribution mains
• Tanks
• Buildings demo</th><th rowspan="10">Percent not applied to costs such as:
• Wells
• PRVs
• Laterals
• Land acquisition
• POETSs</th></tr>
<tr><td>Cottage Grove</td><td>5%</td></tr>
<tr><td>Lake Elmo</td><td>30%</td></tr>
<tr><td>Newport</td><td>5%</td></tr>
<tr><td>Oakdale</td><td>30%</td></tr>
<tr><td>Prairie Island Indian Community</td><td>30%</td></tr>
<tr><td>St. Paul Park</td><td>5%</td></tr>
<tr><td>West Lakeland</td><td>30%</td></tr>
<tr><td>Woodbury-Lake Elmo interconnect[1]</td><td>25-30%</td></tr>
<tr><td>Woodbury</td><td>25%</td></tr>
</table>

Note:

1. The alternative where Lake Elmo receives supplemental water supply via an interconnect with Woodbury includes improvements that would be constructed in both communities of Lake Elmo and Woodbury; therefore, percentages applied for stormwater management costs in this alternative are either 25% or 30%, depending on the specific improvement line item.

- **Service laterals and city fees:** During the process of updating the recommended options, communities with public water systems provided feedback on applicability of city fees associated with new home and/or neighborhood connections, also known as service laterals. These city fees are considered to be an additional cost above the cost to construct the service lateral connection. The types of fees include water meter charges, permits, water availability charges, connection fees, and meter costs. Since these fees are unique to each community in the amount charged and what the money is used for, there was concern that they would overlap with the capital costs previously included for infrastructure components such as tanks and new wells that the fees would be used to fund. Based on the feedback received, some of the fees cover current infrastructure costs incurred by the communities at the time of connection; however, some fees cover costs of estimated future infrastructure needs. Because it is difficult to determine the percent allocation of funds between current or future infrastructure projects and those required due to PFAS contamination, the cost estimates include all fees resulting from the neighborhood/home connections costs. In turn, we removed the costs for infrastructure, such as storage tanks and new public water supply wells, that were previously included on a prorated basis using the estimated demand from the additional home connections as a percentage of overall demand per community. This is because these types of infrastructure are anticipated to be funded via the city fees that are collected as part of the neighborhood/home connections. The resulting service lateral costs and city fees per connection for the communities with municipal systems are presented in Table E.6.

Table E.6. Service lateral costs and associated city fees per connection for each relevant community.

Community	Service Lateral Installation	Water Availability Charge (WAC)	Connection Fee	Meter Cost	Permit	Total Service Lateral Per Connection Cost
Lake Elmo	$8,100	$3,000	$1,000	$1,540		$13,640
Oakdale	$4,000	$550	$0	$400	$80	$5,030
Woodbury	$4,000	$1,122.5		$400		$5,523
Cottage Grove	$8,000	$1,006	$1,160	$354	$52	$10,572
West Lakeland	$8,100	$0	$1,000	$0		$9,100
St. Paul Park	$7,500	$885	$0	$525	$175	$9,085
Newport	$7,500	$1,050	$400	$350	$100	$9,400
Lakeland	$4,975	$0	$0	$425	$400	$5,800
PIIC	$3,500	$0	$0	$0	$0	$3,500

- **POETSs** are GAC media-based systems for a non-municipal supply well to treat PFAS contamination. These systems will be provided for drinking water wells that meet or exceed the given HI threshold under the recommended options discussed in this appendix and are not being connected to a municipal system. The number of wells included are estimates based on wells present in the MWI and MDH sampling data as of October 2020.

  POETSs have been provided for impacted, non-municipal wells prior to, as well as following, the Settlement being reached. For the purpose of estimating costs for the Conceptual Plan, POETSs installed since February 20, 2018 (date Settlement was reached), for both capital and O&M, are included in the cost estimates, provided that those wells will continue to use their POETS as a long-term solution for PFAS treatment. These costs are consistent with estimates included in in the Conceptual Plan, and include both the installation cost (capital) per POETS and O&M for the approximate number of years the POETS had been installed as of February 20, 2021. In the base cost summaries, these costs can be found just above “Total Capital” in the cost estimate tables, and are included in the total capital costs. No contingencies will be applied to these dollar amounts.

- The cost estimates include **O&M costs** for public treatment facilities, including media change-out, facility operation and maintenance, and staff costs, as well as treatment media change-out for POETSs on private wells. Distribution system O&M and recapitalization is not included as an eligible cost, and will be the responsibility of the communities.

  The O&M costs are presented for a period of 20 years. Two sets of O&M costs are presented: one without any interest or inflation (annual O&M multiplied by 20 years) and one with interest and inflation accounted for. The Co-Trustees expect earnings on the funds set aside for O&M to outpace inflation on O&M costs. It has been assumed that O&M costs would increase 3% annually due to inflation, and that funds would be managed by the State Board of Investment and earn an annual average of 3.5%. The present value calculation below was used to estimate the O&M costs over 20 years while accounting for interest and inflation:

$$PV_n = \sum \frac{Z_n}{(1+r)^n}$$

  - PV_n = present value of costs at year n
  - Z_n = Cash flow out over time at year n (annual costs)
  - r = Discount rate (interest earned -inflation)

- **20-year costs (capital + O&M)** are calculated by adding the "Total Capital" presented for each table to the 20-year O&M cost without interest and inflation.
- **20-year present value costs (capital + O&M and inflation + interest)** are calculated by adding the "Total Capital" presented for each table to the 20-year O&M cost that includes interest and inflation, as explained in the O&M description above.
- **Costs per 1,000 gallons** were calculated by dividing the 20-year present value costs by the total treated water volume. This volume includes water treated by the WTPs and POETSs.

E.2 Recommended Option 1

Recommended Option 1 consists of the selected community-specific alternatives identified in previous analyses presented in Appendix H and also described below for the treatment threshold of **HI ≥ 0.5**. Figures E.1 and E.2 provide an overview of the updated recommended Option 1 for non-municipal and municipal supply projects, respectively. The following subsections describe the improvements to address PFAS contamination for each community.

In addition to this section, the municipal wells requiring treatment in updated recommended Options 1–3 are listed in Section E.5, Table E.85, and the total number of existing and proposed POETSs for each community is provided in Section E.6, Table E.86.

E.2.1 Afton

E.2.1.1 Project summary

The improvement considered for Afton under recommended Option 1 is to install POETSs on PFAS-impacted, non-municipal wells that meet or exceed the HI threshold of 0.5 (HI ≥ 0.5). The improvements are shown in Figure E.1.

E.2.1.2 Project improvements

Afton does not have an existing municipal water supply, and therefore WTPs, water main extensions, and other municipal water supply components were not considered under this option.

POETSs

This option would provide POETSs for PFAS-impacted non-municipal wells according to the HI ≥ 0.5 threshold. Based on data provided by the city compared to MWI and sampling data as of October 2020, an estimated 242 of the estimated 1,195 total existing non-municipal wells have been sampled. The total number of existing wells was estimated based on county parcel data and confirmed with city staff after it was identified that the MWI contained records for only 808 wells.

Of the 242 sampled wells, 39 currently have POETSs installed. Under the HI ≥ 0.5 alternative, an additional 13 new POETSs would need to be installed for a total of 52 POETSs as long-term solutions for residents with non-municipal wells.

E.2.1.3 Hydraulic modeling analysis

A drinking water distribution model was not created for this community, as there is no municipal water system within Afton.

E.2.1.4 Groundwater modeling analysis

Forward particle tracking to year 2040 was conducted from known PFAS sources and areas where HI ≥ 1 under dry and wet climate conditions, as shown in Figures E.10 and E.11, respectively. Particle movement simulated in the model travels in the direction of groundwater flow. In Afton, groundwater in the uppermost bedrock aquifers generally flows toward the St. Croix River. The eastern region of Afton is located within the Hudson-Afton Horst (HAH). The uppermost bedrock aquifers within the HAH are primarily the Prairie Du Chien and Jordan Sandstone; however, the Tunnel City Group and Wonewoc Sandstone are the uppermost bedrock aquifers in the northeast corner of Afton. West of the HAH, the uppermost bedrock aquifer is either St. Peter Sandstone or Prairie du Chien.

A small cluster of groundwater samples with HI ≥ 1 is located on the northeast corner of Afton. The samples were collected from wells drilled into the Tunnel City Group and/or Wonewoc Sandstone aquifers. Particles originating around this cluster of wells travel east toward the St. Croix River. A larger cluster of wells with HI ≥ 1 is located north of Afton in West Lakeland. The samples from this cluster were collected from wells drilled into the Prairie Du Chien and/or Jordan Sandstone aquifers. Particles originating around this cluster of wells also travel east toward the St. Croix River.

Within Afton, groundwater in the Jordan, Prairie du Chien, and Tunnel City aquifers generally moves west to east across the city under the normal and wet climate conditions. Under the dry condition, the groundwater flow direction simulated by the calibrated model is very similar to under the wet condition. The results indicate that the primary groundwater flow direction is relatively stable, and significant volumes of water would need to be pumped to alter the simulated paths. Under the current groundwater flow patterns, the groundwater model indicates that PFAS contamination in the northern area of Afton may migrate along groundwater flow paths and impact additional non-municipal wells by the year 2040, as described above.

A drawdown analysis was not performed for Afton since no new wells were proposed.

E.2.1.5 Base cost estimate breakdown

Base capital and O&M costs are summarized in Table E.7 and include only Settlement-eligible costs. The base costs do not consider those costs incurred as a result of the groundwater model particle tracking analysis, which helped identify potentially impacted areas out to the year 2040. Those costs will be outlined in the following section. Table E.7 includes the capital costs for the non-municipal wells requiring the installation of a new POETS that meet the HI ≥0.5 threshold and currently do not have a POETS as of October 2020 sampling data. O&M costs for 20 years were also included for wells with existing and proposed POETSs.

Table E.7. Base costs for improvements included in Option 1 for Afton.

Item	Quantity	Units	Description	Total Cost (GAC)
New Capital Costs				
POETSs	13	POETSs	Standard household systems, $2,500 per well	$32,500
			Subtotal	$32,500
			Contingency (25%)	$8,125
			Professional services (15%)	$4,875
			Costs for POETSs installed since 2/20/2018	$169,000
			Total Capital	**$214,500**

Item	Quantity	Units	Description	Total Cost (GAC)
Annual O&M Cost				
POETSs	52	POETSs	Standard household systems, $1,000 per well	$52,000
			Subtotal	$52,000
			20 years of annual O&M	$1,040,000
			20 years of annual O&M present value (inflation + interest)	$992,283
			20-year costs (capital + O&M)	**$1,254,500**
			20-year present value costs (capital + O&M and inflation + interest)	**$1,206,783**
			Capital and operating cost per 1,000 gal	$7.77
			Operating only cost per 1,000 gallons	$6.39

E.2.1.6 Cost implications of particle tracking

The cost implications of the particle tracking analyses are provided in Table E.8 below and would be over and above base costs. For Afton, an additional 180 POETSs may potentially be necessary if PFAS travel further or impact additional wells in the northern part of Afton.

Table E.8. Option 1 Particle tracking costs for Afton.

Item	Quantity	Units	Description	Total Cost (GAC)
New Capital Costs				
POETSs	180	POETSs	Standard household systems, $2,500 per well	$450,000
			Subtotal	$450,000
			Contingency (25%)	$112,500
			Professional services (15%)	$67,500
			Total Capital	**$630,000**
Annual O&M Cost				
POETSs	180	POETSs	Standard household systems, $1,000 per well	$180,000
			Subtotal	$180,000
			20 years of annual O&M	$3,600,000
			20 years of annual O&M present value (inflation + interest)	$3,434,824
			20-year costs (capital + O&M)	**$4,230,000**
			20-year present value costs (capital + O&M and inflation + interest)	**$4,064,824**

E.2.2 Cottage Grove

E.2.2.1 Project summary

Cottage Grove currently has PFAS impacts to its municipal water system, which serves the majority of the community, with some areas to the south and east remaining less populated and therefore remaining unserved. The improvements considered for Cottage Grove under recommended Option 1 include the installation of centralized WTPs and expanding the existing distribution system to supply nearby neighborhoods that currently have PFAS-impacted non-municipal wells. In addition, POETSs would be installed for the remaining impacted non-municipal wells that were not proposed to be connected to the municipal water system in this option based on cost or constructability constraints, primarily in the neighborhoods in the southeast, southwest, and eastern boundary areas of the city. The proposed infrastructure modifications included in this option are shown in Figure E.2a/b. The implications for Cottage Grove's private and non-municipal wells are shown in Figure E.1, which illustrates which wells will receive POETSs or be connected to the distribution system for the East Metropolitan Area.

Water supply

Cottage Grove's municipal water system consists of 12 existing municipal wells. Due to PFAS contamination, as shown in Table E.9 below, not all wells are currently in service. However, if all wells received treatment based on the treatment threshold and other guidelines discussed in E.1.3.3, the wells would have a total combined design capacity of 14,000 gpm and a firm capacity of 10,500 gpm with the two largest capacity wells (2,000 gpm and 1,500 gpm) out of service as shown below.

Table E.9. Cottage Grove municipal well HI values and pumping rates as of first quarter 2021.

Well No.	Pressure Zone	Design Pumping Rate (gpm)	HI Value[1]
1	Low	600	0.59
2	Low	600	2.32
3	Intermediate	800	2.43
4	Intermediate	1,000	2.97
5	Intermediate	1,000	1.20
6	Intermediate	1,000	2.10
7	Intermediate	1,000	1.23
8	Intermediate	1,500	1.14
9	Intermediate	1,500	0.80
10	Low	2,000	2.65
11	High	1,500	0.31
12	High	1,500	0.01
Total		14,000	

Note:

1. HI values for municipal wells are based on sampling completed as of the first quarter of 2021.

Assuming the intermediate-pressure-zone well field is able to support these sustained pumping rates and their proximity to each other does not impact pumping capacities (see Section E. 2.2.3), the total firm capacity of 10,500 gpm with the two largest capacity wells out of service would meet their current 2020 MDD of 8,000 gpm (11.5 mgd) and anticipated 2040 MDD of approximately 9,800 gpm (14.1 mgd) without the addition of new wells. However, no pumping tests have been performed for this well field.

E.2.2.2 Project improvements

New municipal supply wells

Cottage Grove does not need any additional wells to meet their 2040 MDD. However, wells 1 and 2 are the city's lowest producing wells that have been contaminated by PFAS, as shown in Table E.9 above, and are the farthest away from the other municipal supply wells. The previous analysis in Appendix H examined whether it was more cost-effective to treat the two wells or replace them with a new well closer to well 10 and the proposed low-pressure-zone WTP. The results indicated that it was more cost-effective to seal the two existing wells and drill a new replacement well. The new well would have a pumping capacity equal to that of the two existing wells, at 1,200 gpm.

WTPs

All of the municipal supply wells in Cottage Grove except wells 11 and 12 would be treated through a combination of centralized groundwater WTPs under Option 1, not accounting for the implications of particle tracking. As mentioned above, wells would be selected for treatment based on their current HI values.

Under the previous evaluation, the more cost-effective solution is to provide two WTPs. One centralized WTP (WTP1) would serve the high- and intermediate-pressure-zone wells, and a second WTP (WTP2) would serve the low-pressure-zone wells. If wells 11 and 12 were to receive treatment, a dedicated raw water main would convey water from wells 11 and 12 in the high-pressure zone to WTP1 in the intermediate-pressure zone. All intermediate-pressure-zone wells (i.e., wells 3–9) would be routed to WTP1 via two 24" dual raw water trunk lines. The WTP would be located near the existing booster pump station at 80th Street in Pine Tree Pond Park. In order to treat water from the intermediate-pressure-zone wells, the WTP would have a capacity of 7,100 gpm. If wells 11 and 12 are routed to the intermediate-pressure zone, the WTP will need additional capacity of 3,000 gpm for a total capacity of 10,100 gpm.

The second WTP (WTP2), located near Ideal Avenue and 110th Street, would serve the low-pressure zone and would have the capacity to treat water from well 10 and the new replacement well for wells 1 and 2. This plant would be sized to meet the flow from both wells, or 3,200 gpm.

For drinking water distribution modeling purposes, the above options were grouped into two alternatives – one to consider the implications of particle tracking and the routing of wells 11 and 12 to treatment, and one without the implications of particle tracking. Under the alternatives described below, municipal supply wells were routed to WTPs to provide operational flexibility, while the treatment facilities were sized to meet the 2040 MDDs for cost purposes. Further discussion regarding the sizing of treatment facilities can be found in Appendix F, Section F.4.

Water storage

Under 2040 demand conditions, the city would need to add another storage facility with a minimum storage volume of 0.7 million gallons based on their ADD and required fire flow needs. For cost estimating purposes, this tank was not considered eligible for funding, and therefore not included in the costs presented for Cottage Grove.

Fire flow is the quantity of water available (for a city with a municipal distribution system) for fire-protection purposes in excess of that required for other purposes.

"Fire flow." Merriam-Webster.com Dictionary, Merriam-Webster, https://www.merriam-webster.com/dictionary/fire%20flow. Accessed 6

Water main extensions and distribution lines

In addition to the WTPs outlined above, additional infrastructure modifications would need to be implemented to accommodate the proposed projects as listed below. The modifications listed below do not include any approved expedited projects.

New raw water transmission lines would be required to convey flows from municipal supply wells to the proposed WTPs. These new transmission lines would include a new parallel raw water transmission line to provide redundancy for conveying flow from wells 3 through 9 to the intermediate-pressure-zone WTP.

New distribution lines would be installed to connect the neighborhoods along Goodview Avenue, Harkness Avenue, and Point Douglas Rd. Table E.4 provides a list of potential neighborhood and individual home connections. Two 8" PRVs would help mitigate the pressures in the neighborhoods along Goodview Avenue/Goodview Court and 70th Street, as the topography in this area rapidly slopes downward toward Trunk Highway 61, but have not been included in costs.

POETSs

Under this option, non-municipal wells would be selected for treatment using the threshold of HI ≥ 0.5. Current or anticipated PFAS-impacted non-municipal wells would be provided with POETSs that were not proposed to be connected to the municipal water system. According to PFAS sampling data from October 2020 and MWI data, Cottage Grove has an estimated 868 existing non-municipal wells, of which 723 have been sampled. For those sampled, 67 homes within three different neighborhoods (as indicated in Table E.4) are proposed to be connected to the municipal system, and an additional eight homes have both a well with HI ≥ 0.5 and a water line already in front of their home, for a total of 75 homes being connected to the municipal system in Cottage Grove as part of recommended Option 1. Of the remaining wells, 68 currently are and will remain on POETSs, while 49 new non-municipal wells will receive a POETS as their HI values are greater than or equal to 0.5, for a total of 117 POETSs as long-term solutions for residents with non-municipal wells. These counts exclude any wells that would be replaced with a connection to the city's municipal water system through expedited projects, future water line extensions, or previous connections to existing water lines.

E.2.2.3 Hydraulic modeling analysis

Once all the infrastructure improvements discussed above were included, the hydraulic model was run under 2040 MDD conditions. Modifications to pump operating points were made as necessary to regulate pressures and achieve a pressure range that is consistent with observed pressure data provided by the city. It was found that the intermediate-pressure-zone booster pump station would need to be modified and upgraded to accommodate the higher flows and maintain pressures. Since there is the potential for more flow to be coming from the higher pressure zones, the PRV settings to the low-pressure zone may need to be adjusted. Increasing the pressure setting slightly would keep the PRV near the intersection of 80th Street and Hadley Ave open during certain periods, allowing flow to enter the low-pressure zone. Flow would also enter the low-pressure zone through the line on Belden Blvd, even though this is a 6-inch line. It is recommended, and was modeled thus, that the 8-inch lines to the tower be increased in size to 12-inch diameter pipe to increase capacity needed for 2040 conditions.

Under this option, Cottage Grove's municipal supply wells would be routed to their respective WTPs prior to distribution to the public. The city would not need to blend water from wells containing low levels of PFAS; otherwise, operations would be similar to existing operating procedures, with the city optimizing well operations. The water supply improvements based on the hydraulic modeling are included in base capital costs in Section E.2.2.5.

E.2.2.4 Groundwater modeling analysis

Drawdown at existing and new municipal wells was evaluated within Cottage Grove, with wells operating at average rates based on the 2040 ADD. Under this option, the new well is extracting groundwater from the Jordan Sandstone aquifer at an ADD of 400 gpm, and wells 1 and 2 are out of service. Table E.10 provides a summary of pumping rates used in the groundwater model for existing and proposed wells.

Table E.10. Summary of Cottage Grove ADD for the existing and new municipal wells.

Well	Unique Well Number	ADD (gpm)
1	208808	Off
2	208809	Off
3	208807	187
4	208805	233
5	208806	233
6	201238	233
7	201227	233
8	110464	350
9	165602	350
10	191904	466
11	655944	350
12	830682	350
New well		280

Using the guidance provided by the DNR, drawdown at the existing wells and new locations was evaluated under a drier setting that approaches drought-like conditions (worst-case and herein referred to as dry) to determine whether drawdown exceeds the 50% threshold. Under dry conditions, the ADD rates for the Cottage Grove water supply wells were increased by multiplying the current condition (i.e., average 2016–2018) rates by a factor of 1.18 (the ratio of maximum per capita demand over average per capita demand from Years 2005–2015). Pumping rates at irrigation wells were also increased by taking the maximum annual volume reported over a 30-year period (1988–2018). Drawdown under dry and wet conditions in the Prairie Du Chien and Jordan Sandstone aquifers is shown in Figures E.6-E.9.

Under dry conditions, drawdown does not exceed the 50% available head in the Jordan Sandstone. The Prairie du Chien aquifer is currently unconfined at the Cottage Grove existing and new water supply well locations; therefore, head thresholds could not be applied to it. Table E.11 provides a summary of drawdown in the Jordan Sandstone aquifer under wet and dry conditions

Table E.11. Summary of drawdown in the Jordan Sandstone aquifer under wet and dry conditions.

Well	Jordan Sandstone aquifer			
	Drawdown (m)		Available Head (m)	Dry Drawdown as Percent of Available Head (%)
	Wet	Dry		
1	Off			
2	Off			
3	3	5	45	11
4	7	10	45	22
5	5	7	45	16
6	7	9	46	20
7	3	3	45	8
8	8	11	45	24
9	2	2	45	5
10	<1	<1	39	0
11	<1	<1	44	0

Well	Jordan Sandstone aquifer			
	Drawdown (m)		Available Head (m)	Dry Drawdown as Percent of Available Head (%)
	Wet	Dry		
12	9	12	58	20
New well	6	7	42	17

Forward particle tracking to year 2040 was conducted from known PFAS sources and areas where HI ≥ 1 under dry and wet climate conditions, as shown in Figures E.10 and E.11, respectively. Wells 3 through 12, along with the new well, were operating at the average daily rates used for the drawdown analysis discussed above. Under each climate condition, the general groundwater flow direction in Cottage Grove is from northeast to southwest in the uppermost bedrock aquifers (Prairie Du Chien and Jordan Sandstone aquifers). Particles originating from, but not captured by, pollution control wells at the 3M Woodbury disposal site were captured by the down-gradient municipal well cluster located in the central region (wells 3 through 9), as well as well 11. Particles originating at the 3M Cottage Grove site travel toward the Mississippi River and are not intercepted by the Cottage Grove municipal wells. No particles were captured by the new well.

E.2.2.5 Base cost estimate breakdown

Base capital and O&M costs are summarized in Table E.12 and include only Settlement-eligible costs. Base costs do not consider those costs incurred as a result of the groundwater model particle tracking analysis, which helped identify potentially impacted areas out to the year 2040. For PFAS treatment, only GAC was considered to treat the city's municipal wells, as well as iron and manganese pretreatment. In addition to the treatment facilities, the proposed raw water transmission lines and proposed distribution lines would be sized for 2040 MDDs. While Cottage Grove also requires modifications to their current municipal water treatment and distribution system to accommodate future growth, these growth-related costs for water storage and new wells are not eligible for Settlement funding. Additional infrastructure modifications such as PRVs would also not be eligible for Settlement funding, as they are considered necessary for operational modifications due to growth. A breakdown of base capital and O&M costs is provided in Table E.12 below.

Table E.12. Base costs for improvements included in Option 1 for Cottage Grove.

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
PFAS WTPs	2	WTPs	7,100 gpm MDD WTP (interm. zone), 3,200 gpm WTP (low zone)	$20,870,000
Sewer Line from WTP	1	Lump Sum	Line to convey backwash to storm sewer system	$395,750
Temporary Treatment Facility Demo	3	Lump Sum	Remove existing treatment facility (at wells 3, 7, 10)	$1,500,000
Municipal Well Demo	2	Ea	$130K per well ($49K to seal well, wells 1 and 2)	$260,000
New Well	1	Well	1,200 gpm (replacement well for Well 1 and 2)	$2,178,000
Well Modifications	9	Well	Well & Supervisory Control and Data Acquisition (SCADA) upgrades	$1,800,000

Item	Quantity	Units	Description	Total Cost (GAC)
Raw Water Transmission Mains	3.7	Miles	From wells to WTPs	$8,131,446
Neighborhood mains	2.4	Miles	Connect 67 homes	$1,920,672
16" Distribution Line	0.8	Miles	Flow to Grange Tank	$756,800
Stormwater Costs	1	Lump Sum	Stormwater Costs 5% of Linear and Facility Projects	$1,691,733
Service Laterals	75	Ea	Connect homes to existing mains ($8,000 ea)	$600,000
Cottage Grove City Fees for New Connections	75	Ea	City Fees include WAC ($1,006), Connection Fee ($1,160), Meter ($354), and Permit ($52)	$192,900
Private Well Sealing	75	Ea	$2,700 per well	$202,500
Land acquisition (site + water mains)	12.3	Acres	1/2 acre per well, 5 acres for WTPs, 20 ft easements (50%)	$4,429,510
Existing GAC POETS Removal	16	Ea	$400	$6,400
GAC POETSs	49	POETSs	Standard household systems, $2,500 per well	$122,500
			Subtotal	$45,058,211
			Contingency (25%)	$11,264,553
			Professional services (15%)	$6,758,732
			Costs for POETSs installed since 2/20/2018	$156,000
			Total Capital	**$63,237,496**
Annual O&M Cost				
PFAS WTPs	2	WTP	Media Cost	$78,154
PFAS WTPs	2	WTP	Maint. and Operations	$1,251,500
GAC POETSs	117	POETSs	Standard household systems, $1,000 per well	$117,000
			Subtotal	$1,446,654
			20 years of annual O&M	$28,933,080
			20 years of annual O&M present value (inflation + interest)	$27,605,567
			20-year costs (capital + O&M)	**$92,170,576**
			20-year present value costs (capital + O&M and inflation + interest)	**$90,843,063**
			Capital and operating cost per 1,000 gal	$0.84
			Operating only cost per 1,000 gallons	$0.25

E.2.2.6 Cost Implications of particle tracking

The cost implications of the particle tracking analyses are provided in Table E.13 below and would be over and above base costs. For Cottage Grove, the particle tracking increased the number of POETSs, number of municipal connections, and pretreatment and treatment plant capacity.

Taking into account the groundwater particle tracking analysis, an additional 20 non-municipal wells have the potential to be impacted by PFAS contamination and may need a POETS. In addition, 13 non-municipal wells would be replaced with a connection to the existing distribution system. With regard to the municipal supply, both wells 11 and 12 may require treatment and would be routed to the intermediate-pressure-zone WTP (WTP1), which would be expanded to accommodate the additional capacity needed.

Table E.13. Option 1 Particle tracking costs for Cottage Grove.

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
PFAS WTP	1	WTPs	Additional 3,000 gpm MDD capacity at WTP 1	$4,800,000
Raw water transmission mains	2.67	Miles	From wells to WTPs	$5,736,664
Stormwater Costs	1	Lump Sum	Stormwater Costs 5% of Linear and Facility Projects	$526,833
Service Laterals	14	Ea	Connect homes to existing mains ($8,000 ea)	$112,000
Cottage Grove City Fees for New Connections	14	Ea	City Fees include WAC ($1,006), Connection Fee ($1,160), Meter ($354), and Permit ($52)	$36,008
Private Well Sealing	14	Ea	$2,700 per well	$37,800
Land acquisition (site + water mains)	3.24	Acres	20 ft easements (50%)	$494,130
GAC POETSs	58	POETSs	Standard household systems, $2,500 per well	$145,500
			Subtotal	$11,888,435
			Contingency (25%)	$2,972,109
			Professional services (15%)	$1,783,265
			Total Capital	**$16,643,809**
Annual O&M Cost				
PFAS WTPs	1	WTP	Media Cost	$21,200
PFAS WTPs	1	WTP	Maint. and Operations	$305,220
GAC POETSs	58	POETSs	Standard household systems, $1,000 per well	$58,000
			Subtotal	$384,420
			20 years of annual O&M	$7,688,400
			20 years of annual O&M present value (inflation + interest)	$7,335,639
			20-year costs (capital + O&M)	**$24,332,209**
			20-year present value costs (capital + O&M and inflation + interest)	**$23,979,449**

E.2.2.7 Pretreatment cost summary

The following table provides a cost summary for iron and manganese pretreatment as a potential future cost. Pretreatment costs also include associated stormwater costs. These costs were used to inform decisions made as part of the Conceptual Plan, but may not be Settlement-eligible unless determined to be the most cost-effective alternative, as described in Chapter 9.

Table E.14. Summary of pretreatment costs for Cottage Grove.

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
Pretreatment at WTP	2	Lump Sum	Iron/Manganese	$13,947,634
Stormwater Costs	1	Lump Sum	Stormwater Costs 5% of Linear and Facility Projects	$697,382
			Subtotal	$14,645,015
			Contingency (25%)	$3,661,254
			Professional services (15%)	$2,196,752
			Total Capital	**$20,503,022**
Annual O&M Cost				
Pretreatment at WTP	1	gpm	Backwash fees, Maintenance, and FTEs	$1,362,620
			Subtotal	$1,362,620
			20 years of annual O&M	$27,252,392
			20 years of annual O&M present value (inflation + interest)	$26,001,993
			20-year costs (capital + O&M)	**$47,755,414**
			20-year present value costs (capital + O&M and inflation + interest)	**$46,505,014**

E.2.3 Denmark

E.2.3.1 Project summary

The improvement considered for Denmark Township (Twp) under recommended Option 1 is to install POETSs on PFAS-impacted, non-municipal wells that meet or exceed the HI threshold of 0.5 (HI ≥ 0.5). The improvements are shown in Figure E.1.

E.2.3.2 Project improvements

Denmark does not have an existing municipal water supply, and therefore WTPs, water main extensions, and other municipal water supply components were not considered under this option.

POETSs

This option provides POETSs for PFAS-impacted non-municipal wells according to the HI ≥ 0.5 threshold. As of October 2020 sample data, 133 of the estimated 761 total existing non-municipal wells have been sampled. Of the 133 sampled wells, none currently have POETSs installed. Under the HI ≥ 0.5 alternative, four new POETSs would need to be installed as long-term solutions for residents with non-municipal wells.

E.2.3.3 Hydraulic modeling analysis

A drinking water distribution model was not created for this community, as there is no municipal water system within Denmark.

E.2.3.4 Groundwater modeling analysis

Groundwater in Denmark moves primarily west to east across the Township. Forward particle tracking to year 2040 was conducted for the East Metro Area from known PFAS sources and areas where HI ≥ 1 under dry and wet climate conditions, as shown in Figures E.10 and E.11, respectively. Based on this analysis, PFAS contamination is not expected to migrate into Denmark and impact non-municipal wells by 2040. A drawdown analysis was not performed for Denmark, since no new wells were proposed.

E.2.3.5 Base cost estimate breakdown

Base capital and O&M costs are summarized in Table E.15 and include only Settlement-eligible costs; the base costs do not consider those costs incurred as a result of the groundwater model particle tracking analysis. For Denmark, the base costs include only the costs associated with proposed POETSs.

Table E.15. Base costs for improvements included in Option 1 for Denmark.

Item	Quantity	Units	Description	Total Cost (GAC)
New Capital Cost				
GAC POETSs	4	POETSs	Standard household systems, $2,500 per well	$10,000
			Subtotal	$10,000
			Contingency (25%)	$2,500
			Professional services (15%)	$1,500
			Costs for POETSs installed since 2/20/2018	$0
			Total Capital	**$14,000**
Annual O&M Cost				
GAC POETSs	4	POETSs	Standard household systems, $1,000 per well	$4,000
			Subtotal	$4,000
			20 years of annual O&M	$80,000
			20 years of annual O&M present value (inflation + interest)	$76,329
			20-year costs (capital + O&M)	**$94,000**
			20-year present value costs (capital + O&M and inflation + interest)	**$90,329**
			Capital and operating cost per 1,000 gal	$8.29
			Operating only cost per 1,000 gallons	$7.00

E.2.3.6 Cost Implications of particle tracking

As shown on Figures E.1, E.10 and E.11, the groundwater particle tracking analysis did not project there to be any potential future areas of PFAS contamination out to year 2040. Therefore, there were no cost implications due to particle tracking for Denmark.

E.2.4 Grey Cloud Island

E.2.4.1 Project summary

The improvement considered for Grey Cloud Island Twp under recommended Option 1 is to install POETSs on PFAS-impacted non-municipal wells. The improvements are shown in Figure E.1.

E.2.4.2 Project improvements

Grey Cloud Island does not have an existing municipal water supply, and therefore WTPs, water main extensions, and other municipal water supply components were not considered under this option.

POETSs

This option provides POETSs for PFAS-impacted non-municipal wells under year 2040 conditions. As of October 2020 sample data, Grey Cloud Island has an estimated 121 existing non-municipal wells, of which 111 wells have been sampled. Of these sampled wells, 53 currently have POETSs installed. Based on available sampling data, 23 non-municipal wells have HI values greater than or equal to 0.5, and would receive treatment through new POETSs, for a total of 76 non-municipal wells with POETSs as long-term solutions for residents with non-municipal wells.

E.2.4.3 Hydraulic modeling analysis

A drinking water distribution model was not created for this community, as there is no municipal water system within Grey Cloud Island.

E.2.4.4 Groundwater modeling analysis

The non-municipal wells in Grey Cloud Island draw water from the Prairie du Chien aquifer. However, the majority of wells in Grey Cloud Island are of unknown depth and therefore unknown aquifers. Groundwater in the Prairie du Chien aquifer generally moves northeast to southwest across the township. Forward particle tracking to year 2040 was conducted from known PFAS sources and areas where HI ≥ 1 under dry and wet climate conditions, as shown in Figures E.10 and E.11, respectively. Based on this analysis, Grey Cloud Island may see further spread of contamination to wells that are not currently impacted. A drawdown analysis was not performed for Grey Cloud Island, since no new wells were proposed.

E.2.4.5 Base cost estimate breakdown

Base capital and O&M costs are summarized in Table E.16, and include only Settlement-eligible costs. Base costs do not consider those costs incurred as a result of the groundwater model particle tracking analysis, which helped identify potentially impacted areas out to the year 2040. Table E.16 includes the capital costs for the non-municipal wells requiring the installation of a new POETS that meet the HI ≥ 0.5 threshold and currently do not have a POETS as of October 2020 sampling data. O&M costs for 20 years were also included for wells with existing and proposed POETSs.

Table E.16. Base costs for improvements included in Option 1 for Grey Cloud Island

Item	Quantity	Units	Description	Total Cost (GAC)
New Capital Cost				
GAC POETSs	23	POETSs	Standard household systems, $2,500 per well	$57,500
			Subtotal	$57,500
			Contingency (25%)	$14,375
			Professional services (15%)	$8,625
			Costs for POETSs installed since 2/20/2018	$38,000
			Total Capital	**$118,500**
Annual O&M Cost				
GAC POETSs	76	POETSs	Standard household systems, $1,000 per well	$76,000
			Subtotal	$76,000
			20 years of annual O&M	$1,520,000
			20 years of annual O&M present value (inflation + interest)	$1,450,259
			20-year costs (capital + O&M)	**$1,638,500**
			20-year present value costs (capital + O&M and inflation + interest)	**$1,568,759**
			Capital and operating cost per 1,000 gal	$13.49
			Operating only cost per 1,000 gallons	$12.47

E.2.4.6 Cost Implications of particle tracking

As shown in Figures E.1, E.10 and E.11, the particle tracking indicated that most of the community is within an area of potential future PFAS contamination. The cost implications of the particle tracking analyses are provided in Table E.17 below, and would be over and above base costs. For Grey Cloud Island, the groundwater model flow path analysis estimated that by 2040 an additional 45 wells may potentially be impacted, for a total of 121 non-municipal wells that may need treatment through existing or proposed POETSs for the HI ≥ 1 alternative.

Table E.17. Option 1 Particle tracking costs for Grey Cloud Island

Item	Quantity	Units	Description	Total Cost (GAC)
New Capital Cost				
GAC POETSs	45	POETSs	Standard household systems, $2,500 per well	$112,500
			Subtotal	$112,500
			Contingency (25%)	$28,125
			Professional services (15%)	$16,875
			Total Capital	**$157,500**
Annual O&M Cost				
GAC POETSs	45	POETSs	Standard household systems, $1,000 per well	$45,000
			Subtotal	$45,000
			20 years of annual O&M	$900,000
			20 years of annual O&M present value	$858,706
			20-year costs (capital + O&M)	**$1,057,500**
			20-year present value costs (capital + O&M)	**$1,016,206**

E.2.5 Lake Elmo

Lake Elmo currently has PFAS impacts to its municipal water system, which serves a portion of the community, while the rest of the community currently relies on private wells for drinking water. In addition, a portion of the community and one of their municipal wells lies within a an area which is subject to court-ordered aquifer use restrictions. This has put the community at a disadvantage in terms of planning for a future water supply. Therefore, two alternatives were considered for Lake Elmo under recommended Option 1. The first alternative, described in Section E.2.5.1, evaluated an interconnect between Woodbury and Lake Elmo that would allow Woodbury to supplement Lake Elmo's existing water supply, and is also included in the groundwater modeling analysis as "Iteration 1." The second alternative, described in Section E.2.5.2, evaluated Lake Elmo's water supply remaining autonomous, and installing additional groundwater supply wells to meet their 2040 MDD; this is included in the groundwater modeling analysis as "Iteration 2."

The overall recommended Option 1 costs for Lake Elmo will include the greater of each capital and O&M cost from the two alternatives. This is because uncertainties of Lake Elmo's future water supply, discussed above as well as in Chapters 8 and 9, make it currently impossible to select one solution, and because it is best to be conservative with costs for budgeting purposes. Based on the capital costs for each alternative, the costs associated with the Woodbury-Lake Elmo interconnect were greater, and therefore were included. Based on the O&M costs for each alternative, the costs associated with Lake Elmo's autonomous alternative were greater, and therefore included. These costs will be used for the summary table in Section E.2.14. The costs and modeling analyses are presented here for both alternatives.

E.2.5.1 Woodbury/Lake Elmo interconnect alternative

E.2.5.1.1 Project summary for Woodbury-Lake Elmo Interconnect Alternative

Under this alternative, Lake Elmo's water supply would be supplemented by Woodbury through a new interconnect and booster pump station to Lake Elmo's existing Water Tower 4. Individual residences and neighborhoods on private wells would be connected to the existing distribution system. Those properties with PFAS-impacted wells that are not connected to the system would receive POETSs. The proposed infrastructure modifications included in this alternative are shown in Figure E.2a. The implications for Lake Elmo's private and non-municipal wells are shown in Figure E.1.

E.2.5.1.2 Project improvements for Woodbury-Lake Elmo Interconnect Alternative

Due to potential groundwater pumping restrictions within Lake Elmo to mitigate reduced water levels at White Bear Lake, this alternative includes three additional wells in Woodbury's South well field to supplement Lake Elmo's current municipal water supply and provide for future demand. Woodbury would need to provide approximately 2,700 gpm to supplement the current demand and accommodate the increase in water demand resulting from growth in Lake Elmo up to year 2040. The 2,700 gpm is the difference between Lake Elmo's 2020 MDD and 2040 MDD. See Section E.2.13 for further description of Woodbury's municipal system.

Based on historic sampling of Woodbury well 19 (currently the only municipal well in the south well field) that indicates HI values are less than 0.5, the new wells in the South well field are not assumed to require treatment. However, more-recent trends from PFAS sampling at Woodbury well 19 suggest that groundwater may exceed the HI threshold of 0.5 in this area. Although the costs to treat the new wells are not currently included, contingency funding would be available as part of the Conceptual Plan in case treatment for these wells is needed.

Water main extension to existing neighborhoods

The available sample data as of October 2020 indicates that the majority of non-municipal wells are currently impacted by PFAS, and many have had a POETS installed or been replaced with a connection to the municipal system wherever possible according to the current well advisory threshold of HI ≥ 1.0. Under the recommended Option 1 HI threshold, three existing neighborhoods comprising 86 homes on private wells would require a water main extension to be connected to the city's municipal water system. In addition, 11 residences with PFAS-impacted wells that have an existing water line in front of their house would be connected to the system, for a total of 97 connections. These neighborhoods are also described in the neighborhood connections discussion in Section E.1.3.3 and Table E.4.

POETSs

According to PFAS sampling data from October 2020 and MWI data, Lake Elmo has an estimated 1,386 existing non-municipal wells, of which 645 have been sampled. After expedited projects and neighborhoods that would be connected to the municipal system as part of this option, 11 of the remaining non-municipal wells that have been sampled already have a POETS installed. Under Option 1, 18 additional wells would require a new POETS to be installed based on the treatment threshold, for a total of 29 POETSs included as long-term solutions for residents with non-municipal wells.

E.2.5.1.3 Hydraulic modeling analysis

The base model used to evaluate Lake Elmo's autonomous alternative was modified to evaluate the interconnect between Lake Elmo and Woodbury. In the hydraulic model, it is assumed that the average pressure at the connection point in Woodbury's system is approximately 74 pounds per square inch (psi). A booster pump station was placed at the connection point and sized to provide flow to the city's existing Tower 4. From there, water would be conveyed to the distribution system. Under normal operating conditions it is assumed that wells 2 and 4 are in operation and well 5 is off-line. The model was run under 2040 MDD conditions and with all proposed and previously approved neighborhoods connected to the system. The model results indicated that PRVs would still be needed to allow flow to go from the high-pressure zone east to the low-pressure zone. However, the model results indicated that a PRV was not necessary when flowing north from the high-pressure zone to the intermediate-pressure zone. The water supply improvements based on the hydraulic modeling are included in base capital costs in Section E.2.5.1.5.

E.2.5.1.4 Groundwater modeling analysis

A groundwater divide is present in Lake Elmo as shown by Berg (2019) and simulated with the groundwater model. Groundwater east of the divide flows toward the St. Croix River and groundwater west of the divide flows toward the Mississippi River. Since the divide is located on the western side of Lake Elmo, groundwater within the city limits generally flows in an easterly direction toward the St. Croix River.

Two iterations were analyzed using the groundwater model for Lake Elmo under recommended Option 1: 1) Woodbury interconnect with Lake Elmo and 2) Lake Elmo autonomous, referred to here as Iteration 1 and Iteration 2, respectively. Iteration 1 is described below, and Iteration 2 is described in Section E.2.5.2.4.

Iteration 1: Woodbury Interconnect with Lake Elmo

In the groundwater modeling simulation, three wells were added to Woodbury's South well field to help meet the city of Lake Elmo 2040 MDD without drilling new wells in Lake Elmo. Each of the three new wells in Woodbury was assigned an average pumping rate of 439 gpm. Further discussion of the analysis for Woodbury can be found in Section E.2.13.4.1. For Lake Elmo under this alternative, wells 2, 4, and 5 are operating at average rates based on the 2040 ADD, as shown in Table E.18. Wells 1 and 3 are not included in the groundwater model.

Table E.18. Summary of Iteration 1 ADD for the existing municipal wells in Lake Elmo under recommended Option 1.

Well	Unique well Number	ADD (gpm)
1	208448	Off
2	603085	257
3	655910	Off
4	767874	321
5	Not Available	321

Using the guidance provided by the DNR, drawdown at the existing wells and new locations was evaluated under a drier setting that approaches drought-like conditions (worst-case and herein referred to as dry) to determine whether drawdown exceeds the 50% threshold. Under dry conditions, ADD rates for the Lake Elmo water supply wells were increased by multiplying the current condition rates by a factor of 1.33 (the ratio of maximum per capita demand over average per capita demand from years 2005–2015). Pumping rates at irrigation wells were also increased by taking the maximum annual volume reported over a 30-year period (1988–2018). Drawdown under dry and wet conditions in the Prairie Du Chien and Jordan Sandstone aquifers is shown in Figures E.6a-E.9a.

For each iteration under dry conditions, drawdown does not exceed the 50% available head in either the Jordan Sandstone or Prairie Du Chien aquifers. Additionally, the effect of pumping is localized such that the general groundwater flow direction is not altered. The computed drawdown at wells 2, 4, and 5 is similar between Iteration 1 and Iteration 2. Table E.19 provides a summary of drawdown in the Jordan Sandstone aquifer under wet and dry conditions and drawdown in the Prairie du Chien aquifer under dry conditions.

Table E.19. Summary of drawdown in the Jordan Sandstone and Prairie du Chien aquifers under wet and dry conditions (Iteration 1).

	Jordan Sandstone aquifer				Prairie du Chien Aquifer		
	Drawdown (m)		Available Head (m)	Dry Drawdown as Percent of Available Head (%)	Drawdown (m)	Available Head (m)	Dry Drawdown as Percent of Available Head (%)
Well	Wet	Dry			Dry		
1	Off						
2	2	3	39	8	1	11	12
3	Off						
4	7	10	42	22	Not Present		
5	2	3	38	7	<1	20	0

Forward particle tracking to the year 2040 was conducted from known PFAS sources and areas where HI ≥ 1 under dry and wet climate conditions, as shown on Figures E.10 and E.11, respectively. Lake Elmo wells 2, 4, and 5 were operating at the average daily rates used for the drawdown analysis discussed above. Wells 1 and 3 were not pumping during the particle tracking iterations, as the wells were either taken out of service (well 1) or had never been equipped or placed into service (well 3). Particles are not captured by wells 2, 4, and 5, as these wells are located upgradient of PFAS sources and areas where HI ≥ 1.

E.2.5.1.5 Base cost estimate breakdown

Base capital and O&M costs are summarized in Table E.20 and include only Settlement-eligible costs for this interconnect alternative for Lake Elmo. Base costs do not consider those costs incurred as a result of the groundwater model particle tracking analysis, which helped identify potentially impacted areas out to the year 2040. The costs included in this alternative are those associated with the Woodbury- Lake Elmo interconnect, including one interconnect, water transmission mains for the new wells in Woodbury, water main extensions to certain neighborhoods within Lake Elmo, and the installation of POETSs to account for residences that may not be connected to the municipal water system due to feasibility or other unforeseen factors.

Note that this alternative includes improvements that would be constructed in both Lake Elmo and Woodbury; therefore, percentages applied for stormwater management costs in this alternative are either 25% or 30%, depending on the specific improvement line item, as indicated by the community listed in parenthesis in the “Item” column of Table E.20.

Table E.20. Base costs for improvements included in Option 1 Alternative 1 for Lake Elmo.

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
Interconnects	1	Stations	Woodbury to Lake Elmo	$375,000
Booster Pump Station (BPS)	1	Stations	Woodbury to Lake Elmo BPS	$1,700,500
Neighborhood distribution mains (Lake Elmo)	2.37	Miles	Connect 257 homes	$1,900,152
Transmission or connecting mains in distribution system (Lake Elmo)	3.59	Miles	Distribution lines and transmission main from interconnect to Tank #4	$8,856,285
Raw water distribution mains (Woodbury)	0.48	Miles	From three “Lake Elmo” wells to treatment plant	$1,006,632
Water distribution mains (Woodbury)	0.15	Miles	800 linear feet from dist system to BPS interconnect	$261,600
Stormwater Costs	1	Lump Sum	Stormwater costs 30% of linear and facility Projects in Lake Elmo and 25% of projects in Woodbury	$4,166,639
Service Laterals (Lake Elmo)	97	Ea	Connect homes to existing mains ($8,100 ea)	$785,700
Lake Elmo City Fees for New Connections	97	Ea	City Fees include WAC ($3,000), Connection Fee ($1,000), Meter ($1,540), and Permit ($0)	$537,380
Well Sealing (Lake Elmo)	97	Ea	$2,700 per private well	$261,900
Existing GAC POETS Removal (Lake Elmo)	25	Ea	$400 each	$10,000
Land acquisition, Lake Elmo (site + water mains)	12.4	Acres	20 ft easements (50%)	$2,356,100
Land acquisition, Woodbury (site + water mains)	1.8	Acres	1/2 acre per site, 20 ft easements (50%)	$464,189
GAC POETSs (Lake Elmo)	18	POETSs	Standard household systems, $2,500 per well	$45,000
			Subtotal	$22,727,078*
			Contingency (25%)	$5,681,769
			Professional services (15%)	$3,409,062
			Costs for POETSs installed since 2/20/2018	$27,500
			Total Capital	**$31,845,409***

Item	Quantity	Units	Description	Total Cost (GAC)
Annual O&M Cost				
GAC POETSs (Lake Elmo)	29	POETSs	Standard household systems, $1,000 per well	$29,000
			Subtotal	$29,000
			20 years of annual O&M	$580,000
			20 years of annual O&M present value (inflation + interest)	$553,388
			20-year costs (capital + O&M)	**$32,425,409**
			20-year present value costs (capital + O&M and inflation + interest)	**$32,398,797**
			Capital and operating cost per 1,000 gal	$1.12
			Operating only cost per 1,000 gallons	$0.02

*Line items do not sum to the exact total due to rounding (+/- $1.00)

E.2.5.1.6 Cost Implications of particle tracking

As shown in Figures E.1, E.10 and E.11, the particle tracking indicated that most of the community is within an area of potential future PFAS contamination. The cost implications of the particle tracking analyses are provided in Table E.21 below and would be over and above base costs. Results from the particle tracking analysis indicate that additional non-municipal wells may require POETSs and several would be replaced with a connection to the city's distribution system.

Table E.21. Option 1 Alternative 2 Particle tracking costs for Lake Elmo.

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
Service Laterals	133	Ea	Connect homes to existing mains ($8,100 ea)	$1,077,300
Lake Elmo City Fees for New Connections	133	Ea	City Fees include WAC ($3,000), Connection Fee ($1,000), Meter ($1,540), and Permit ($0)	$736,820
Well Sealing	133	Ea	$2,700 per well	$359,100
GAC POETSs	234	POETSs	Standard household systems, $2,500 per well	$585,000
			Subtotal	$2,758,220
			Contingency (25%)	$689,555
			Professional services (15%)	$413,733
			Total Capital	**$3,861,508**
Annual O&M Cost				
GAC POETSs (Lake Elmo)	234	POETSs	Standard household systems, $1,000 per well	$234,000
			Subtotal	$234,000
			20 years of annual O&M	$4,680,000
			20 years of annual O&M present value (inflation + interest)	$4,465,271
			20-year costs (capital + O&M)	**$8,541,508**
			20-year present value costs (capital + O&M and inflation + interest)	**$8,326,779**

E.2.5.2 Lake Elmo autonomous alternative

E.2.5.2.1 Project summary

In this second alternative, Lake Elmo remains autonomous, and two new municipal supply wells would be installed in the southwest region of the city that would be routed to a treatment facility. These two wells would be required to meet the city's 2040 MDD. Additional projects are the same as the first alternative described in Section E.2.5.1; they include extending water mains to nearby neighborhoods currently on PFAS-impacted, non-municipal wells, and providing POETSs for any remaining PFAS-impacted non-municipal wells that are not being connected to the existing municipal water system. The proposed infrastructure improvements included in this alternative are shown in Figure E.2b. Figure E.1 is a regional map illustrating improvements for private and non-municipal wells.

Water supply

Lake Elmo has a municipal water system consisting of two existing wells (wells 2 and 4) that have a combined design pumping capacity of 2,250 gpm. Previously, there were two additional wells, wells 1 and 3. However, sample data from well 3 indicated the well was contaminated with PFAS and was never equipped or placed into service, and well 1 was a multi-aquifer well contaminated with PFAS that DNR required to be taken out of service. If both existing municipal supply wells were in operation, the city would have a calculated firm capacity of 1,000 gpm with the largest well out of service. The city is currently installing an additional well, well 5, which is expected to have a 1,250-gpm pumping capacity and would increase the firm capacity to 2,250 gpm. With all three wells (wells 2, 4, and 5), this firm capacity of 2,250 gpm would meet their current 2020 maximum daily demand of approximately 1,600 gpm, but would be less than the anticipated 2040 maximum daily demand of 4,235 gpm. Table E.22 below summarizes the city's municipal well HI values and designed pumping rates.

Table E.22. Lake Elmo municipal well HI values and pumping rates as of first quarter 2021.

Well No.	Design Pumping Rate (gpm)	HI Value[1]
1	TAKEN OUT OF SERVICE	
2	1,000	0.27
3	NEVER PLACED INTO SERVICE	
4	1,250	0.01
5	1,250	N/A

Note:
1. HI values for municipal wells are based on sampling completed as of the first quarter of 2021.

E.2.5.2.2 Project improvements for Lake Elmo Autonomous Alternative

New municipal supply wells

In order to supply enough clean drinking water to meet 2040 MDDs and firm capacity requirements, two additional municipal supply wells, each with a capacity of 1,000 gpm, would be required. These wells would be constructed to pump water from the Jordan aquifer and would be located in the southwestern region along Keats Avenue. While this location maximizes the distance from White Bear Lake, it is within the Special Well and Boring Construction Area (SWBCA). This SWBCA designation indicates, and informs the public of, potential health risks due to groundwater contamination in the area, and/or provides controls on drilling municipal and non-municipal water supply wells. In addition, available water quality sampling data indicates that there are levels of PFAS present above the treatment threshold of HI ≥ 0.5, and wells in this area are assumed to require treatment under recommended Option 1.

The groundwater model was used to evaluate well placement through a well interference and drawdown analysis. Proposed well locations were provided to the groundwater modeling team along with the design flow rates to determine whether the potential drawdown exceeded the current limits. The modeling performed to assess improvements for the Lake Elmo autonomous alternative is discussed in the hydraulic and groundwater modeling sections (E.2.5.2.3 and E.2.5.2.4, respectively).

WTPs

Under this alternative it was assumed that both new wells would require treatment based on available sampling data. Flows from the two new wells would be routed via 12" and 16" lines to a treatment facility located at Water Tower 4. Treated water would then be conveyed to the storage tower for storing and distributing to customers. The WTP would have a firm capacity of 2,000 gpm.

Homes with non-municipal wells

Costs for neighborhood water main extensions and POETSs included for this alternative are the same as those discussed in Section E.2.5.1.2.

E.2.5.2.3 Hydraulic modeling analysis

As Lake Elmo's well 5 and proposed two wells have yet to be installed, a single point system curve was created for each well pump to maintain system pressures currently observed in the system. In addition, the drawdown analysis done by the groundwater modeling team provided the dynamic or pumping water level at each well location to increase the accuracy of the model. Similarly, for evaluating changes to the system, a single point design curve was used for existing wells 2 and 4 to determine the necessary operating point and whether the pumps would need to be modified.

Under 2040 conditions, certain modifications to the system were made that were consistent across all alternatives and HI conditions. First, water lines for new neighborhood connections as well as those required for the approved expedited projects were added to the distribution systems model. Second, a new water storage tower was added in the southeast corner, based on information provided by the city, to meet the increased 2040 demands as well as demands added due to new connections. The proposed storage facility will have a total volume of 1 MG.

New wells and raw water transmission lines to the proposed WTP were added to the hydraulic model. Once the raw water from the wells is treated it will be conveyed to existing storage Tower 4 to be fed to the distribution system. The Inwood BPS would be left in place in the event that the community were to be relying solely on wells 2, 4, and 5. The water supply improvements based on the hydraulic modeling are included in base capital costs in Section E.2.5.2.5.

E.2.5.2.4 Groundwater modeling analysis

A groundwater divide is present in Lake Elmo as shown by Berg (2019) and simulated with the groundwater model. Groundwater east of the divide flows toward the St. Croix River and groundwater west of the divide flows toward the Mississippi River. Since the divide is located on the western side of Lake Elmo, groundwater within the city limits generally flows in an easterly direction toward the St. Croix River.

Two iterations were analyzed using the groundwater model for Lake Elmo under recommended Option 1: 1) Woodbury interconnect with Lake Elmo and 2) Lake Elmo autonomous, referred to here as Iteration 1 and Iteration 2, respectively. Iteration 1 was described in Section E.2.5.1.4 above, and Iteration 2 is described below.

Iteration 2: Lake Elmo Autonomous

For the autonomous option (Iteration 2), two new municipal supply wells have been proposed for Lake Elmo that would extract water from the Jordan Sandstone aquifer. The rates used for Iteration 2 are summarized in Table E.23. The proposed new wells along with wells 2, 4, and 5 were simulated to operate at average rates based on the 2040 ADD.

Table E.23. Summary of Iteration 2 ADD for the existing and new municipal wells in Lake Elmo under Recommended Option 1.

Well	Unique Well Number	ADD (gpm)
1	208448	Off
2	603085	257
3	655910	Off
4	767874	321
5	Not Available	321
New Well 1		257
New Well 2		257

Under dry conditions, drawdown does not exceed the 50% available head in either the Jordan Sandstone or Prairie Du Chien aquifers. Additionally, the effect of pumping is localized such that the general groundwater flow direction is not altered. Table E.24 provides a summary of drawdown in the Jordan Sandstone aquifer under wet and dry conditions and drawdown in the Prairie du Chien under dry conditions.

As shown in Table E.24, drawdown computed at existing wells is well below the 50% threshold. The Prairie du Chien aquifer is not present at new well 2 nor at the relocated well 4, and therefore, Prairie du Chien head thresholds would not apply to these locations. Since the drawdowns do not exceed 50%, a transient analysis was not warranted.

Table E.24. Summary of drawdown in the Jordan Sandstone and Prairie du Chien aquifers under wet and dry conditions (Iteration 2).

	Jordan Sandstone aquifer				Prairie du Chien Aquifer		
	Drawdown (m)		Available Head (m)	Dry Drawdown as Percent of Available Head (%)	Drawdown (m)	Available Head (m)	Dry Drawdown as Percent of Available Head (%)
Well	Wet	Dry			Dry		
1	Off						
2	2	3	39	8	1	11	12
3	Off						
4	7	10	42	22	Not Present		
5	2	3	38	7	<1	20	0
New Well 1*	1	3	63	4	2	22	11
New Well 2*	2	3	63	4	Not Present		

Forward particle tracking to the year 2040 was conducted from known PFAS sources and areas where HI ≥ 1 under dry and wet climate conditions. Lake Elmo wells 2, 4, and 5 along with the two new wells in the southern region were operating at the average daily rates used for the drawdown analysis discussed above. Wells 1 and 3 were not pumping during the particle tracking modeling, as the wells were either taken out of service (well 1) or were never equipped or placed into service (well 3). Iteration 2 particles are captured by the new wells by year 2040; these wells are located directly down gradient of areas where HI ≥ 1. Particles are not captured by wells 2, 4, and 5, as these wells are located up gradient of PFAS sources and areas where HI ≥ 1.

E.2.5.2.5 Base cost estimate breakdown

Base capital and O&M costs are summarized in Table E.25. Base costs include only Settlement-eligible costs and do not consider those costs incurred as a result of the groundwater model particle tracking analysis that helped identify potentially impacted areas out to the year 2040. The improvements included in this option for Lake Elmo include two new municipal supply wells to replace wells impacted by PFAS, water main extensions to certain PFAS-impacted neighborhoods, and the installation of POETSs to account for residences that may not be connected to the municipal water system by 2040 due to feasibility or other unforeseen factors. Any cost for relocation of wells unrelated to the Settlement would not be Settlement-eligible.

Table E.25. Base costs for improvements included in Option 1 Alternative 2 for Lake Elmo.

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
PFAS WTPs	1	WTP	2,000 gpm MDD central WTP (at Tank #4) for two new wells	$5,810,000
Sewer Line from WTP	1	Lump Sum	Line to convey backwash to SS system	$280,800
Raw water transmission mains	2.5	Miles	From wells to WTP at Tank #4	$2,275,034
Water distribution mains	1.5	Miles	Connecting distribution mains	$2,846,448
Neighborhood mains	2.4	Miles	Connect 86 homes	$1,900,152
Stormwater Costs	1	Lump Sum	Stormwater Costs 30% of Linear and Facility Projects	$3,933,730
Service Laterals	97	Ea	Connect homes to existing mains ($8,100 ea)	$785,700
Lake Elmo City Fees for New Connections	97	Ea	City Fees include WAC ($3,000), Connection Fee ($1,000), Meter ($1,540), and Permit ($0)	$537,380
Well Sealing	97	Ea	$2,700 per well	$261,900
Existing GAC POETS Removal	25	Ea	$400	$10,000
Land acquisition (site + water mains)	10.0	Acres	20 ft easements (50%)	$1,899,216
GAC POETSs	18	POETSs	Standard household systems, $2,500 per well	$45,000
			Subtotal	$20,585,360
			Contingency (25%)	$5,146,340
			Professional services (15%)	$3,087,804
			Costs for POETSs installed since 2/20/2018	$27,500
			Total Capital	**$28,847,004**

Item	Quantity	Units	Description	Total Cost (GAC)
Annual O&M Cost				
PFAS WTPs	1	WTP	Media Cost	$2,572
PFAS WTPs	1	WTP	Maint. and Operations	$394,500
GAC POETSs	29	POETSs	Standard household systems, $1,000 per well	$29,000
			Subtotal	$426,072
			20 years of annual O&M	$8,521,445
			20 years of annual O&M present value (inflation + interest)	$8,130,463
			20-year costs (capital + O&M)	**$37,368,450**
			20-year present value costs (capital + O&M and inflation + interest)	**$36,977,467**
			Capital and operating cost per 1,000 gal	$1.71
			Operating only cost per 1,000 gallons	$0.37

E.2.5.2.6 Cost Implications of particle tracking

The cost implications of the particle tracking analyses are provided in Table E.26 below and would be over and above base costs. For Lake Elmo, the particle tracking costs include additional POETSs and homes connected to the existing distribution system.

Table E.26. Option 1 Alternative 2 Particle tracking costs for Lake Elmo.

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
Service Laterals	133	Ea	Connect homes to existing mains ($8,100 ea)	$1,077,300
Lake Elmo City Fees for New Connections	133	Ea	City Fees include WAC ($3,000), Connection Fee ($1,000), and Meter ($1,540)	$736,820
Well Sealing	133	Ea	$2,700 per well	$359,100
GAC POETSs	234	POETSs	Standard household systems, $2,500 per well	$585,000
		Subtotal	$2,758,220	
		Contingency (25%)	$689,555	
		Professional services (15%)	$413,733	
		Total Capital	**$3,861,508**	
Annual O&M Cost				
GAC POETSs	234	POETSs	Standard household systems, $1,000 per well	$234,000
		Subtotal	$234,000	
		20 years of annual O&M	$4,680,000	
		20 years of annual O&M present value (inflation + interest)	$4,465,271	
		20-year costs (capital + O&M)	**$8,541,508**	
		20-year present value costs (capital + O&M and inflation + interest)	**$8,326,779**	

E.2.5.2.7 Pretreatment cost summary

The following table provides a cost summary for iron and manganese pretreatment as a potential future cost. Pretreatment costs also include associated stormwater costs. Pretreatment was estimated for this alternative due to the potential need for pretreatment as part of the WTP for the two new wells. These costs were used to inform decisions made as part of the Conceptual Plan, but may not be Settlement-eligible unless determined to be the most cost-effective alternative, as described in Chapter 9.

Table E.27. Pretreatment costs for Lake Elmo Option 1 Alternative 2.

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
Pretreatment at WTP	1	Lump Sum	Iron/Manganese	$3,172,217
Stormwater Costs	1	Lump Sum	Stormwater Costs 30% of Linear and Facility Projects	$951,665
			Subtotal	$4,123,882
			Contingency (25%)	$1,030,970
			Professional services (15%)	$618,582
			Total Capital	**$5,773,435**
Annual O&M Cost				
PreTreatment at WTP	1	WPT	Backwash fees, Maintenance, and FTEs	$315,772
			Subtotal	$315,772
			20 years of annual O&M	$6,315,448
			20 years of annual O&M present value (inflation + interest)	$6,025,681
			20-year costs (capital + O&M)	**$12,088,882**
			20-year present value costs (capital + O&M and inflation + interest)	**$11,799,116**

E.2.6 Lakeland, Lakeland Shores, and Lake St. Croix Beach

E.2.6.1 Project summary

Lakeland currently has a municipal water system to serve the majority of their community, which is not currently impacted by PFAS. The improvements considered for Lakeland, including the communities of Lakeland Shores and Lake St. Croix Beach under recommended Option 1, include replacing remaining non-municipal wells with connections to the municipal water system. Currently the city of Lakeland's municipal water system serves the other communities of Lakeland Shores and Lake St. Croix Beach. The community of St. Mary's Point is also discussed, as it is adjacent to these communities and has the potential to be connected to Lakeland's distribution system. However, costs for St. Mary's Point are not included in the Conceptual Plan. The implications for Lakeland's non-municipal wells are shown in Figure E.1. Lakeland's existing municipal system is also shown on Figure E.2a/b.

Water supply

Lakeland's municipal water system consists of two existing municipal wells (wells 1 and 2) that have a combined design capacity of 1,500 gpm, as shown in Table E.28. Both municipal wells were drilled to the Mt. Simon aquifer, one of the deepest drinking water aquifers in the area. Due to high iron and manganese levels, both wells are receiving treatment for these compounds. Under firm capacity conditions with their largest well out of service, Lakeland's current supply produces 750 gpm, which is sufficient to meet their current demand as well as their 2040 maximum daily demand of approximately

750 gpm, which includes Lakeland, Lakeland Shores, Lake St. Croix Beach, and St. Mary's Point. The existing distribution system is almost completely built out for the communities of Lakeland, Lakeland Shores, and Lake St. Croix Beach. The city has also reserved capacity of their municipal supply wells that would enable them to extend water lines to St. Mary's Point. The cost of installing new distribution lines to serve St. Mary's Point was not included in the Conceptual Plan.

Table E.28. Lakeland's municipal well HI values and Pumping rates as of first quarter 2021.

Well No.	Design Pumping Rate (gpm)	HI Value[1]
1	750	0.002
2	750	0.002
Total	1,500	

Note:
1. HI values for municipal wells are based on sampling completed as of the first quarter of 2021.

E.2.6.2 Project improvements

WTPs

Under this option, wells were selected for treatment using an HI threshold of HI ≥ 0.5. Based on the available sampling data, neither of the municipal wells would require PFAS treatment. However, each well currently has treatment for iron and manganese that would remain.

Connections to the municipal water system

The city of Lakeland has indicated that they plan to continue connecting residents and businesses to their municipal water system as needed. Some residents and businesses are already connected but appear to still have a non-municipal well – this could be for irrigation purposes or out of a desire to keep the well for other reasons, or the information on MWI may be outdated or incorrect. Based on data provided by the city compared to MWI and sampling data, there are an estimated 280 properties with wells that also are connected to the existing municipal system. Under this option, costs are included for existing wells exceeding the HI threshold to be sealed and the homes to be connected to the existing municipal water system if not already connected. Based on data from the city, the MWI, and sampling data as of October 2020, it was estimated that 225 non-municipal wells would be replaced with connections to Lakeland's municipal water system and 280 wells would be sealed.

POETSs

According to PFAS sampling data from October 2020 and MWI data, Lakeland, including Lakeland Shores, Lake St. Croix Beach, and St. Mary's Point, has an estimated 610 existing non-municipal wells, of which 139 have been sampled. Table E.29 shows the breakdown of number of wells included in MWI as well as the number of wells sampled in each of these communities.

Table E.29. Summary of non-municipal wells.

Community	Number of wells from CWI	Number of wells sampled
Lake St. Croix Beach	122	6
Lakeland	342	112
Lakeland Shores	44	16
St. Mary's Point	102	5
LAKELAND TOTAL	610	139

As described in the previous section, non-municipal wells are assumed to be sealed and replaced by a connection to the existing distribution system, if they were not already connected. Under this option, only one well had an existing POETS that would remain as a long-term solution.

E.2.6.3 Hydraulic modeling analysis

System operations for Lakeland would not change under this option. The municipal supply wells would continue to operate as they are currently across one pressure zone. Under 2040 MDD conditions, the range of pressures seen in the system ranged from 40 to 90 psi. No modifications to the municipal water system are recommended at this time to meet 2040 demands. However, if the city implements PFAS treatment to address future contamination, the well pumps may need to be modified to operate at a higher head or discharge pressure to move water through the treatment vessels. If the city decides to serve St. Mary’s Point, further analysis would be required to expand the existing distribution system; however, the city has enough water supply to meet the additional demand. The water supply improvements based on the hydraulic modeling are included in base capital costs in Section E.2.6.5.

E.2.6.4 Groundwater modeling analysis

Forward particle tracking to year 2040 was conducted from known PFAS sources and areas where HI ≥ 1 under dry and wet climate conditions, as shown on Figures E.10 and E.11, respectively. Particle movement simulated in the model is in the direction of groundwater flow, which in the uppermost bedrock aquifers is east toward the St. Croix River. Lakeland (and included communities of Lakeland Shores and Lake St. Croix Beach) is located within the HAH formation. The uppermost bedrock aquifer is primarily the Mt. Simon Sandstone; however, Tunnel City Group and Wonewoc Sandstone are also present in the southwest corner of Lakeland and western region of Lake St. Croix Beach. A large cluster of groundwater samples with HI ≥ 1 is located in neighboring West Lakeland Township. The samples were collected primarily from wells drilled into the Prairie Du Chien and Jordan Sandstone aquifers. Additionally, a smaller cluster of HI ≥ 1 samples were collected from Tunnel City Group and Wonewoc Sandstone aquifers in the northeast corner of the neighboring city of Afton. Particles inserted around those clusters of wells travel east across faults bounding the HAH into Lakeland, and will be reaching wells (Lakeland well 2 and other non-municipal wells) within the city limits by the year 2040. Well 1 does not appear to capture particles; however, the well is located within close proximity to a small cluster of Quaternary wells with HI ≥ 1 along the northern Lakeland boundary. A drawdown analysis was not performed for Lakeland since no new wells were proposed.

E.2.6.5 Base cost estimate breakdown

Base capital and O&M costs are summarized in Table E.30 and include only Settlement-eligible costs. Base costs analysis does not consider those costs incurred as a result of the groundwater model particle tracking analysis. For Lakeland and associated communities, the base costs include only the costs associated with existing and/or proposed POETSs and the municipal system connections.

Table E.30. Base costs for improvements included in Option 1 for Lakeland, Lakeland Shores, and Lake St. Croix Beach.

Item	Quantity	Units	Description	Total Cost (GAC)
New Capital Cost				
Service Laterals	29	Ea	Connect homes to existing mains ($4,975 ea)	$144,275
Lakeland City Fees for New Connections	29	Ea	City Fees include Meter ($425) and Permit ($400)	$23,925
Existing GAC POETS Removal	4	Ea	$400	$1,600
Well Sealing	309	Ea	$2,700 per well	$834,300
GAC POETSs	0	POETSs	Standard household systems, $2,500 per well	$0
			Subtotal	$1,004,100
			Contingency (25%)	$251,025
			Professional services (15%)	$150,615
			Costs for POETSs installed since 2/20/2018	$4,500
			Total Capital	**$1,410,240**
Annual O&M Cost				
GAC POETSs	1	POETSs	Standard household systems, $1,000 per well	$1,000
			Subtotal	$1,000
			20 years of annual O&M	$20,000
			20 years of annual O&M present value (inflation + interest)	$19,082
			20-year costs (capital + O&M)	**$1,430,240**
			20-year present value costs (capital + O&M and inflation + interest)	**$1,429,322**
			Capital and operating cost per 1,000 gal	$1.84
			Operating only cost per 1,000 gallons	$0.02

E.2.6.6 Cost Implications of particle tracking

The projected areas of impact resulting from the particle tracking analysis shown on Figure E.1 encompass almost all of the communities of Lakeland, Lakeland Shores, and Lake St. Croix Beach. While the particle tracking area covers only a portion of Lake St. Croix Beach, the entire community was considered for the particle tracking costs, since the community is already being served by Lakeland's municipal distribution system. Lakeland's municipal well 2 also appeared to be capturing particles during the particle tracking analysis, despite being located in the deeper Mt. Simon aquifer. The cost implications of the particle tracking analyses are provided in Table E.31 below and would be over and above base costs. Well 1 did not appear to capture particles during this analysis. A total of 196 additional connections to the existing municipal system are included in particle tracking costs as well, and cover any remaining homes that are not covered in base costs.

Table E.31. Option 1 Particle tracking costs for Lakeland, Lakeland Shores, and Lake St. Croix Beach.

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
PFAS WTPs	1	WTPs	750 gpm MDD capacity	$3,220,000
Stormwater Costs	1	Lump Sum	Stormwater Costs 30% of Linear and Facility Projects	$966,000
Service Laterals	196	Ea	Connect homes to existing mains ($4,975 ea)	$975,100
Lakeland City Fees for New Connections	196	Ea	City Fees include WAC ($0), Connection Fee ($0), Meter ($425), and Permit ($400)	$161,700
Well Sealing	196	Ea	$2,700 per well	$529,200
			Subtotal	$5,852,000
			Contingency (25%)	$1,463,000
			Professional services (15%)	$877,800
			Total Capital	**$8,192,800**
Annual O&M Cost				
PFAS WTPs	1	WTP	Media Cost	$4,175
PFAS WTPs	1	WTP	Maint. and Operations	$223,140
			Subtotal	$227,315
			20 years of annual O&M	$4,546,300
			20 years of annual O&M present value (inflation + interest)	$4,337,706
			20-year costs (capital + O&M)	**$12,739,100**
			20-year present value costs (capital + O&M and inflation + interest)	**$12,530,506**

E.2.7 Maplewood

E.2.7.1 Project summary

The improvements considered for Maplewood under recommended Option 1 include providing POETSs for those non-municipal wells that exceed the HI threshold of HI ≥ 0.5. The implications for Maplewood's private and non-municipal wells are shown in Figure E.1.

E.2.7.2 Project improvements

Maplewood does have an existing municipal water supply in the community from SPRWS. However, the southern portion of the east section of Maplewood remains on private wells. Sampling has indicated this portion of Maplewood is impacted by PFAS. In previous analyses discussed in Appendix H, it was determined to be more cost-effective to include POETSs in this area of the community rather than extend water mains. Therefore WTPs, water main extensions, and other municipal water supply components were not considered.

POETSs

As of October 2020 sample data, Maplewood has an estimated 615 existing non-municipal wells, of which 59 wells have been sampled. Within the southern region of Maplewood, five residences have POETSs installed. An additional five have an HI value greater than or equal to 0.5, and will receive POETSs, for a total of 10 POETSs, as long-term solutions for residents with non-municipal wells under this option.

E.2.7.3 Hydraulic modeling analysis

No drinking water distribution model was created for Maplewood. Since the improvements for recommended Option 1 are POETSs, it was not necessary to perform a hydraulic analysis.

E.2.7.4 Groundwater modeling analysis

Forward particle tracking to year 2040 was conducted from known PFAS sources and areas where HI ≥ 1 under dry and wet climate conditions, as shown on Figures E.10 and E.11, respectively. The particles inserted into the model travel in the direction of groundwater flow. In Maplewood, groundwater flow in the Prairie Du Chien and Jordan Sandstone aquifers is generally from northeast to southwest, toward the Mississippi River. Although the southern region of Maplewood is down gradient from known PFAS sources and areas where HI ≥ 1, particles originating at those areas do not reach wells located in Maplewood by 2040 according to the particle tracking analysis. A drawdown analysis was not performed for Maplewood, since no new wells were proposed.

E.2.7.5 Base cost estimate breakdown

Base capital and O&M costs are summarized in Table E.32 and include only Settlement-eligible costs. Base costs do not consider those costs incurred as a result of the groundwater model particle tracking analysis. For Maplewood, the base costs include only the costs associated with existing and/or proposed POETSs.

Table E.32. Base costs for improvements included in Option 1 for Maplewood.

Item	Quantity	Units	Description	Total Cost (GAC)
New Capital Cost				
GAC POETSs	5	POETSs	Standard household systems, $2,500 per well	$12,500
			Subtotal	$12,500
			Contingency (25%)	$3,125
			Professional services (15%)	$1,875
			Costs for POETSs installed since 2/20/2018	$0
			Total Capital	**$17,500**
Annual O&M Cost				
GAC POETSs	10	POETSs	Standard household systems, $1,000 per well	$10,000
			Subtotal	$10,000
			20 years of annual O&M	$200,000
			20 years of annual O&M present value (inflation + interest)	$190,824
			20-year costs (capital + O&M)	**$217,500**
			20-year present value costs (capital + O&M and inflation + interest)	**$208,324**
			Capital and operating cost per 1,000 gal	$10.66
			Operating only cost per 1,000 gallons	$9.76

E.2.7.6 Cost Implications of particle tracking

As briefly described above and shown in Figures E.1, E.10 and E.11, the projected areas of impact resulting from the particle tracking analysis did not include any areas within Maplewood's community boundaries. As a result, there are no additional cost implications due to particle tracking.

E.2.8 Newport

E.2.8.1 Project summary

Newport currently has a municipal water system to serve the majority of their community, which is not currently impacted by PFAS. The improvements considered for Newport under recommended Option 1 include interconnects with neighboring communities, connecting residents to the distribution system, and installing POETSs on PFAS-impacted non-municipal wells with a threshold of HI ≥ 0.5. The proposed infrastructure modifications included in this option are shown in Figure E.2a/b, and the implications for Newport's non-municipal wells are shown in Figure E.1.

Water supply

The city of Newport's municipal water system consists of two existing municipal wells (wells 1 and 2) that have a combined design capacity of 1,800 gpm and a firm capacity with their largest well out of service of 800 gpm, as shown in Table E.33. The city also has three existing water storage tanks with a total capacity of 1.02 MG. Under firm capacity conditions with their largest well out of service, Newport is able to meet their current demand as well as their 2040 maximum daily demand of approximately 400 gpm. The city does not need any additional wells for water supply through year 2040.

Table E.33. Newport municipal well HI values and pumping rates as of first quarter 2021.

Well No.	Design Pumping Rate (gpm)	HI Value[1]
1	1,000	0.033
2	800	0.056
Total	1,800	

Note:

1. HI values for municipal wells are based on sampling completed as of the first quarter of 2021.

E.2.8.2 Project improvements

Interconnects with neighboring communities

The city of Newport does not currently have an interconnect with a neighboring community it can rely on in the event of an emergency. In order to provide resiliency and an alternative water supply for the city in the future should it become necessary due to PFAS impacts, two interconnects are included for Newport with Woodbury and Cottage Grove. If Newport's wells become contaminated with PFAS in the future, the city would prefer to receive water via one or both of these interconnects rather than implement treatment on their wells. If Newport eventually receives its water from interconnects, the state would require the city to seal its two municipal wells.

Both interconnects would require the installation of new transmission lines, a metering vault, and PRV. The interconnect with Cottage Grove would extend south on Century Avenue and would connect at a future water line along Goodview Avenue that would be installed as part of the Sullivan Pines subdivision. If the interconnect is implemented prior to the completion of the Sullivan Pines subdivision, the water line along Goodview Avenue would need to be installed. The interconnect with Woodbury would tie into the existing water line at the intersection of Lydia Lane and Bailey Road, and extend west along Bailey Road before connecting to the Newport's existing distribution system in the Bailey Meadows subdivision. Infrastructure needed for these interconnects is shown in Figure E.2a/b.

Connections to the municipal water system

Wherever possible according to the HI threshold, homes with PFAS-impacted non-municipal wells would be connected to the city's municipal distribution system. While the majority of homes in the city of Newport are connected to the existing municipal distribution system, the city still has residents that are on private wells, particularly in the neighborhoods off Kolff Street and Wild Ridge Trail. Under this option, no water mains were proposed to be extended, and those private wells would remain and receive treatment with POETSs based on available sampling data and the HI threshold as discussed below. However, three non-municipal wells exceed the HI threshold and are adjacent to existing distribution lines. These wells would be replaced with a connection to existing water distribution mains with service laterals, and the well would be sealed.

POETSs

This option includes POETSs for PFAS-impacted non-municipal wells with an HI ≥ 0.5. As of October 2020 sample data, Newport has an estimated 134 existing non-municipal wells, of which 57 have been sampled. There is one well with a POETS currently, but it is one of the wells to be replaced with a connection to the distribution system as discussed above. After accounting for those wells being connected, six non-municipal wells have HI values greater than or equal to 0.5 and would receive POETSs as long-term solutions.

E.2.8.3 Hydraulic modeling analysis

A drinking water distribution model was created and calibrated based on the data provided by the city. Pressures in the system are consistent with those recently observed during hydrant testing. The model was used to evaluate interconnects with neighboring communities as opposed to providing treatment at the municipal supply wells in the event that these wells become contaminated in the future. The hydraulic model indicated that there would be a need for a PRV for the interconnect with Cottage Grove, as there was a difference in hydraulic grade of approximately 185 ft. Without a PRV, the pressures in Newport would be above the acceptable operating range. However, the difference in hydraulic grade between Newport and Woodbury was considerably less, at approximately 40 ft, and a PRV is not needed. In addition, there is an existing pressure sustaining valve at BPS #2, which can allow water to move from the high-pressure zone to the lower pressure zones and can be used if higher pressures are observed from the Woodbury supply. Water from Woodbury would feed the tank in Newport's high-pressure zone, while water from Cottage Grove would be conveyed to the two ground storage tanks off Glen Road in Loveland Park. The water supply improvements based on the hydraulic modeling are included in base capital costs in Section E.2.8.5.

E.2.8.4 Groundwater modeling analysis

Forward particle tracking to year 2040 was conducted from known PFAS sources and areas where HI ≥ 1 under dry and wet climate conditions, as shown on Figures E.10 and E.11, respectively. Particles inserted into the model travel in the direction of groundwater flow. In Newport, groundwater flow in the uppermost bedrock aquifers (Prairie Du Chien and Jordan Sandstone aquifers) is generally from northeast to southwest, toward the Mississippi River. Although there are areas of PFAS contamination in the uppermost bedrock aquifers that are located upgradient from Newport, particles originating at these locations are not shown to reach wells located within the city limits by the year 2040. A drawdown analysis was not performed for Newport, since no new wells were proposed.

E.2.8.5 Base cost estimate breakdown

Base capital and O&M costs are summarized in Table E.34; they include only Settlement-eligible costs, and do not consider those costs incurred as a result of the groundwater model particle tracking analysis. For Newport, the base costs include the interconnects, water mains, three service lateral connections, and six POETSs.

Table E.34. Base costs for improvements included in Option 1 for Newport.

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
Interconnect with Woodbury	1	Stations	8" interconnect w/ flow meter and PRV	$200,000
Woodbury interconnect Water distribution mains	0.51	Miles	From Woodbury to Newport, 8" mains	$448,200
Interconnect with Cottage Grove	1	Stations	8" interconnect w/ flow meter and PRV	$200,000
Cottage Grove interconnect Water distribution mains	0.76	Miles	From Woodbury to Newport, 8" mains	$664,000
Municipal Well Demo	2	Ea	$130K per well	$260,000
Stormwater Costs	1	Lump Sum	Stormwater Costs 5% of Linear and Facility Projects	$75,610
Service Laterals	3	Ea	Connect homes to existing mains ($7500 ea)	$22,500
Newport City Fees for New Connections	3	Ea	City Fees include WAC ($1,050), Connection Fee ($400), Meter ($350), and Permit ($100)	$5,700
Well Sealing	3	Ea	$2,700 per well	$8,100
Existing GAC POETS Removal	1	Ea	$400	$400
Land acquisition (water mains)	1.5	Acres	20 ft easements (50%)	$208,370
GAC POETSs	6	POETSs	Standard household systems, $2,500 per well	$15,000
			Subtotal	$2,107,880
			Contingency (25%)	$526,970
			Professional services (15%)	$316,182
			Costs for POETSs installed since 2/20/2018	$0
			Total Capital	**$2,951,032**
Annual O&M Cost				
GAC POETSs	6	POETSs	Standard household systems, $1,000 per well	$6,000
			Subtotal	$6,000
			20 years of annual O&M	$120,000
			20 years of annual O&M present value (inflation + interest)	$114,494
			20-year costs (capital + O&M)	**$3,071,032**
			20-year present value costs (capital + O&M and inflation + interest)	**$3,065,526**
			Capital and operating cost per 1,000 gal	$0.69
			Operating only cost per 1,000 gallons	$0.03

E.2.8.6 Cost Implications of particle tracking

The cost implications of the particle tracking analyses are provided in Table E.35 below and would be over and above base costs. For Newport, the groundwater particle tracking analysis estimated that by 2040 a portion in the southeastern region of the city has the potential to become impacted by PFAS. As a result, costs are included for an additional 16 non-municipal wells to receive POETSs.

Table E.35. Option 1 Particle tracking costs for Newport.

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
GAC POETSs	16	POETSs	Standard household systems, $2,500 per well	$40,000
			Subtotal	$40,000
			Contingency (25%)	$10,000
			Professional services (15%)	$6,000
			Total Capital	**$56,000**
Annual O&M Cost				
GAC POETSs	16	POETSs	Standard household systems, $1,000 per well	$16,000
			Subtotal	$16,000
			20 years of annual O&M	$320,000
			20 years of annual O&M present value (inflation + interest)	$305,318
			20-year costs (capital + O&M)	**$376,000**
			20-year present value costs (capital + O&M and inflation + interest)	**$361,318**

E.2.9 Oakdale

E.2.9.1 Project summary

Oakdale currently has PFAS impacts to its municipal water system, which serves nearly all of their community. The improvements considered for Oakdale under recommended Option 1 would include the expansion of the city's centralized WTP to treat two of their existing municipal supply wells, and relocation of other wells closer to the centralized WTP. While the majority of the city is connected to the municipal distribution system, POETSs would be installed for PFAS-impacted non-municipal wells that meet the treatment threshold and could not be connected to the existing system. The infrastructure improvements included in this option are shown in Figure E.2a/b, and the implications on Oakdale's private and non-municipal wells are shown in Figure E.1.

Water supply

Oakdale's municipal water system consists of seven existing municipal wells (wells 1, 2, 3, 5, 7, 9, and 10) that have a combined design capacity of 6,675 gpm, as shown in Table E.36. Due to high iron and manganese levels, well 6 has been taken out of service. Well 8 was taken out of service due to PFAS impacts. Well 8 is also the farthest well away from the existing treatment facility and the closest to a source area (Oakdale Disposal Site). They are not currently using wells 1, 2, and 7, as those wells have HI values above 1 and are not receiving treatment. It is more cost-effective to use the proposed new wells relocated closer to centralized treatment than it would be to treat the wells from their current locations.

Under firm capacity conditions with their largest well out of service, Oakdale's current supply produces 5,575 gpm, which is sufficient to meet their current demand as well as their year 2040 maximum daily demand of approximately 4,900 gpm. In addition, the city's current permitted capacity is 1,210 million gallons per year or 3.32 MGD, which is also sufficient to cover their 2040 ADD of 3.06 MGD. Their existing treatment facility has 2,000 gpm of capacity and currently treats wells 5 and 9. By 2040, additional wells will need treatment in order to meet demands.

Table E.36. Oakdale municipal well HI values and Pumping rates as of first quarter 2021.

Well No.	Design Pumping Rate (gpm)	HI Value[1]
1	925	7.95
2	950	7.86
3	1,000	0.013
5	850	59.33
6	TAKEN OUT OF SERVICE	
7	1,000	30.57
8	TAKEN OUT OF SERVICE	
9	1,100	48.11
10	850	0.007
Total	6,675	

Note:
1. HI values for municipal wells are based on sampling completed as of the first quarter of 2021.

E.2.9.2 Project improvements

New municipal supply wells

New municipal wells are not required from a capacity perspective to meet Oakdale's 2040 MDDs and firm capacity requirements. However, based on historical sampling conducted at municipal and non-municipal wells in Oakdale, any additional wells, existing or new, will require PFAS treatment. Because it is more cost-effective to treat wells at a centralized location than run raw water from existing well locations, three new wells will be drilled closer to the existing treatment facility.

The groundwater model was used to determine well placement through a well interference and drawdown analysis. Proposed well locations were provided to the groundwater modeling team along with the design flow rates to determine whether the potential drawdown exceeded the current limits. The modeling performed to assess improvements for Oakdale will be discussed in the hydraulic and groundwater modeling sections (E.2.9.3 and E.2.9.4, respectively).

WTPs

Based on a threshold of HI ≥ 0.5, wells 5 and 9 would remain routed to the existing treatment facility, which would be expanded to accommodate flow from three new wells. This would require the treatment facility capacity to increase by 2,050 gpm for a firm treatment capacity of 4,050. Neither of the wells located in the north (wells 3 and 10) have HI values at or above 0.5, nor would they receive treatment. Appendix F Section F.4 provides additional information on how treatment facility capacities were determined.

Water main extensions and distribution lines

Wherever possible according to the HI threshold, homes with PFAS-impacted non-municipal wells would be connected to the city's municipal water system. However, currently 96% of the city's population is served by the existing municipal water distribution system. Therefore, no water main extensions were proposed to be extended to new neighborhoods. Under this Option, four existing non-municipal wells would be replaced with connections to the existing distribution system lines by installing a service lateral and sealing the well.

POETSs

Current PFAS-impacted non-municipal wells that are not proposed to be connected to the municipal water system would be provided with POETSs based on the HI threshold. According to PFAS sampling data from October 2020 and MWI data, Oakdale has an estimated 109 existing non-municipal wells, of which 23 have been sampled. Of the sampled wells, four would be replaced with a connection to the existing distribution system and no wells would require a POETS. Furthermore, no wells had an existing POETS that would require continued O&M.

E.2.9.3 Hydraulic modeling analysis

The hydraulic analysis focused on the pumping requirements and sizing of the raw water transmission lines required to replace existing wells with new wells closer to and expanding the existing WTP. Since almost the entire city is connected to the municipal distribution system, no neighborhood distribution line extensions were included. The drawdown analysis using the groundwater model provided the dynamic or pumping water level at each well location to help determine the appropriate operating point of the pump and maintain sufficient system pressures. In order to maintain system pressures, existing well pumps for wells 5 and 9 would need to be modified when they are routed to a centralized treatment facility. Well modifications could entail bowl, motor, or impellor modifications, or improvements to match the new system curve. Additional improvements may also be needed to local programmable logic controllers, instrumentation, or SCADA systems. In addition, as the capacity of the existing WTP is increased and more flow is conveyed to the facility from new wells, a parallel influent and effluent line will be required to increase conveyance capacity.

In the southern region, the hydraulic model indicates that the majority of the pressures ranged between 60 and 90 psi. However, the southeastern corner experiences pressures between 90 to 100 psi resulting from lower elevations. Areas of low pressure were more centrally located near Hale Avenue and places with higher surface or ground elevations such as those areas near Tank 4.

In the central region, pressures were slightly higher, with pressures along the western half ranging from 75 to 90 psi and pressures on the eastern side ranging from 60 to 90 psi. The highest pressures were found to be more centrally located and on the far east side.

In the northern region, the majority of the pressures were in the 60 to 70 psi range, with pressures increasing along the northern boundary up to 90 psi. The lowest pressures in the northern region were more centrally located as well. These pressures in all regions were consistent with those currently observed in the system, and pump modifications and design operating points were considered to keep this consistency. Thus, no additional PRVs or booster pump stations to modify the existing pressures were required. The water supply improvements based on the hydraulic modeling are included in base capital costs in Section E.2.9.5.

E.2.9.4 Groundwater modeling analysis

The pumping conditions analyzed using the groundwater model are summarized in Table E.37. Three additional supply wells, which would extract water from the Jordan Sandstone, were added to replace existing wells that will be taken out of service. The rates assigned to the existing and new wells represent long-term averages based on the anticipated 2040 ADD.

Table E.37. Summary of Oakdale ADD for existing and new municipal wells under Recommended Option 1.

Well	Unique Well ID	ADD (gpm)
1	208462	Off
2	208463	Off
3	208454	318
4	226607	Off
5	127287	271
6	151575	Off
7	463534	Off
8	572608	Off
9	611059	350
10	773389	271
New Well 1		294
New Well 2		302
New Well 3		318

The simulated drawdown was analyzed to ensure that both the Jordan Sandstone and Prairie du Chien aquifers do not become unconfined. The aquifers were analyzed using written guidance from the DNR.

Under dry conditions, ADD rates for the Oakdale water supply wells were increased by multiplying the current condition rates by a factor of 1.25 (the ratio of maximum per capita demand over average per capita demand from years 2005–2015). Pumping rates at irrigation wells were also increased by taking the maximum annual volume reported over a 30-year period (1988–2018). Drawdown under dry and wet conditions in the Prairie Du Chien and Jordan Sandstone aquifers is shown in Figures E.6, E.7, E.8, and E.9. Table E.38 below provides a summary of drawdown in the Jordan Sandstone aquifer under wet and dry conditions and drawdown in the Prairie du Chien under dry conditions.

Table E.38. Summary of drawdown in the Jordan Sandstone and Prairie du Chien aquifer under wet and dry conditions.

	Jordan Sandstone aquifer				Prairie du Chien Aquifer		
	Drawdown (m)		Available Head (m)	Dry Drawdown as Percent of Available Head (%)	Drawdown (m)	Available Head (m)	Dry Drawdown as Percent of Available Head (%)
Well	Wet	Dry			Dry		
1	Off						
2	Off						
3	3	5	79	6	2	43	5
4	Off						
5	<1	<1	62	0	<1	36	0
6	Off						
7	Off						
8	Off						
9	<1	<1	72	0	<1	37	0
10	4	6	83	7	3	46	6
New Well 1	10	7	79	9	4	41	10
New Well 2	11	13	78	17	4	40	10
New Well 3	7	8	77	10	3	40	7

Under dry conditions, drawdown does not exceed the 50% available head in the Jordan Sandstone aquifer nor in the Prairie du Chien aquifer. Additionally, the effect of pumping is localized such that the general groundwater flow direction, which is from northeast to southwest, is not altered.

Forward particle tracking to year 2040 was conducted from known PFAS sources and areas where HI ≥ 1 under dry and wet climate conditions, as shown on Figures E.10 and E.11, respectively. Wells 1, 2, 4, 6, 7, 8 were turned off for the particle tracking analysis, as these wells either were replaced or will remain out of service. Wells 3, 5, 9, and 10 along with the new wells were operating at the average daily rates used for the drawdown analysis discussed above. Particles inserted into the model travel in the direction of groundwater flow (northeast to southwest in the Prairie Du Chien and Jordan Sandstone aquifers). Particles traveling under wet and dry conditions were captured by well 5 and the new wells.

E.2.9.5 Base cost estimate breakdown

Base capital and O&M costs are summarized in Table E.39 and include only Settlement-eligible costs. Base costs do not consider those costs incurred as a result of the groundwater model particle tracking analysis. The improvements included for Oakdale include the expansion of the existing treatment facility, new raw water transmission and distribution lines, and the replacement of four wells with connections to the municipal water system. No wells were identified to receive a POETS.

Table E.39. Base costs for improvements included in Option 1 for Oakdale.

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
PFAS WTPs	1	WTPs	4,050 gpm MDD (expand existing WTP by 2,050 gpm)	$5,890,000
Temporary Treatment Facility Demo	1	Lump Sum	At well 7	$500,000
Municipal Well Demo	4	Ea	$130K per well ($49K to seal well, wells 1,2,7,8)	$520,000
WTP site prep	1	Lump Sum	Site Preparation and Demo at Existing Public Works Facility	$250,000
New Well	3	Wells	Replace W1,W2, and W7 - match capacity	$6,534,000
Well Modifications	2	Ea	Well & SCADA upgrades	$400,000
Raw water transmission mains	0.53	Miles	From new wells to exist WTP	$1,119,942
Stormwater Costs	1	Lump Sum	Stormwater Costs 30% of Linear and Facility Projects	$2,483,983
Service Laterals	4	Ea	Connect homes to existing mains ($4,000 ea)	$16,000
Oakdale City Fees for New Connections	4	Ea	City Fees include WAC ($550), Connection Fee (0), Meter ($400), and Permit ($80)	$4,120
Well Sealing	4	Ea	$2,700 per well	$10,800
Land acquisition (site + water mains)	3.1	Acres	1/2 acre per well, 1 acre at WTP, 20 ft easements (50%)	$561,875
GAC POETSs	0	POETSs	Standard household systems, $2,500 per well	$0

Item	Quantity	Units	Description	Total Cost (GAC)
			Subtotal	$18,290,720
			Contingency (25%)	$4,572,680
			Professional services (15%)	$2,743,608
			Costs for POETSs installed since 2/20/2018	$0
			Total Capital	**$25,607,008**
Annual O&M Cost				
PFAS WTPs	1	WTP	Media Cost	$388,957
PFAS WTPs	1	WTP	Maint. and Operations	$398,500
GAC POETSs	0	POETSs	Standard household systems, $1,000 per well	$0
			Subtotal	$787,457
			20 years of annual O&M	$15,749,132
			20 years of annual O&M present value (inflation + interest)	$15,026,528
			20-year costs (capital + O&M)	**$41,356,140**
			20-year present value costs (capital + O&M and inflation + interest)	**$40,633,536**
			Capital and operating cost per 1,000 gal	$1.88
			Operating only cost per 1,000 gallons	$0.70

E.2.9.6 Cost Implications of particle tracking

As shown in Figures E.1, E.10 and E.11, the particle tracking indicated that a large portion of the community is within an area of potential future PFAS contamination. The cost implications of the particle tracking analyses are provided in Table E.40 below and would be over and above base costs. For Oakdale, the results from the groundwater particle tracking analysis indicated that four wells have the potential to be impacted by year 2040 and do not have water lines in front of their homes and therefore would require POETSs. Twenty-five non-municipal wells were captured by particle tracking; these do have adjacent water lines, and may be replaced with a connection to the existing distribution system.

Table E.40. Option 1 Particle tracking costs for Oakdale.

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
Service Laterals	25	Ea	Connect homes to existing mains ($4,000 ea)	$100,000
Oakdale City Fees for New Connections	25	Ea	City Fees include WAC ($550), Connection Fee (0), Meter ($400), and Permit ($80)	$25,750
Well Sealing	25	Ea	$2,700 per well	$67,500
GAC POETSs	4	POETSs	Standard household systems, $2,500 per well	$10,000
			Subtotal	$203,250
			Contingency (25%)	$50,813
			Professional services (15%)	$30,488
			Total Capital	**$284,550**

Item	Quantity	Units	Description	Total Cost (GAC)
Annual O&M Cost				
GAC POETSs	4	POETSs	Standard household systems, $1,000 per well	$4,000
			Subtotal	$4,000
			20 years of annual O&M	$80,000
			20 years of annual O&M present value (inflation + interest)	$76,329
			20-year costs (capital + O&M)	**$364,550**
			20-year present value costs (capital + O&M and inflation + interest)	**$360,879**

E.2.9.7 Pretreatment cost summary

The following table provides a cost summary for iron and manganese pretreatment as a potential future cost. Pretreatment costs also include associated stormwater costs. These costs were used to inform decisions made as part of the Conceptual Plan, but may not be Settlement-eligible unless determined to be the most cost-effective alternative, as described in Chapter 9.

Table E.41. Summary of pretreatment costs for Oakdale.

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
Pretreatment at WTP	1	Lump Sum	Iron/Manganese	$5,492,377
Stormwater Costs	1	Lump Sum	Stormwater Costs 30% of Linear and Facility Projects	$1,647,713
		Subtotal		$7,140,090
		Contingency (25%)		$1,785,022
		Professional services (15%)		$1,071,013
		Total Capital		**$9,996,126**
Annual O&M Cost				
Pretreatment at WTP	1	WPT	Backwash fees, Maintenance, and FTEs	$545,967
		Subtotal		$545,967
		20 years of annual O&M		$10,919,339
		20 years of annual O&M present value (inflation + interest)		$10,418,336
		20-year costs (capital + O&M)		**$20,915,465**
		20-year present value costs (capital + O&M and inflation + interest)		**$20,414,462**

E.2.10 PIIC

E.2.10.1 Project summary

PIIC has land within West Lakeland Township, which is currently undeveloped but is anticipated to be developed for mixed residential and commercial use of their members and guests. The improvements considered for PIIC under recommended Option 1 include the modification of the existing irrigation well to a drinking water well; installation of a WTP and storage tank at the existing well location; and the distribution system to provide water service to future community members as shown in Figure E.2a/b (note that the distribution system is not visible at the scale of these figures).

E.2.10.2 Project improvements

Water supply and WTPs

The parcel of land owned by PIIC has not yet been developed. Currently, there is an irrigation well that is being considered for conversion to a drinking water supply well. Sampling conducted as of October 2020 indicates the well has been impacted by PFAS contamination and has an HI value greater than 1. According to information provided by PIIC, this well can produce somewhere between 600 and 800 gpm once converted, which meets the expected community demand of 300 gpm based on the preliminary site plan for the proposed development. In addition, the well would need to be modified to meet applicable well codes for a drinking water supply well. Under this option, a 300 gpm capacity WTP would be installed at the modified well to serve its future residents. The water supply improvements are included in base capital costs in Section E.2.10.5.

E.2.10.3 Hydraulic modeling analysis

A drinking water distribution model was not created for this community as there is no existing municipal water system within PIIC at this time. However, it was assumed that all proposed distribution lines would be 8" in order to accommodate fire flow. The water supply improvements are included in base capital costs in Section E.2.10.5.

E.2.10.4 Groundwater modeling analysis

A new municipal well extracting water from the Jordan Sandstone aquifer capable of producing an ADD of 300 gpm was evaluated with the groundwater flow model.

Table E.42. Summary of PIIC ADD for existing and new municipal wells under Recommended Option 1.

Well	Unique Well ID	ADD (gpm)
1	443914	300

The simulated drawdown was analyzed to ensure that both the Jordan Sandstone and Prairie du Chien aquifers do not become unconfined. The aquifers were analyzed using written guidance from the DNR. Under dry conditions, the average rate for the new well was increased by multiplying the average rate by a factor of 1.33. Since PIIC does not have an existing public water system, the water system characteristics for Lake Elmo were used, assuming a similar demand trend based on population. The ratio of maximum per capita demand over average per capita demand from years 2005–2015 for Lake Elmo is 1.33. Pumping rates at irrigation wells were also increased by taking the maximum annual volume reported over a 30-year period (1988–2018).

The simulated drawdown is less than 1 meter under both wet and dry conditions, and, therefore, does not exceed the 50% available head in the Jordan Sandstone and Praire du Chien aquifers. The effect of pumping is located such that the general groundwater flow direction is not altered. Table E.43 below provides a summary of drawdown in the Jordan Sandstone aquifer under wet and dry conditions and drawdown in the Prairie du Chien under dry conditions.

Table E.43. Summary of drawdown in the Jordan Sandstone and Prairie du Chien aquifer under wet and dry conditions.

	Jordan Sandstone Aquifer				Prairie du Chien Aquifer		
	Drawdown (m)		Available Head (m)	Percent of Available Head (dry)	Drawdown (m)	Available Head (m)	Percent of Available Head (dry)
Well	Wet	Dry			Dry		
1	<1	<1	56	0	<1	31	0

Forward particle tracking to year 2040 was conducted from known PFAS sources and areas where HI ≥ 1 under dry and wet climate conditions, as shown on Figures E.10 and E.11, respectively. Particles inserted into the model follow the direction of groundwater flow. In the vicinity of PIIC, the general direction of groundwater flow in the Prairie Du Chien and Jordan Sandstone aquifers is from west to east toward the St. Croix River, as represented by particle tracking figures. The irrigation well to be converted to a potable water supply well has been impacted by PFAS contamination. Additionally, in each of the particle tracking conditions, the new well is located along particle pathways that originate from upgradient areas where HI ≥ 1. Particle tracking also indicates the southern area of PIIC may be impacted; therefore, drilling a new well in the southern portion of PIIC is not a likely option for providing drinking water without treatment.

E.2.10.5 Base cost estimate breakdown

Base capital and O&M costs are summarized in Table E.44 and include only Settlement-eligible costs. Base costs do not consider those costs incurred as a result of the groundwater model particle tracking analysis. The improvements for PIIC include modification of the existing irrigation well to a drinking water well and installation of a WTP, storage tank, distribution system, service lateral connections, and land costs. No previous or future POETSs are included.

Table E.44. Base costs for improvements included in Option 1 for PIIC.

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
PFAS WTPs	1	WTP	300 gpm MDD	$1,734,956
Well Modifications	1	Wells	Well upgrades	$113,250
Storage tanks	1	Tank	60k Gallon	$780,000
Water distribution mains	1.66	Miles	Water distribution system for 80 lots	$962,610
Stormwater Costs	1	Lump Sum	Stormwater Costs 30% of Linear and Facility Projects	$1,043,270
Service Laterals	80	Ea	Connect homes to existing mains ($3500 ea)	$280,000
Land acquisition (site + water mains)	1.5	Acres	0.5 acres at each WTP, 20 ft easements (50%)	$211,702
GAC POETSs	0	POETSs	Standard household systems, $2,500 per well	$0
			Subtotal	$5,125,787*
			Contingency (25%)	$1,281,447
			Professional services (15%)	$768,868
			Costs for POETSs installed since 2/20/2018	$0
			Total Capital	**$7,176,102***

Item	Quantity	Units	Description	Total Cost (GAC)
Annual O&M Cost				
PFAS WTPs	1	WTP	Media Cost	$2,337
PFAS WTPs	1	WTP	Maint. and Operations	$138,748
GAC POETSs	0	POETSs	Standard household systems, $1,000 per well	$0
			Subtotal	$141,085
			20 years of annual O&M	$2,821,696
			20 years of annual O&M present value (inflation + interest)	$2,692,230
			20-year costs (capital + O&M)	**$9,997,798**
			20-year present value costs (capital + O&M and inflation + interest)	**$9,868,333**
			Capital and operating cost per 1,000 gal	$3.13
			Operating only cost per 1,000 gallons	$0.85

*Line items do not sum to the exact total due to rounding (+/- $1.00)

E.2.10.6 Cost Implications of particle tracking

As shown in Figures E.1, E.10 and E.11, the particle tracking indicated that the entire parcel owned by PIIC is within an area of potential future PFAS contamination. However, because the existing supply well would require treatment and all future homes would be connected to the system under this option regardless of the particle tracking analysis, there are no costs resulting from the analysis.

E.2.10.7 Pretreatment cost summary

The following table provides a cost summary for iron and manganese pretreatment as a potential future cost. Pretreatment costs also include associated stormwater costs. These costs were used to inform decisions made as part of the Conceptual Plan, but may not be Settlement-eligible unless determined to be the most cost-effective alternative, as described in Chapter 9.

Table E.45. Summary of pretreatment costs for PIIC.

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
Pretreatment at WTP	300	gpm	Iron/Manganese	$852,057
Stormwater Costs	1	Lump Sum	Stormwater Costs 30% of Linear and Facility Projects	$255,617
			Subtotal	$1,107,674
			Contingency (25%)	$276,918
			Professional services (15%)	$166,151
			Total Capital	**$1,550,743**
Annual O&M Cost				
Pretreatment at WTP	gpm	gpm	Backwash fees, Maintenance, and FTEs	$105,073
			Subtotal	$105,073
			20 years of annual O&M	$2,101,461
			20 years of annual O&M present value (inflation + interest)	$2,005,042
			20-year costs (capital + O&M)	**$3,652,205**
			20-year present value costs (capital + O&M and inflation + interest)	**$3,555,785**

E.2.11 St. Paul Park

E.2.11.1 Project summary

St. Paul Park currently has PFAS impacts to its municipal water system, which serves the majority of the community. The improvements considered for St. Paul Park under recommended Option 1 include installing a centralized WTP to treat the existing municipal supply wells, replacing non-municipal wells with connections to existing water mains, and maintaining existing POETSs. The infrastructure improvements included in this option are shown in Figure E.2a/b, and the implications on St. Paul Park's private and non-municipal wells are shown in Figure E.1.

Water supply

St. Paul Park's municipal water system consists of three existing municipal wells (wells 2, 3, and 4) that have a total combined design capacity of 2,100 gpm and a firm capacity with their largest well (well 4) out of service of 1,200 gpm, as shown in Table E.46. With a 2040 MDD of just under 1,200 gpm, St. Paul Park is able to meet this demand with their existing wells under firm capacity conditions.

Table E.46. St. Paul Park municipal well HI values and Pumping rates as of first quarter 2021.

Well No.	Design Pumping Rate (gpm)	HI Value[1]
2	600	0.71
3	600	1.58
4	900	1.31
Total	2,100	

Note:

1. HI values for municipal wells are based on sampling completed as of the first quarter of 2021.

E.2.11.2 Project improvements

WTPs

St. Paul Park has recently implemented a 2,200 gpm temporary WTP to treat groundwater supplied by wells 3 and 4. Eventually, the city plans to connect well 2 to the temporary WTP and upgrade it to meet 2040 MDDs and what the city considers to be its ultimate buildout capacity. Under this option, the WTP would be made permanent and all municipal supply wells (including well 2) would be routed to the WTP.

Water main extension to existing neighborhoods

Wherever possible according to the HI threshold, homes with PFAS-impacted non-municipal wells would be connected to the city's municipal water system. However, no additional distribution lines are required to be installed in St. Paul Park at this time. Under this option, six existing non-municipal wells would be replaced with connections to existing distribution system lines by installing a service lateral and sealing the well.

POETSs

This option would provide POETSs for PFAS-impacted non-municipal wells that meet the treatment threshold. As of October 2020 sample data, St. Paul Park has an estimated 66 existing non-municipal wells, of which 25 wells have been sampled. All remaining sampled wells that are not being connected and do not have an existing POETS have an HI value less than 0.5, and thus, no new POETSs are proposed under this Option. There are, however, five existing POETSs that would need to be included in the O&M costs.

E.2.11.3 Hydraulic modeling analysis

Similar to other communities, St. Paul Park currently has a hydraulic model that they have used to determine upgrades and improvements to their system. The existing model is an extended period simulation, while the models that Wood had developed are steady state. Wood used pressure data provided by the city to calibrate the model so that it reflects actual conditions at a particular time. There were no pump curves available to use in the model, and a single point design curve was used for each of the pumps based off the data provided by the city. Using a pump curve allowed the flow and head or pressure from the pump to vary with changes made to the system. and reflects how the pump would typically operate. It is recommended for future analysis that an extended period simulation be used and that the pump curves for the pumps currently in operation be used in the model.

The city has observed an issue with filling the two storage towers with the proposed WTP in operation, as one tower is located next to the WTP and fills at a faster rate, while the other tower is considerably further away. To address this, it is recommended that an altitude valve be installed at the Lincoln Tower to allow flow to be conveyed to the Broadway Tower. However, the city had reported that the closing of the altitude valve would cause pressure spikes around 30 psi. While the hydraulic modeling performed under this project was not an extended period analysis, the steady-state results could not duplicate the 30-psi pressure spike, but did see a pressure spike of approximately 23 psi near the tank. Pressures in this area increase from approximately 60 psi to 83 psi. To mitigate this pressure, and increase, and facilitate flows to the Broadway Tower, the city had requested that a 12-inch line be installed from the treatment facility up to the tower in addition to the existing line. Based on Wood's modeling results, it is recommended that a parallel 12-inch line along Summit Ave from 13th Ave to Broadway be installed. The water supply improvements based on the hydraulic modeling are included in base capital costs in Section E.2.11.5.

E.2.11.4 Groundwater modeling analysis

Forward particle tracking to year 2040 was conducted from known PFAS sources and areas where HI ≥ 1 under dry and wet climate conditions, as shown on Figures E.10 and E.11, respectively. Particles inserted into the model travel in the direction of groundwater flow. In St. Paul Park, groundwater flow in the Prairie Du Chien and Jordan Sandstone aquifers is generally from east/northeast to west/southwest, toward the Mississippi River. A cluster of groundwater samples with HI ≥ 1 is located within close proximity to the city's northeast boundary. The samples were collected from wells drilled into Prairie Du Chien and Jordan Sandstone aquifers. Particles inserted around this cluster of wells travel west/southwest into St. Paul Park and will reach municipal and non-municipal wells within the city limits by the year 2040. A drawdown analysis was not performed for St. Paul Park since no new wells were proposed.

E.2.11.5 Base cost estimate breakdown

Base capital and O&M costs are summarized in Table E.47 and include only Settlement-eligible costs. Base costs do not consider those costs incurred as a result of the groundwater model particle tracking analysis. The improvements for St. Paul Park include installing a centralized WTP to treat the existing municipal supply wells with some modifications, associated land and stormwater costs, service lateral connections for homes next to existing water lines, and maintaining POETSs.

Table E.47. Base costs for improvements included in Option 1 for St. Paul Park.

Item	Quantity	Units	Description	Total Cost (GAC)
New Capital Cost				
PFAS WTPs	1	WTP	2,200 gpm MDD WTP for wells 2,3,4	$5,706,804
Well Modifications	3	Wells	Well & SCADA upgrades	$600,000
Raw water transmission mains	0.61	Miles	From wells to WTP	$1,448,261
Water distribution mains	1.05	Miles	12" to Broadway Tank	$2,605,356
Stormwater Costs	1	Lump Sum	Stormwater Costs 5% of Linear and Facility Projects	$488,021
Service Laterals	6	Ea	Connect homes to existing mains ($7500 ea)	$45,000
St. Paul Park City Fees for New Connections	6	Ea	City Fees include WAC ($885), Connection Fee ($0), Meter ($525), and Permit ($175)	$9,510
Well Sealing	6	Ea	$2,700 per well	$16,200
Existing GAC POETS Removal	1	Ea	$400	$400
Land acquisition (site + water mains)	3.0	Acres	1 acre at WTP, 20 ft easements (50%)	$408,592
GAC POETSs	0	POETSs	Standard household systems, $2,500 per well	$0
			Subtotal	$11,328,144
			Contingency (25%)	$2,832,036
			Professional services (15%)	$1,699,222
			Costs for POETSs installed since 2/20/2018	$21,000
			Total Capital	**$15,880,401***
Annual O&M Cost				
PFAS WTPs	1	WTP	Media cost	$26,579
PFAS WTPs	1	WTP	Maint. and operations	$389,340
GAC POETSs	5	POETSs	Standard household systems, $1,000 per well	$5,000
			Subtotal	$420,919
			20 years of annual O&M	$8,418,384
			20 years of annual O&M present value (inflation + interest)	$8,032,130
			20-year costs (capital + O&M)	**$24,298,785**
			20-year present value costs (capital + O&M and inflation + interest)	**$23,912,532**
			Capital and operating cost per 1,000 gal	$1.03
			Operating only cost per 1,000 gallons	$0.35

*Line items do not sum to the exact total due to rounding (+/- $1.00)

E.2.11.6 Cost Implications of particle tracking

As shown in Figure E.1, the particle tracking indicated that a large portion of St. Paul Park is within an area of potential future PFAS contamination. The cost implications of the particle tracking analyses are provided in Table E.48 below and would be over and above base costs. For St. Paul Park, the particle tracking estimated an additional 20 POETSs and 13 connections to the municipal system may be needed.

Table E.48. Option 1 Particle tracking costs for St. Paul Park.

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
Service Laterals	13	Ea	Connect homes to existing mains ($7,500 ea)	$97,500
SPP City Fees for New Connections	13	Ea	City Fees include WAC ($885), Connection Fee ($0), Meter ($525), and Permit ($175)	$20,605
Well Sealing	13	Ea	$2,700 per well	$35,100
GAC POETSs	20	POETSs	Standard household systems, $2,500 per well	$50,000
		Subtotal	$203,205	
		Contingency (25%)	$50,801	
		Professional services (15%)	$30,481	
		Total Capital	**$284,487**	
Annual O&M Cost				
GAC POETSs	20	POETSs	Standard household systems, $1,000 per well	$20,000
		Subtotal	$20,000	
		20 years of annual O&M	$400,000	
		20 years of annual O&M present value (inflation + interest)	$381,647	
		20-year costs (capital + O&M)	**$684,487**	
		20-year present value costs (capital + O&M and inflation + interest)	**$666,134**	

E.2.11.7 Pretreatment cost summary

The following table provides a cost summary for iron and manganese pretreatment as a potential future cost. Pretreatment costs also include associated stormwater costs. These costs were used to inform decisions made as part of the Conceptual Plan, but may not be Settlement-eligible unless determined to be the most cost-effective alternative, as described in Chapter 9.

Table E.49. Summary of pretreatment costs for St. Paul Park.

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
Pretreatment at WTP	2200	gpm	Iron/Manganese	$3,542,577
Stormwater Costs	1	LS	Stormwater Costs 5% of Linear and Facility Projects	$177,129
		Subtotal	$3,719,706	
		Contingency (25%)	$929,926	
		Professional services (15%)	$557,956	
		Total Capital	**$5,207,588**	

Item	Quantity	Units	Description	Total Cost (GAC)
Annual O&M Cost				
Pretreatment at WTP	2200	gpm	Backwash fees, Maintenance, and FTEs	$345,431
		Subtotal	$345,431	
		20 years of annual O&M	$6,908,611	
20 years of annual O&M present value (inflation + interest)			$6,591,629	
20-year costs (capital + O&M)			**$12,116,199**	
20-year present value costs (capital + O&M and inflation + interest)			**$11,799,216**	

E.2.12 West Lakeland

West Lakeland Township (WLT) is considered a rural community and does not have an existing municipal water supply. However, West Lakeland has PFAS contamination within the aquifers used by non-municipal drinking water wells across the southern two-thirds of the community. Two alternatives were considered and evaluated for West Lakeland to address PFAS contamination within the community. One alternative (Alternative 1) would provide POETSs for all wells exceeding the HI threshold and is described in Section E.2.12.1. Another alternative (Alternative 2) includes implementation of a new municipal water treatment and distribution system and is described in Section E.2.12.2. The Conceptual Plan ultimately includes costs for West Lakeland residents to remain on private wells and receive POETSs as determined by sampling and based on the treatment threshold of HI ≥ 0.5 (Alternative 1), as discussed in Chapters 8 and 9.

E.2.12.1 West Lakeland POETS alternative

E.2.12.1.1 Project summary

The improvements considered for West Lakeland under recommended Option 1 Alternative 1 was to keep residents and water users on private or non-municipal wells. POETSs would be provided to any resident with PFAS-impacted wells that exceed the threshold of HI ≥ 0.5. The implications for West Lakeland's private and non-municipal wells which correspond to Alternative 1 only are shown in Figure E.1.

E.2.12.1.2 Project improvements

This alternative includes only POETSs as long-term solutions for West Lakeland, and therefore WTPs, water main extensions, and other municipal water supply components were not considered.

POETSs

Under this option, PFAS-impacted non-municipal wells would be provided treatment with POETSs based on the threshold of HI ≥ 0.5. According to MWI data and feedback from township Work Group members, West Lakeland has an estimated 1,393 existing non-municipal wells. Based on PFAS sampling data from October 2020, 995 of these wells have been sampled. Of the sampled wells, 552 currently have POETSs installed to treat PFAS, while approximately 111 wells have POETSs in the northern region due to unrelated trichloroethylene (TCE) contamination. There is some overlap between wells that have a POETS install for TCE and those that meet the treatment threshold for PFAS and/or already have POETSs installed for PFAS. It may be possible to reuse or modify POETSs installed for TCE to also treat PFAS. However, for the purposes of cost estimating, it is assumed that POETSs installed for TCE will not be reused for PFAS treatment. New POETSs are included in cases where a well meets the treatment threshold and already has a POETS for TCE. According to available sampling data, 103 wells exceed the threshold and would require POETSs, for a total of 766 POETSs as long-term solutions.

E.2.12.1.3 Hydraulic modeling analysis

No drinking water distribution model was created for this alternative for West Lakeland.

E.2.12.1.4 Groundwater modeling analysis

Forward particle tracking to year 2040 was conducted from known PFAS sources and areas where HI ≥ 1 under dry and wet climate conditions, as shown on Figures E.10 and E.11, respectively. Particle movement simulated in the model is in the direction of groundwater flow. In West Lakeland, groundwater in the uppermost bedrock aquifers generally flows west to east toward the St. Croix River. The non-municipal wells are located in an area where groundwater particles are traveling from areas with HI > 1, and many wells in West Lakeland exceed HI > 1 within the same Prairie Du Chien and/or Jordan Sandstone aquifers. Based on this analysis, West Lakeland may see additional impacts to wells that are not currently impacted based on additional sampling or localized movement of PFAS. A drawdown analysis was not performed for this alternative for West Lakeland since no new wells are proposed.

E.2.12.1.5 Base cost estimate breakdown

Base capital and O&M costs are summarized in Table E.50 and include only Settlement-eligible costs. Base costs do not consider those costs incurred as a result of the groundwater model particle tracking analysis. For West Lakeland, the base costs are for 552 existing and 103 new POETSs.

Table E.50. Base costs for improvements included in Option 1 for West Lakeland.

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
GAC POETSs	103	POETSs	Standard household systems, $2,500 per well	$257,500
			Subtotal	$257,500
			Contingency (25%)	$64,375
			Professional services (15%)	$38,625
			Costs for POETSs installed since 2/20/2018	$1,958,000
			Total Capital	**$2,318,500**
Annual O&M Cost				
GAC POETSs	655	POETSs	Standard household systems, $1,000 per well (change-out 1x per year)	$655,000
			Subtotal	$655,000
			20 years of annual O&M	$13,100,000
			20 years of annual O&M present value (inflation + interest)	$12,498,943
			20-year costs (capital + O&M)	**$15,418,500**
			20-year present value costs (capital + O&M and inflation + interest)	**$14,817,443**
			Capital and operating cost per 1,000 gal	$10.99
			Operating only cost per 1,000 gallons	$9.27

E.2.12.1.6 Cost Implications of particle tracking

As shown in Figures E.1, E.10 and E.11, the particle tracking indicated that the entire community is within an area of potential future PFAS contamination. The cost implications of the particle tracking analyses are provided in Table E.51 below and would be over and above base costs. For West Lakeland, the groundwater particle tracking analysis estimated that by 2040 all non-municipal wells may be impacted by PFAS contamination as indicated by the projected impact areas, and would receive treatment through existing or proposed POETSs. If the entire community were to be provided POETSs, an additional 738 systems would need to be installed and maintained above what is included in base costs.

Table E.51. Option 1 Particle tracking costs for West Lakeland.

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
GAC POETSs	738	POETSs	Standard household systems, $2,500 per well	$1,845,000
			Subtotal	$1,845,000
			Contingency (25%)	$461,250
			Professional services (15%)	$276,750
			Total Capital	**$2,583,000**
Annual O&M Cost				
GAC POETSs	738	POETSs	Standard household systems, $1,000 per well (change-out 1x per year)	$738,000
			Subtotal	$738,000
			20 years of annual O&M	$14,760,000
			20 years of annual O&M present value (inflation + interest)	$14,082,779
			20-year costs (capital + O&M)	**$17,343,000**
			20-year present value costs (capital + O&M and inflation + interest)	**$16,665,779**

E.2.12.2 West Lakeland municipal system alternative

E.2.12.2.1 Project summary

The improvements considered for West Lakeland under recommended Option 1 Alternative 2 include a new municipal water treatment and supply system. Under this alternative, West Lakeland would be provided with new municipal groundwater supply wells; a treatment facility; water storage tanks; and distribution system complete with BPSs, PRVs, and all appurtenances. The infrastructure improvements corresponding to Alternative 2 are shown in Figure E.2a/b.

E.2.12.2.2 Project improvements

New municipal supply wells

WLT is classified as rural residential, and all water supplied is from private or non-municipal wells. However, if West Lakeland were to implement a municipal water treatment and distribution system, they would need to drill a new municipal well capable of producing approximately 1,200 gpm. A second, redundant well with the same capacity is also included in costs.

The capacity needed to supply the community was calculated based on the per capita demand of nearby Lake Elmo, along with feedback from the township, which indicated that the per capita demands were greater than for Lake Elmo due to irrigation use for larger lot sizes. This calculation is described further in Appendix F, Section F.4.6.

The groundwater model was used to evaluate municipal well placement through a well interference and drawdown analysis. Proposed well locations were included in the groundwater model along with the design flow rates to determine whether the potential drawdown exceeded the DNR guidance. The modeling performed to assess improvements for the West Lakeland municipal system alternative will be discussed in the hydraulic and groundwater modeling sections (E.2.12.2.3 and E.2.12.2.4, respectively).

WTPs
Based on sampling data as of October 2020 and the extent of current PFAS contamination within the township as shown in Figure E.1, the municipal wells were assumed to need treatment, as it is likely that their HI values would exceed the threshold of 0.5. The WTP would have a capacity of 1,200 gpm to meet the community water supply demands, as discussed above.

New municipal water distribution system
Under this option, West Lakeland would receive a water distribution system with storage facilities and any necessary booster pump stations and PRVs to control system pressures. The distribution system was modeled (as discussed in a later section) and sized to meet 2040 MDD as well as provide for irrigation and fire flow. Line sizes consisted of both 8" and 12" pipe. The proposed distribution system would be limited to the southern two-thirds of the community based on current PFAS sampling data. The northern region currently impacted by only TCE would not be served by the proposed distribution system, as sampling has not shown PFAS impacts in this area and improvements there would not be Settlement-eligible. Wood also received feedback from the township regarding locations that would be less cost-effective to serve from the distribution system as compared to POETSs; these locations were not included in an effort to reduce pipe lengths and overall costs of the system.

Using these assumptions, approximately 1,190 wells would be replaced with a connection to the new distribution system. The distribution system remains the same based on the groundwater particle tracking analysis results as it is described here for base cost conditions.

POETSs
In addition to the treatment and distribution system, POETSs will be provided as necessary for non-municipal wells with PFAS impacts meeting the treatment threshold that are not already included as part of the proposed distribution system. Under these assumptions, approximately 12 existing POETSs would remain, and eight new POETSs would be included, for a total of 20 POETSs as long-term solutions for residents with non-municipal wells.

E.2.12.2.3 Hydraulic modeling analysis

A hydraulic model was created for West Lakeland to evaluate the proposed municipal water treatment and distribution system for this alternative. The proposed system was hydraulically modeled assuming that it would provide 1,200 gpm under MDD conditions and a fire flow of 1,000 gpm as the design flow rate specified by the township. In order to convey these flow rates, the distribution system comprises 8" and 12" lines. The model includes service to only those areas impacted by PFAS contamination, as described above. If the township decides in the future to provide service to additional areas, a separate hydraulic model evaluation should be performed.

West Lakeland has widely varying topography, with ground elevations ranging from 805 to 1,030 feet. The nature of its landscape creates hydraulic challenges for regulating system pressures. In order to maintain adequate pressures, both PRVs and BPSs would be required. The groundwater supply wells were placed on the west side of the township on a county-owned parcel, as shown in Figure E.2a/b. Water storage towers were placed at high points in the system provided by the township, and booster pump stations were placed along the boundaries of the high-pressure zones. PRVs were used to isolate pressure zones along the eastern side of the township and keep system pressures below 90 psi. The water supply improvements based on the hydraulic modeling are included in base capital costs in Section E.2.12.2.5.

E.2.12.2.4 Groundwater modeling analysis

Two new municipal wells were proposed for West Lakeland, one capable of producing an ADD of 405 gpm, and a redundant well, which would be used for back-up. Both wells would extract water from the Jordan Sandstone aquifer. Since the wells would be in close proximity to one another and would not be used at the same time, only one well location was evaluated for the groundwater modeling analysis.

Under dry conditions, the average rate for the new well was increased by multiplying the average rate by a factor of 1.33. Since West Lakeland does not have an existing public water system, the water system characteristics for Lake Elmo were used assuming a similar demand trend based on population. The ratio of maximum per capita demand over average per capita demand from years 2005–2015 for Lake Elmo is 1.33. Pumping rates at irrigation wells were also increased by taking the maximum annual volume reported over a 30-year period (1988–2018). Drawdown under dry and wet conditions are shown on Figures E.6, E.7, E.8, and E.9, respectively.

Under dry conditions, drawdown does not exceed the 50% available head in the Jordan Sandstone. The Prairie du Chien aquifer is currently unconfined at the new well location; therefore, head thresholds could not be applied to it. The effect of pumping is localized such that the general groundwater flow direction is not altered. Table E.52 provides a summary of drawdown in the Jordan Sandstone aquifer under wet and dry conditions. The back-up well would be located in close proximity to the new well 1; therefore, only one well was evaluated.

Table E.52. Summary of drawdown in the Jordan Sandstone aquifer under wet and dry conditions.

	Jordan Sandstone aquifer			
	Drawdown (m)		Available Head (m)	Dry Drawdown as Percent of Available Head (%)
Well	Wet	Dry		
New well 1	5	7	58	12

Forward particle tracking to 2040 was conducted from known PFAS sources and areas where HI ≥ 1 under dry and wet climate conditions, as shown on Figures E.10 and E.11, respectively. Since the new well is located in an area where surrounding non-municipal wells have an HI > 1, particles were captured by the well in the particle tracking analysis, suggesting the potential for PFAS contamination by the year 2040.

E.2.12.2.5 Base cost estimate breakdown

Base capital and O&M costs are summarized in Table E.53 and include only Settlement-eligible costs. Base costs do not consider those costs incurred as a result of the groundwater model particle tracking analysis. For this alternative, the base costs include those associated infrastructure elements required to implement a complete water treatment and distribution system, as well as POETSs where the distribution system would not reach.

Table E.53. Base costs for improvements included in Option 1 for West Lakeland.

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
PFAS WTPs	1	WTPs	1,200 gpm MDD	$3,986,000
New well	2	Wells	Each well 1200 gpm	$4,356,000
Fire Protection Cost Adder	1	Lump Sum	2 BPS (2–1900 gpm), extra 100k gal of storage per tank, upsized ~50,000 linear feet of 8" to 12" mains	$4,031,493
Pressure Reducing Valves	2	Stations	Two (2) PRVs	$250,000
Storage tanks	2	Tanks	0.6 MG total (0.3 MG each)	$2,204,000
Water distribution mains	44.7	Miles	8-12" distribution mains (PVC) for 1190 connections	$68,673,763
Stormwater Costs	1	Lump Sum	Stormwater Costs 30% of Linear and Facility Projects	$23,668,577
Service Laterals	1190	Ea	Connect homes to existing mains ($8,100 ea)	$9,639,000
West Lakeland Proposed City Fees for New Connections	1190	Ea	City Fees include WAC ($0), Connection Fee ($1,000), Meter ($0), and Permit ($0)	$1,190,000
Well Sealing	1190	Ea	$2,700 per well	$3,213,000
Existing GAC POETS Removal	540	Ea	$400	$216,000
Land acquisition (site + water mains)	57.2	Acres	1/2 acre per well, 1 acre at WTP, 20-ft easements (50%)	$8,078,648
GAC POETSs	8	POETSs	Standard household systems, $2,500 per well	$20,000
			Subtotal	$132,369,481
			Contingency (25%)	$33,092,370
			Professional services (15%)	$19,855,422
			Costs for POETSs installed since 2/20/2018	$52,000
			Total Capital	**$185,369,274**
Annual O&M Cost				
PFAS WTPs	1	WTP	Media Cost	$20,956
PFAS WTPs	1	WTP	Maint. and Operations	$303,300
GAC POETSs	20	POETSs	Standard household systems, $1,000 per well (change-out 1x per year)	$20,000
			Subtotal	$344,256
			20 years of annual O&M	$6,885,118
			20 years of annual O&M present value (inflation + interest)	$6,569,213
			20-year costs (capital + O&M)	**$192,254,391**
			20-year present value costs (capital + O&M and inflation + interest)	**$191,938,487**
			Capital and operating cost per 1,000 gal	$15.17
			Operating only cost per 1,000 gallons	$0.52

E.2.12.2.6 Cost Implications of particle tracking

As shown in Figures E.1, E.10 and E.11, the particle tracking indicated that the entire community is within an area of potential future PFAS contamination. The cost implications of the particle tracking analyses are provided in Table E.54 below, and would be over and above base costs. For West Lakeland, the particle tracking estimated that by 2040 all remaining non-municipal wells may be impacted by PFAS contamination, as indicated by the projected impact areas, and therefore are included in particle tracking costs. To provide treatment for the areas not served by the distribution system, the particle tracking costs include 270 POETSs.

Table E.54. Option 1 Particle tracking costs for West Lakeland.

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
GAC POETSs	270	POETSs	Standard household systems, $2,500 per well	$675,000
			Subtotal	$675,000
			Contingency (25%)	$168,750
			Professional services (15%)	$101,250
			Total Capital	**$945,000**
Annual O&M Cost				
GAC POETSs	270	POETSs	Standard household systems, $1,000 per well	$270,000
			Subtotal	$270,000
			20 years of annual O&M	$5,400,000
			20 years of annual O&M present value (inflation + interest)	$5,152,236
			20-year costs (capital + O&M)	**$6,345,000**
			20-year present value costs (capital + O&M and inflation + interest)	**$6,097,236**

E.2.12.2.7 Pretreatment cost summary

Since this alternative requires PFAS treatment as part of the municipal system, it is possible that pretreatment would be beneficial. The following table provides a cost summary for iron and manganese pretreatment as a potential future cost. Pretreatment costs also include associated stormwater costs. These costs were used to inform decisions made as part of the Conceptual Plan, but may not be Settlement-eligible unless determined to be the most cost-effective alternative, as described in Chapter 9.

Table E.55. Summary of pretreatment costs for West Lakeland

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
Pretreatment at WTP	1	Lump Sum	Iron/Manganese	$1,963,137
Stormwater Costs	1	Lump Sum	Stormwater Costs 30% of Linear and Facility Projects	$588,941
			Subtotal	$2,552,078
			Contingency (25%)	$638,019
			Professional services (15%)	$382,812
			Total Capital	**$3,572,909**

Item	Quantity	Units	Description	Total Cost (GAC)
Annual O&M Cost				
Pretreatment at WTP	1	Lump Sum	Backwash fees, Maintenance, and FTEs	$210,758
			Subtotal	$210,758
			20 years of annual O&M	$4,215,155
			20 years of annual O&M present value (inflation + interest)	$4,021,755
			20-year costs (capital + O&M)	**$7,788,064**
			20-year present value costs (capital + O&M and inflation + interest)	**$7,594,664**

E.2.13 Woodbury

E.2.13.1 Project summary

Woodbury currently has PFAS impacts to its existing municipal water system, which serves the majority of their community, with approximately the south third of the community remaining unserved. The city requested temporary treatment in order to accommodate increased demands during summer months, and in 2020 a new temporary facility was brought online to treat four of their municipal wells. For the purposes of the Conceptual Plan, this facility is considered only a temporary measure and is not reflected in costs (i.e., due to potential modifications to the system, reuse of equipment, or demolition of the facility).

The improvements considered for Woodbury under recommended Option 1 include the installation of a centralized WTP to treat the existing and proposed municipal water supply wells; connecting homes in neighborhoods with existing water distribution mains; and providing POETSs for non-municipal wells that meet or exceed the treatment threshold. While the improvements related to Woodbury suppling Lake Elmo through an interconnect were described in section E.2.5.1, this section will provide supplementary information regarding modeling analyses considerations. However, the costs include only those improvements that address Woodbury. The proposed infrastructure modifications included in this option are shown in Figures E.2a/b, and the implications on Woodbury's private and non-municipal wells are shown in Figure E.1. Note that Figures E.2a and E.2b reflect different alternatives for Lake Elmo, as described in Section E.2.5.

Water supply wells

Woodbury currently has 19 municipal supply wells to provide drinking water to the community. The wells are split among three well fields: Tamarack, East, and South well fields. Table E.56 below summarizes the city well fields, well HI values, and pumping rates. Of the 19 wells, several have been taken out of service due to PFAS contamination.

Table E.56. Woodbury municipal well HI values and Pumping rates as of first quarter 2021.

Well No.	Well Field	Actual Pumping Rate (gpm)	HI Value[1]
1	Tamarack	725	2.76
2	Tamarack	760	0.46
3	Tamarack	860	0.35
4	Tamarack	990	2.23
5	Tamarack	940	0.72
6	Tamarack	1,150	3.46

Well No.	Well Field	Actual Pumping Rate (gpm)	HI Value[1]
7	Tamarack	1,350	3.40
8	Tamarack	900	0.38
9	Tamarack	1,050	2.79
10	Tamarack	1,305	0.22
11	Tamarack	1,150	0.430
12	Tamarack	1,220	0.35
13	Tamarack	1,530	3.90
14	Tamarack	1,400	0.24
15	East	1,850	0.03
16	East	1,980	0.19
17	Tamarack	1,500	0.71
18	East	2,000	0.03
19	South	2,000	0.35
Total		24,660	

Note:
1. HI values for municipal wells are based on sampling completed as of the first quarter of 2021.

E.2.13.2 Project improvements

New municipal supply wells

The total pumping rate or capacity available from the Tamarack well field was important in order to determine the number of additional municipal supply wells needed to meet projected 2040 demands. This is because the Tamarack well field is the largest source of drinking water for the community – see Table E.56. However, due to the wells being out of service because of PFAS contamination in the Tamarack well field, there was no pumping data available to determine maximum capacity of all the wells operating simultaneously (i.e., maximum operating capacity). Based on well pumping configurations provided by the city, it was estimated that the Tamarack well field could produce on average about 7,500 gpm, with a maximum operating capacity of 10,500 gpm. This includes well 1, which is considered part of the Tamarack well field but is located farthest from the proposed centralized WTP, being taken out of service. Given that the well would require treatment based on current sampling results, it would be more cost-effective to relocate well 1 closer to the proposed centralized WTP.

To be conservative, it was assumed that the Tamarack well field could produce a maximum of 9,600 gpm with the flexibility to turn on additional wells if a well were taken out of service in the East or South well fields. It is recommended that a pump test or tests be performed to determine actual pumping rates. Because the majority of the groundwater supply for Woodbury would be coming from the Tamarack well field, it was recommended that a dual raw water trunk line be implemented for redundancy in case of a pipe break or other line failure.

Furthermore, it was assumed that the East well field would remain unchanged and could produce 2,850 –2,980 gpm. The South well field (i.e., well 19) can currently produce 2,000 gpm and is proposed to be expanded with new wells to collectively add approximately 6,150 gpm to meet the city's 2040 MDD. Groundwater modeling, as discussed further in Section E.2.13.4, indicates that five new wells could be implemented near well 19 and could produce the additional flow required. One of these wells is considered to be a replacement for well 1.

WTPs

Under this recommended option, the new 11,600 gpm WTP would be located near the South well field to treat all municipal supply wells from the Tamarack well field and well 19 in the South well field. For Option 1, only municipal wells with an HI ≥ 0.5 would receive treatment. However, treatment is included for all wells in the Tamarack well field despite several of the wells having an HI < 0.5. This is due to a combination of factors: operational challenges due to lack of pumping data as a result of current PFAS contamination; the proximity of PFAS-impacted wells to non-PFAS-impacted wells; and the uncertainty of groundwater movement as well as PFAS movement in the area of the well field, especially once treatment is implemented and Woodbury begins to use all of the wells in the Tamarack well field.

Based on historic sampling of well 19 (currently the only municipal well in the south well field) that indicates HI values are less than 0.5, the new wells in the South well field are not assumed to require treatment. However, more-recent trends from PFAS sampling at well 19 suggest that groundwater may exceed the HI threshold of 0.5 in this area. Thus, the capacity to treat well 19 is included as part of the south well field WTP. Settlement funding eligibility for this additional treatment capacity would be conditional upon further sampling to confirm the HI threshold of 0.5 is met for well 19. Any new wells that are installed in the future would also need to be sampled in order to determine if the HI threshold is met. Although the costs to treat the new wells are not currently included, contingency funding would be available as part of the Conceptual Plan in the event that the wells are found to meet the HI threshold. Wells in the East well field currently have and are anticipated to have HI values less than 0.5 and would not require treatment under this option.

Water main extension to existing neighborhoods

Wherever possible according to the HI threshold, homes with PFAS-impacted non-municipal wells would be connected to the city's municipal water system. However, for Woodbury, no water mains were proposed to be extended, either because it was not cost-effective to do so as compared to using POETSs, or because sampling data indicated that HI levels were below the threshold of 0.5. Under this Option, five existing non-municipal wells would be replaced with connections to existing distribution system lines by installing a service lateral and sealing the well.

POETSs

Under this option, non-municipal wells would be selected for treatment using the threshold of HI ≥ 0.5. Current PFAS-impacted non-municipal wells would be provided with POETSs that are not proposed to be connected to the municipal water system. According to PFAS sampling data from October 2020 and MWI data, Woodbury has an estimated 657 existing non-municipal wells, of which 258 have been sampled. Of these wells two had existing POETSs and 25 would require new POETSs to be installed according to the HI threshold.

E.2.13.3 Hydraulic modeling analysis

Woodbury currently operates across one pressure zone with the existing municipal supply wells discharging directly to the system. However, the implementation of centralized WTPs will require the addition of raw water transmission lines and upsizing of the existing pumps to maintain sufficient pressures in the system if the treatment process remains pressurized. In addition, the increase in demand would require an additional 2 MG of storage within the system for emergencies and fire flow. However, this tank would not be Settlement-eligible because it is needed due to demand growth and not PFAS-related.

The drinking water distribution model used a set of pressures and elevations provided by the city with the corresponding tank levels and pumps running. Once the preliminary calibration was performed, the alternatives were simulated with the proposed treatment plant locations. The model was set up such that the well pumps were sized to pump through the WTP and into the system while maintaining pressures typically seen by the city with their existing pumping conditions. Flow from the Tamarack and South well fields is routed to the proposed WTP located near well 19, as shown on Figure E.2a/b. As such, pressures in the distribution system near and south of the proposed WTP were found to have increased pressures reaching between roughly 110 psi and 120 psi. Therefore, a pressure zone was created for the southern region of the distribution system to help regulate pressures. In the existing system, pressures were similar to higher pressures observed in the central low-lying areas near lakes and on the eastern side of the city parallel to Woodbury Drive as indicated from pressure data provided by the city. The low-pressure area is located in the northwestern region along Valley Creek Rd and I-494. The observed pressures ranged from roughly 40 to 120 psi.

Feedback from the city indicated a preference to have a hydraulic break (transition from a pressurized system) located at the WTP as a result of the potential treatment processes. In this case, the well pumps would not have to be sized to maintain system pressures. Rather, they would be sized to deliver flow to the plant and potentially through the treatment processes, depending on where the hydraulic break would be located. Under these conditions, a dedicated booster pump station would then need to convey the treated water back into the pressurized distribution system. However, a hydraulic model was not created for this condition. For the purposes of this Conceptual Plan, the cost estimates include the costs of well modifications assuming a continuously pressurized system. The water supply improvements based on the hydraulic modeling are included in base capital costs in Section E.2.13.5.

E.2.13.4 Groundwater modeling analysis

The groundwater model was used to assess impacts from increased and changing pumping conditions in Woodbury based on the simulated recommended Option 1 improvements. Five additional municipal supply wells would be installed and operated in the South well field (near well 19) to meet Woodbury's 2040 MDD. As part of alternative 1 for Lake Elmo, an interconnect between Lake Elmo and Woodbury would be established to provide drinking water to Lake Elmo to help meet their 2040 MDD, and an additional three new municipal supply wells would be installed in Woodbury. This results in a total of eight new wells installed in Woodbury's South well field. Alternative 2 for Lake Elmo does not include the interconnect, and therefore only the five new wells needed for Woodbury are included. These alternatives for Lake Elmo do not affect the improvements included in costs for Woodbury, as the additional costs are included in Lake Elmo alternative 1 and 2 costs. However, they do have different implications for groundwater behavior in Woodbury. The results of drawdown analyses for Woodbury, including the new wells for the Lake Elmo interconnect (alternative 1), are discussed in Section E.2.13.4.1 below. Drawdown analyses results for Lake Elmo remaining autonomous (alternative 2) are discussed in Section E.2.13.4.2.

For both alternatives, forward particle tracking to 2040 was conducted from known PFAS sources and areas where HI ≥ 1 under wet and dry climate conditions, as shown on Figures E.10 and E.11, respectively. The existing and new wells were operating at the average daily rates used for the drawdown analysis discussed above. Particles were not captured by existing or new municipal wells under wet or dry conditions. However, particles did reach areas where private wells are still present, which are addressed in Section E.2.13.6.

E.2.13.4.1 Woodbury/Lake Elmo interconnect (Lake Elmo alternative 1)

Drawdown at existing and new municipal wells in Woodbury was evaluated within the various well fields operating at average pumping rates based on the 2040 ADD. The eight new wells proposed for Woodbury and Lake Elmo future water supply along with existing well 19 would extract groundwater from the Jordan Sandstone aquifer. Table E.57 provides a summary of long-term average daily pumping rates assigned to existing and new/proposed wells. Pumping rates for new wells are distributed such that existing wells are operating at their current average rates and the remaining flow required to meet the 2040 ADD for both Woodbury and Lake Elmo is spread among the new wells.

Table E.57. Summary of Woodbury ADD for existing and new wells (including Lake Elmo alternative/Iteration 1).

Well	Unique Well Number	ADD (gpm)
1	208420	Off
2	208422	Off
3	208423	Off
4	208005	187
5	150353	179
6	151569	99
7	433281	89
8	509051	Off
9	463539	108
10	541763	Off
11	563000	345
12	596646	Off
13	593657	Off
14	611094	392
15	676415	472
16	706811	400
17	759572	348
18	786210	Off
19	805361	376
All New Wells		3509

Under dry conditions, ADD rates for the Woodbury water supply wells were increased by multiplying the current condition rates by a factor of 1.15 (the ratio of maximum per capita demand over average per capita demand from years 2005–2015). Pumping rates at irrigation wells were also increased by taking the maximum annual volume reported over a 30-year period (1988–2018). Drawdown under dry and wet conditions are shown on Figures E.6a, E.7a, and E.8a, and E.9a.

Under dry conditions, drawdown does not exceed the 50% available head in either the Jordan Sandstone or Prairie Du Chien aquifers. Additionally, the effect of pumping is localized such that the general groundwater flow direction (which is from east/northeast to west/southwest in Woodbury) is not altered. Table E.58 provides a summary of drawdown in the Jordan Sandstone aquifer under wet and dry conditions and drawdown in the Prairie du Chien under dry conditions.

All of the existing wells in the Tamarack and East well fields have less than one meter of drawdown. This is due to several of the wells either being turned off or pumping at lower rates compared to average 2016–2018 rates.

Table E.58. Summary of drawdown in the Jordan Sandstone and Prairie du Chien aquifer under wet and dry conditions in Woodbury (including Lake Elmo alternative/Iteration 1).

	Jordan Sandstone aquifer				Prairie du Chien Aquifer		
	Drawdown (m)		Available Head (m)	Dry Drawdown as Percent of Available Head (%)	Drawdown (m)	Available Head (m)	Dry Drawdown as Percent of Available Head (%)
Well	Wet	Dry			Dry		
1	Off						
2	Off						
3	Off						
4	<1	<1	63	0	<1	18	0
5	<1	<1	58	0	<1	18	0
6	<1	<1	63	0	<1	20	0
7	<1	<1	68	0	<1	23	0
8	Off						
9	<1	<1	59	0	<1	16	0
10	Off						
11	<1	<1	56	0	<1	13	0
12	Off						
13	Off						
14	<1	<1	50	0	<1	12	0
15	<1	<1	69	0	<1	19	0
16	<1	<1	51	0	<1	14	0
17	<1	<1	68	0	<1	23	0
18	Off						
19	9	12	70	17	8	33	24
New well 1	15	19	71	26	11	33	31
New well 2	12	16	69	23	10	30	33
New well 3	14	17	67	25	6	23	24
New well 4	14	18	74	24	8	36	23
New well 5	15	19	67	29	8	26	31
New well 6*	11	14	64	22	6	20	28
New well 7*	12	16	65	25	10	27	37
New well 8*	13	17	68	25	9	30	32

*New wells 6-8 are in order to accommodate the interconnect with Lake Elmo.

E.2.13.4.2 Woodbury and Lake Elmo autonomous (Lake Elmo alternative 2)

As discussed above, an alternative was evaluated in which Lake Elmo is autonomous (Lake Elmo alternative/Iteration 2) as presented in Section E.2.5.2. In this alternative, only five wells are pumping in Woodbury's South well field in addition to well 19. Pumping rates assigned to Woodbury existing and new municipal wells are shown in Table E.59.

Table E.59. Summary of Woodbury ADD for existing and new wells as simulated in the drawdown analysis (Iteration 2).

Well	Unique Well Number	ADD (gpm)
1	208420	Off
2	208422	Off
3	208423	Off
4	208005	187
5	150353	179
6	151569	99
7	433281	89
8	509051	Off
9	463539	108
10	541763	Off
11	563000	345
12	596646	Off
13	593657	Off
14	611094	392
15	676415	472
16	706811	400
17	759572	348
18	786210	Off
19	805361	376
New wells		2609

Simulated drawdown does not exceed the 50% available head in either the Jordan Sandstone or Prairie Du Chien aquifers. Table E.60 provides a summary of drawdown in the Jordan Sandstone aquifer under wet and dry conditions and drawdown in the Prairie du Chien under dry conditions.

Table E.60. Summary of drawdown in the Jordan Sandstone and Prairie du Chien aquifer under wet and dry conditions for Iteration 2.

	Jordan Sandstone aquifer				Prairie du Chien Aquifer		
	Drawdown (m)		Available Head (m)	Dry Drawdown as Percent of Available Head (%)	Drawdown (m)	Available Head (m)	Dry Drawdown as Percent of Available Head (%)
Well	Wet	Dry			Dry		
1	Off						
2	Off						
3	Off						
4	<1	<1	63	0	<1	18	0
5	<1	<1	58	0	<1	18	0
6	<1	<1	63	0	<1	20	0
7	<1	<1	68	0	<1	23	0
8	Off						
9	<1	<1	59	0	<1	16	0
10	Off						

Well	Jordan Sandstone aquifer				Prairie du Chien Aquifer		
	Drawdown (m)		Available Head (m)	Dry Drawdown as Percent of Available Head (%)	Drawdown (m)	Available Head (m)	Dry Drawdown as Percent of Available Head (%)
	Wet	Dry			Dry		
11	<1	<1	56	0	<1	13	0
12	Off						
13	Off						
14	<1	<1	50	0	<1	12	0
15	<1	<1	69	0	<1	19	0
16	<1	<1	51	0	<1	14	0
17	<1	<1	68	0	<1	23	0
18	Off						
19	8	11	70	16	8	33	23
New well 1	16	20	71	28	11	33	31
New well 2	13	16	69	24	9	30	30
New well 3	16	19	67	29	6	23	24
New well 4	17	20	74	28	9	36	24
New well 5	17	22	67	32	8	26	32

E.2.13.5 Base cost estimate breakdown

Base capital and O&M costs are summarized in Table E.61 and include only Settlement-eligible costs. Base costs do not consider those costs incurred as a result of the groundwater model particle tracking analysis. PRVs were included to reduce pressures in the low-lying areas of the community, which is a result of both growth of the community and the installation of a centralized WTP. As such, costs are included in this estimate for 50% of the capital and 50% of the O&M. Existing wells are assumed to need to be modified (e.g. new equipment), and the cost of one new well is included in order to cover the replacement of municipal well 1. No other costs are included for drilling new municipal wells, because they are growth-related, and are not Settlement-eligible. All other costs are related to facilitating the new WTP and modifications to homes with non-municipal wells that meet the treatment threshold, as previously described.

Table E.61. Base costs for improvements included in Option 1 for Woodbury.

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
PFAS WTPs	1	WTPs	11,600 gpm MDD WTP, total capacity (includes well 19)	$20,300,000
Sewer Line from WTP	1	Lump Sum	Line to convey backwash to SS system	$202,800
New well	1	Well	Replacement for well 1 in South Well Field	$2,178,000
Well Modifications	15	Wells	Well & SCADA upgrades	$3,000,000
Pressure Reducing Valves	2	Stations	8" and 20" PRVs (prorated 50%)	$125,000
Raw Water Transmission Mains	5.00	Miles	from wells to WTPs and to distribution system	$12,087,739
Water Distribution Mains	4.00	Miles	Upsizing lines in distribution system	$11,554,655

Item	Quantity	Units	Description	Total Cost (GAC)
Raw Water Transmission Mains (dual pipe)	3.81	Miles	Dual transmission mains for redundancy	$17,558,000
Stormwater Costs	1	Lump Sum	Stormwater Costs 25% of Linear and Facility Projects	$15,458,299
Service Laterals	5	Ea	Connect homes to existing mains ($4,000 ea)	$20,000
Woodbury City Fees for New Connections	5	Ea	City Fees include WAC ($1,006), Connection Fee ($1,160), Meter ($354), and Permit ($52)	$7,615
Private well Sealing	5	Ea	$2,700 per well	$13,500
Municipal well Sealing and Demo	1	Ea	Well 1, $130,000 per site (includes $49K to seal well)	$130,000
Land acquisition (site + water mains)	16.0	Acres	$2.5 M for WTP, 20 ft easements (50%)	$6,709,000
GAC POETSs	18	POETSs	Standard household systems, $2,500 per well	$45,000
			Subtotal	$89,389,608
			Contingency (25%)	$22,347,402
			Professional services (15%)	$13,408,441
			Costs for POETSs installed since 2/20/2018	$3,500
			Total Capital	**$125,148,951**
Annual O&M Cost				
PFAS WTPs	1	WTP	Media Cost	$82,095
PFAS WTPs	1	WTP	Maint. and Operations	$1,364,440
GAC POETSs	20	POETSs	Standard household systems, $1,000 per well	$20,000
			Subtotal	$1,466,535
			20 years of annual O&M	$29,330,700
			20 years of annual O&M present value (inflation + interest)	$27,984,943
			20-year costs (capital + O&M)	**$154,479,651**
			20-year present value costs (capital + O&M and inflation + interest)	**$153,133,894**
			Capital and operating cost per 1,000 gal	$1.26
			Operating only cost per 1,000 gallons	$0.23

E.2.13.6 Cost Implications of particle tracking

The cost implications of the particle tracking analyses are provided in Table E.62 below and would be over and above base costs. The results of the particle tracking analysis estimated that parts of the city are within areas of potential future PFAS contamination. Non-municipal wells in these areas would either be provided POETSs or be connected to the distribution system individually if they already have distribution system lines in front of their properties. The particle tracking costs therefore include 15 non-municipal wells being replaced with a connection to the system and 30 receiving POETSs in addition to those included in base costs. The municipal supply system was not impacted by particle tracking results.

Table E.62. Option 1 Particle tracking costs for Woodbury.

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
Service Laterals	15	Ea	Connect homes to existing mains ($4,000 ea)	$60,000
Private Well Sealing	15	Ea	$2,700 per well	$40,500
Woodbury City Fees for New Connections	15	Ea	City Fees include WAC and Connection Fee ($1,123) and Meter ($400)	$22,845
GAC POETSs	30	POETSs	Standard household systems, $2,500 per well	$75,000
			Subtotal	$198,345
			Contingency (25%)	$49,586
			Professional services (15%)	$29,752
			Total Capital	**$277,683**
Annual O&M Cost				
GAC POETSs	30	POETSs	Standard household systems, $1,000 per well	$30,000
			Subtotal	$30,000
			20 years of annual O&M	$600,000
			20 years of annual O&M present value (inflation + interest)	$572,471
			20-year costs (capital + O&M)	**$877,683**
			20-year present value costs (capital + O&M and inflation + interest)	**$850,154**

E.2.13.7 Pretreatment cost summary

The following table provides a cost summary for iron and manganese pretreatment as a potential future cost. Pretreatment costs also include associated stormwater costs. These costs were used to inform decisions made as part of the Conceptual Plan, but may not be Settlement-eligible unless determined to be the most cost-effective alternative, as described in Chapter 9.

Table E.63. Summary of pretreatment costs for Woodbury

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
Pretreatment at WTP	1	Lump Sum	Iron/Manganese	$14,773,017
Stormwater Costs	1	Lump Sum	Stormwater Costs 25% of Linear and Facility Projects	$3,693,254
			Subtotal	$18,466,271
			Contingency (25%)	$4,616,568
			Professional services (15%)	$2,769,941
			Total Capital	**$25,852,780**
Annual O&M Cost				
Pretreatment at WTP	1	WPT	Backwash fees, Maintenance, and FTEs	$1,430,540
			Subtotal	$1,430,540
			20 years of annual O&M	$28,610,800
			20 years of annual O&M present value (inflation + interest)	$27,298,074
			20-year costs (capital + O&M)	**$54,463,580**
			20-year present value costs (capital + O&M and inflation + interest)	**$53,150,854**

E.2.14 Recommended Option 1 summary

Table E.64 provides a summary of estimates of the base, particle tracking, and pretreatment costs for all the improvements included in recommended Option 1, as described in previous sections. In addition, Section E.5, Table E.85 indicates the municipal wells requiring treatment in updated recommended Options 1–3, and the total number of existing and proposed POETSs for each community is provided in Section E.6 Table E.86.

Table E.64. Base cost estimate summary table for improvements included in Recommended Option 1.

Community served	Components	Base Costs							Particle Tracking Costs					Pretreatment Costs		
		POETSs	Treated Water provided (gpm)	Capital cost ($Ms)	Annual O&M cost ($Ms)	Total 20 year costs ($Ms)	Capital and operating cost per 1,000 gal	Operating only cost per 1,000 gallons	POETSs	Treated Water provided (MGD)	Capital cost ($Ms)	Annual O&M cost ($Ms)	Total 20 year costs ($Ms)	Capital cost ($Ms)	Annual O&M cost ($Ms)	Total 20 year costs ($Ms)
Afton	POETSs only	52	15	0.215	0.052	1.207	7.77	6.39	180	0	0.630	0.180	4.065	N/A	N/A	N/A
Cottage Grove	2 WTPs (7100, 3200 gpm), 1 new well	117	10,350	63.237	1.447	90.843	0.84	0.25	58	4.320	16.644	0.384	23.979	20.503	1.363	46.505
Denmark	POETSs only	4	1	0.014	0.004	0.09	8.29	7.00	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Grey Cloud Island	POETSs only	76	11	0.119	0.076	1.569	13.49	12.47	45	0	0.158	0.045	1.016	N/A	N/A	N/A
Lake Elmo	Capital for 2,700 gpm supplied by Woodbury, O&M for 2,000 gpm WTP in Lake Elmo	29	2,700	31.845	0.426	39.975	1.12 - 1.71	0.02 - 0.37	234	0	3.862	0.234	8.327	N/A	N/A	N/A
Lakeland, Lakeland Shores, Lake St. Croix Beach	225 service connections	1	75	1.410	0.001	1.429	1.84	0.02	0	1.08	8.193	0.227	12.531	N/A	N/A	N/A
Maplewood	POETSs only	10	2	0.018	0.010	0.201	10.66	9.76	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Newport	Interconnects with Woodbury and Cottage Grove	6	400	2.951	0.006	3.066	0.69	0.03	16	0	0.056	0.016	0.361	N/A	N/A	N/A
Oakdale	1 WTP (expand existing), two new wells	0	2,050	25.607	0.787	40.634	1.88	0.70	4	0	0.285	0.004	0.361	9.996	0.546	20.414
Prairie Island Indian Community	300 gpm WTP, PWS with 8" lines and tank	0	300	7.176	0.141	9.868	3.13	0.85	0	N/A	N/A	N/A	N/A	1.551	0.105	3.556
St. Paul Park	2200 gpm WTP	5	2,200	15.880	0.421	23.913	1.03	0.35	20	0	0.284	0.020	0.666	5.208	0.345	11.799
West Lakeland – Municipal System	PWS for 80% Township, 2 wells, 1 WTP, 8"& 12" lines	20	1,200	181.389	0.344	187.958	15.17	0.52	270	0	0.945	0.270	6.097	3.573	0.211	7.595
West Lakeland – POETSs	POETSs only	655	130	2.319	0.655	14.817	10.99	9.27	738	0	2.583	0.738	16.666	N/A	N/A	N/A
Woodbury	1 WTP (11,600 gpm)	20	11,600	125.149	1.467	153.134	1.26	0.23	30	0	0.278	0.030	0.850	25.853	1.431	53.151
Total (West Lakeland on POETSs)		**975**	**29,834**	**275.94**	**5.493**	**380.746**	**N/A**	**N/A**	**1,325**	**5.400**	**32.973**	**1.878**	**68.822**	**63.111**	**3.790**	**135.425**
Total (West Lakeland on municipal supply)		**340**	**30,904**	**455.01**	**5.182**	**553.887**	**N/A**	**N/A**	**857**	**5.400**	**31.335**	**1.410**	**58.253**	**66.684**	**4.001**	**143.020**

E.3 Recommended Option 2

E.3.1 Option summary

Recommended Option 2 is a variation of recommended Option 1 and consists of the selected community-specific alternatives identified in the previous analyses presented in Appendix H. This recommended option includes the same improvements for each community as those presented in the previous Section E.2 for Option 1. However, under recommended Option 2 the HI threshold was reduced from ≥0.5 to ≥0.3 and the associated costs for additional treatment have been included.

The sections below summarize the additional costs included from those presented in Section E.2 recommended Option 1. Figures E.3 and E.4a/b provide an overview of the updated recommended Option 2 for non-municipal and municipal supply projects, respectively. The difference in improvements between Options 1 and 2 is described below. In addition to this section, the municipal wells requiring treatment in updated recommended Options 1–3 are listed in Section E.5 Table E.85, and the total number of existing and proposed POETSs for each community is provided in Section E.6 Table E.86.

E.3.2 Project improvements

POETSs and connections to the municipal system

The reduction of the HI threshold has cost implications for almost all communities. POETSs and connections to the existing municipal distribution for non-municipal or private wells are included in this recommended option if they meet the HI ≥ 0.3 threshold, in addition to those that meet the HI ≥ 0.5 threshold for recommended Option 1. For several communities including Afton, Denmark, Grey Cloud Island, Maplewood, Newport, West Lakeland, and the combined communities of Lakeland, Lakeland Shores, and Lake St. Croix Beach, the cost increase under recommended Option 2 is attributed to only the additional POETSs and/or connections based on the reduced HI threshold, and no municipal system changes were identified. The communities of Oakdale, St. Paul Park, and PIIC had no changes to their costs compared to under Option 1. Figure E.3 is a regional map that illustrates the non-municipal wells that will receive POETSs or be replaced with a connection to the distribution system (as discussed in the following section) according to the HI ≥ 0.3 threshold under recommended Option 2, and also shows the projected areas of PFAS impacts.

The costs presented for the remaining communities of Woodbury, Lake Elmo, and Cottage Grove include increases from Option 1 costs resulting from not only additional POETSs and/or connections but also additional municipal well treatment associated with the HI threshold reduction, which will be discussed further in later sections. Figures 4a and 4b are regional maps that illustrate the municipal system changes for recommended Option 2, and differ depending on the alternative for Lake Elmo (alternative 1 and 2, respectively).

Interconnects

This recommended option includes the same three interconnects as described for recommended Option 1. The first interconnect from Woodbury to Lake Elmo would supply water for the future growth of Lake Elmo and is described in Section E.2.5.1. The second (Newport and Woodbury) and third (Newport and Cottage Grove) interconnects are included to provide an alternative water supply to Newport in case PFAS groundwater contamination at the existing Newport municipal wells meets or exceeds the HI threshold in the future, and are described in Section E.2.8.

WTPs and raw water mains

The lower HI threshold of ≥0.3 resulted in additional municipal improvements including additional infrastructure and treatment costs for municipal wells serving Woodbury, Lake Elmo (for Alternative 1) and Cottage Grove.

For Cottage Grove, reducing the HI threshold would result in the need to treat well 11, which currently has an HI value of 0.33. Under Option 2, this well would be routed to the proposed intermediate WTP for treatment and the facility would have a new capacity of 8,600 gpm as described in Appendix F, Section F.3.

For Woodbury, the five new wells required for growth and the three wells required to supply Lake Elmo through the proposed interconnect (for Alternative 1) are all assumed to meet or exceed the treatment threshold due to their proximity to Woodbury well 19 and the available sampling data for that well, which historically has fallen between the HIs of 0.3 and 0.5. Therefore, Woodbury will need to expand the proposed centralized WTP included in recommended Option 1 by 4,000 gpm for the five new wells required for Woodbury's growth, as well as an additional 2,700 gpm for the three new wells for Lake Elmo, for a total additional capacity of 6,700 gpm. The costs to treat the wells required for Lake Elmo are included separately from the Woodbury-specific WTP costs. The WTP costs are separated between Woodbury and Lake Elmo based on the flow (gpm) treated for each community. However, the WTP sizing and overall cost were developed under the assumption and economies of scale of one centralized WTP to treat all eight of the new wells, as described in Appendix F, Section F.3.

E.3.3 Hydraulic modeling analysis

The hydraulic models developed for the evaluations under Option 1 were modified to evaluate the routing of additional wells for treatment for Cottage Grove and Woodbury. For both communities, the proposed raw water lines and distribution lines were inserted and sized to convey the necessary flow and included in the cost estimates. For both the Woodbury and Cottage Grove WTPs, head losses remained the same, while well modifications were made to ensure the system could remain pressurized. However, depending on the type of treatment implemented during the design phase of these treatment facilities, it is possible that a continuous pressurized system might not be used. As a result, additional, hydraulic modeling should be performed during the preliminary design phase. The water supply improvements based on the hydraulic modeling are included in base capital costs in Section E.3.5.

E.3.4 Groundwater modeling analysis

The change in HI threshold from recommended Option 1 to recommended Option 2 does not affect the number of municipal wells, pumping rates, or potential future movement of PFAS, which are addressed by the groundwater modeling analyses. Therefore, the results from the groundwater analyses performed as described in Section E.2 also apply to this recommended option. This also means that the recommended Option particle tracking analyses apply to this recommended option as well. The potential future areas of impact do not change as a result of the change in HI threshold.

E.3.5 Base cost estimate breakdown

The base costs estimates include only Settlement-eligible costs and do not consider those costs incurred as a result of the groundwater model particle tracking analysis. Base capital and O&M cost details for Cottage Grove, Woodbury, and Lake Elmo that are included as part of updated recommended Option 2 are provided in Tables E.65 and E.66, respectively. Base costs here include Woodbury and Lake Elmo cost estimates for the two Lake Elmo alternatives, including the interconnect with Woodbury (Alternative 1) and the autonomous option (Alternative 2). The costs included for Lake Elmo in the

Option 2 summary tables include the higher of the two alternative costs for both capital and O&M separately. For recommended Option 2, the interconnect alternative had the higher costs for both capital and O&M. Base capital and O&M costs included for all the communities in recommended Option 2 are summarized in Section E.3.8.

Table E.65. Base costs for improvements included in Option 2 for Cottage Grove.

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
PFAS WTPs	2	WTPs	8,600 gpm MDD WTP (interm. zone), 3,200 gpm MDD WTP (low zone)	$23,200,000
Sewer Line from WTP	1	Lump Sum	Line to convey backwash to SS system	$395,750
Temporary Treatment Facility Demo	3	Lump Sum	Remove existing treatment facility (at wells 3, 7, 10)	$1,500,000
Municipal well Demo	2	Ea	$130K per well ($49K to seal well, wells 1, and 2)	$260,000
New well	1	Well	1,200 gpm (replacement well for wells 1 and 2)	$2,178,000
Well Modifications	9	Well	Well & SCADA upgrades	$1,800,000
Raw Water Transmission Mains	5.4	Miles	From wells to WTPs (includes well 11 to WTP)	$11,889,298
Neighborhood Mains	2.4	Miles	Connect 67 homes	$1,920,672
16" Distribution Line	0.8	Miles	Flow to Garage Tank	$756,800
Stormwater Costs	1	Lump Sum	Stormwater costs 5% of linear and facility projects	$1,996,126
Service Laterals	77	Ea	Connect homes to existing mains ($8,000 ea)	$616,000
Cottage Grove City Fees for New Connections	77	Ea	City Fees include WAC ($1,006), Connection Fee ($1,160), Meter ($354), and Permit ($52)	$198,044
Well Sealing	77	Ea	$2,700 per well	$207,900
Land Acquisition (site + water mains)	14.4	Acres	1/2 acre per well, 5 acres at WTPs, 20 ft easements (50%)	$4,748,745
Existing GAC POETS Removal	16	Ea	$400	$6,400
GAC POETSs	70	POETSs	Standard household systems, $2,500 per well	$175,000
			Subtotal	$51,848,735
			Contingency (25%)	$12,962,184
			Professional services (15%)	$7,777,310
			Costs for POETSs installed since 2/20/2018	$156,000
			Total Capital	**$72,744,229**

Item	Quantity	Units	Description	Total Cost (GAC)
Annual O&M Cost				
PFAS WTPs	2	WTP	Media Cost	$83,838
PFAS WTPs	2	WTP	Maint. and Operations	$1,368,000
GAC POETSs	138	POETSs	Standard household systems, $1,000 per well	$138,000
			Subtotal	$1,589,838
			20 years of annual O&M	$31,796,759
			20 years of annual O&M present value (inflation + interest)	$30,337,854
			20-year costs (capital + O&M)	**$104,540,988**
			20-year present value costs (capital + O&M and inflation + interest)	**$103,082,083**
			Capital and operating cost per 1,000 gal	$0.83
			Operating only cost per 1,000 gallons	$0.24

Table E.66. Base costs for improvements included in Option 2 for Woodbury.

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
PFAS WTPs	1	WTPs	15,600 gpm MDD WTP, total capacity	$25,710,000
Sewer Line from WTP	1	Lump Sum	Line to convey backwash to SS system	$202,800
New well	1	Well	Replacement for well 1 in South well Field	$2,178,000
Well Modifications	15	Wells	Well & SCADA upgrades	$3,000,000
Pressure Reducing Valves	2	Stations	8" and 20" PRVs (prorate 50%)	$125,000
Raw Water Transmission Mains	6.59	Miles	From wells to WTPs and to distribution system	$15,424,471
Water Distribution Mains	4.00	Miles	Upsizing lines in distribution system	$11,554,655
Raw Water Transmission Mains (dual pipe)	3.81	Miles	Dual transmission mains for redundancy	$17,557,682
Stormwater Costs	1	Lump Sum	Stormwater Costs 25% of Linear and Facility Projects	$17,644,902
Service Laterals	7	Ea	Connect homes to existing mains ($4,000 ea)	$28,000
Private well Sealing	7	Ea	$2,700 per well	$18,900
Woodbury City Fees for New Connections	7	Ea	City Fees include WAC and Connection Fee ($1,123) and Meter ($400)	$10,661
Municipal well Sealing and Demo	1	Ea	Well 1, $130,000 per site (includes $49K to seal well)	$130,000
Land Acquisition (site + water mains)	18.0	Acres	$2.5 M for WTP, 20 ft easements (50%)	$7,215,701
GAC POETSs	48	POETSs	Standard household systems, $2,500 per well	$120,000

Item	Quantity	Units	Description	Total Cost (GAC)
			Subtotal	$100,920,772
			Contingency (25%)	$25,230,193
			Professional services (15%)	$15,138,116
			Costs for POETSs installed since 2/20/2018	$3,500
			Total Capital	**$141,292,581**
Annual O&M Cost				
PFAS WTPs	1	WTP	Media Cost	$139,774
PFAS WTPs	1	WTP	Maint. and Operations	$1,649,500
GAC POETSs	50	POETSs	Standard household systems, $1,000 per well	$50,000
			Subtotal	$1,839,274
			20 years of annual O&M	$36,785,479
			20 years of annual O&M present value (inflation + interest)	$35,097,681
			20-year costs (capital + O&M)	**$178,078,060**
			20-year present value costs (capital + O&M and inflation + interest)	**$176,390,262**
			Capital and operating cost per 1,000 gal	$1.07
			Operating only cost per 1,000 gallons	$0.21

Table E.67. Base costs for improvements included in Option 2 Alternative 1 for Lake Elmo-Woodbury Interconnect.

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
PFAS WTPs	1	WTPs	+2,700 gpm MDD expansion of Woodbury WTP	$6,950,000
Interconnects	1	Stations	Woodbury to Lake Elmo	$375,000
BPS	1	Stations	Woodbury to Lake Elmo BPS	$1,700,500
Neighborhood Distribution Mains (Lake Elmo)	2.37	Miles	Connect 257 homes	$1,900,152
Transmission or Connecting Mains in Distribution System (Lake Elmo)	3.59	Miles	Distribution lines and transmission main from interconnect to Tank #4	$8,856,285
Raw Water Distribution Mains (Woodbury)	1.15	Miles	From three Lake Elmo wells to treatment plant	$2,400,948
Water Distribution Mains (Woodbury)	0.15	Miles	800 linear feet under highway for interconnect	$261,600
Stormwater Costs	1	Lump Sum	Stormwater costs 30% of linear and facility projects in Lake Elmo and 25% of projects in Woodbury	$6,091,749
Service Laterals (Lake Elmo)	104	Ea	Connect homes to existing mains ($8,100 ea)	$842,400
Lake Elmo City Fees for New Connections	104	Ea	City Fees include WAC ($3,000), Connection Fee ($1,000), Meter ($1,540), and Permit ($0)	$576,160
Well Sealing (Lake Elmo)	104	Ea	$2,700 per private well	$280,800

Item	Quantity	Units	Description	Total Cost (GAC)
Existing GAC POETS Removal (Lake Elmo)	25	Ea	$400 each	$10,000
Land Acquisition, Lake Elmo (site + water mains)	12.4	Acres	20 ft easements (50%)	$2,356,100
Land acquisition, Woodbury (site + water mains)	2.6	Acres	1/2 acre per site, 20 ft easements (50%)	$676,506
GAC POETSs (Lake Elmo)	35	POETSs	Standard household systems, $2,500 per well	$87,500
			Subtotal	$33,365,700
			Contingency (25%)	$8,341,425
			Professional services (15%)	$5,004,855
			Costs for POETSs installed since 2/20/2018	$27,500
			Total Capital	**$46,739,480**
Annual O&M Cost				
PFAS WTPs	1	WTP	Media Cost	$20,000
PFAS WTPs	1	WTP	Maint. and Operations	$399,500
GAC POETSs (Lake Elmo)	46	POETSs	Standard household systems, $1,000 per well	$46,000
			Subtotal	$465,500
			20 years of annual O&M	$9,310,000
			20 years of annual O&M present value (inflation + interest)	$8,882,837
			20-year costs (capital + O&M)	**$56,049,480**
			20-year present value costs (capital + O&M and inflation + interest)	**$55,622,316**
			Capital and operating cost per 1,000 gal	$1.92
			Operating only cost per 1,000 gallons	$0.31

Table E.68. Base costs for improvements included in Option 2 Alternative 2 for Lake Elmo – Autonomous Option.

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
PFAS WTPs	1	WTP	2,000 gpm MDD WTP (at Tank #4) for two new wells	$5,810,000
Sewer Line from WTP	1	Lump Sum	Line to convey backwash to SS system	$280,800
Raw water transmission mains	2.5	Miles	From wells to WTP at Tank #4	$2,275,034
Water distribution mains	1.5	Miles	Connecting distribution mains	$2,846,448
Neighborhood mains	2.4	Miles	Connect 257 homes	$1,900,152
Stormwater Costs	1	Lump Sum	Stormwater Costs 30% of Linear and Facility Projects	$4,885,395
Service Laterals	104	Ea	Connect homes to existing mains ($8,100 ea)	$842,400
Lake Elmo City Fees for New Connections	104	Ea	City Fees include WAC ($3,000), Connection Fee	$576,160

Item	Quantity	Units	Description	Total Cost (GAC)
			($1,000), Meter ($1,540), and Permit ($0)	
Well Sealing	104	Ea	$2,700 per well	$280,800
Existing GAC POETS Removal	25	Ea	$400	$10,000
Land acquisition (site + water mains)	10.0	Acres	20 ft easements (50%)	$1,899,216
GAC POETSs	35	POETSs	Standard household systems, $2,500 per well	$87,500
			Subtotal	$20,742,240
			Contingency (25%)	$5,185,560
			Professional services (15%)	$3,111,336
			Costs for POETSs installed since 2/20/2018	$27,500
			Total Capital	**$29,066,636**
Annual O&M Cost				
PFAS WTPs	1	WTP	Media Cost	$2,572
PFAS WTPs	1	WTP	Maint. and Operations	$394,500
GAC POETSs	46	POETSs	Standard household systems, $1,000 per well	$46,000
				$443,072
			20 years of annual O&M	$8,861,445
			20 years of annual O&M present value (inflation + interest)	$8,454,863
			20-year costs (capital + O&M)	**$37,928,082**
			20-year present value costs (capital + O&M and inflation + interest)	**$37,521,499**
			Capital and operating cost per 1,000 gal	$1.73
			Operating only cost per 1,000 gallons	$0.39

E.3.6 Cost implications of particle tracking

As shown in Figures E.3, E.10 and E.11 and described in Section E.1.3.2.1 above, the particle tracking analysis indicated that additional wells may be impacted in the future under recommended Option 2. The cost implications of the particle tracking analyses would be over and above base costs. For Cottage Grove, the particle tracking analysis resulted in PFAS treatment and associated pretreatment for an additional well (well 12), 52 POETSs, and 14 home connections as presented in Table E.69. For the remaining communities, the particle tracking analyses resulted in additional POETSs and home connections. This includes particle tracking analyses for Woodbury and Lake Elmo, details of which are provided in Tables E.70 and E.71, respectively. The cost implications across all communities under recommended Option 2 are summarized in Section E.3.8 below.

Table E.69. Option 2 Particle tracking costs for Cottage Grove.

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
PFAS WTPs	1	WTPs	Additional 1,500 gpm MDD capacity	$2,400,000
Raw water transmission mains	2.67	Miles	From wells to WTPs	$1,978,812
Stormwater Costs	1	Lump Sum	Stormwater Costs 5% of Linear and Facility Projects	$218,941
Service Laterals	14	Ea	Connect homes to existing mains ($8000 ea)	$112,000
Cottage Grove City Fees for New Connections	14	Ea	City Fees include WAC ($1,006), Connection Fee ($1,160), Meter ($354), and Permit ($52)	$36,008
Private well Sealing	14	Ea	$2,700 per well	$37,800
Land acquisition (site + water mains)	1.15	Acres	20 ft easements (50%)	$174,895
Existing GAC POETS Removal	0	Ea	$400	$0
GAC POETSs	52	POETSs	Standard household systems, $2,500 per well	$130,000
			Subtotal	$5,088,456
			Contingency (25%)	$1,272,114
			Professional services (15%)	$763,268
			Total Capital	**$7,123,838**
Annual O&M Cost				
PFAS WTPs	1	WTP	Media Cost	$10,600
PFAS WTPs	1	WTP	Maint. and Operations	$152,610
GAC POETSs	52	POETSs	Standard household systems, $1,000 per well	$52,000
			Subtotal	$215,210
			20 years of annual O&M	$4,304,200
			20 years of annual O&M present value (inflation + interest)	$4,106,714
			20-year costs (capital + O&M)	**$11,428,038**
			20-year present value costs (capital + O&M and inflation + interest)	**$11,230,552**

Table E.70. Option 2 Particle tracking costs for Woodbury.

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
Service Laterals	15	Ea	Connect homes to existing mains ($4,000 ea)	$60,000
Private well Sealing	15	Ea	$2,700 per well	$40,500
Woodbury City Fees for New Connections	15	Ea	City Fees include WAC and Connection Fee ($1,123) and Meter ($400)	$22,845
GAC POETSs	27	POETSs	Standard household systems, $2,500 per well	$67,500
			Subtotal	$190,845
			Contingency (25%)	$47,711
			Professional services (15%)	$28,627
			Total Capital	**$267,183**
Annual O&M Cost				
GAC POETSs	27	POETSs	Standard household systems, $1,000 per well	$27,000
			Subtotal	$27,000
			20 years of annual O&M	$540,000
			20 years of annual O&M present value (inflation + interest)	$515,224
			20-year costs (capital + O&M)	**$807,183**
			20-year present value costs (capital + O&M and inflation + interest)	**$782,407**

Table E.71. Option 2 Particle tracking costs for Lake Elmo Alternative 1 & 2.

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
Service Laterals	126	Ea	Connect homes to existing mains ($8,100 ea)	$1,020,600
Lake Elmo City Fees for New Connections	126	Ea	City Fees include WAC ($3,000), Connection Fee ($1,000), Meter ($1,540), and Permit ($0)	$698,040
Well Sealing	126	Ea	$2,700 per well	$340,200
GAC POETSs	220	POETSs	Standard household systems, $2,500 per well	$550,000
			Subtotal	$2,608,840
			Contingency (25%)	$652,210
			Professional services (15%)	$391,326
			Total Capital	**$3,652,376**
Annual O&M Cost				
GAC POETSs (Lake Elmo)	220	POETSs	Standard household systems, $1,000 per well	$220,000
			Subtotal	$220,000
			20 years of annual O&M	$4,400,000
			20 years of annual O&M present value (inflation + interest)	$4,198,118
			20-year costs (capital + O&M)	**$8,052,376**
			20-year present value costs (capital + O&M and inflation + interest)	**$7,850,494**

E.3.7 Pretreatment cost summary

The following tables provide cost summaries for iron and manganese pretreatment as a potential future cost. Pretreatment costs also include associated stormwater costs.

Under recommended Option 2, municipal wells in Cottage Grove, Woodbury and Lake Elmo require treatment for PFAS, and therefore have potential pretreatment costs associated, as provided in Tables E.68-E.71. For Cottage Grove these costs include pretreatment for well 11, along with the rest of the municipal supply wells besides well 12. For Woodbury, the costs include pretreatment for all the proposed new wells in the South well field – eight for the Woodbury-Lake Elmo interconnect alternative and five for the autonomous alternative – as well as the rest of the municipal wells besides those in the East well field. For the Lake Elmo autonomous alternative, the pretreatment costs are the same as in Option 1 and include the two new wells. These costs were used to inform decisions made as part of the Conceptual Plan, but may not be Settlement-eligible unless determined to be the most cost-effective alternative, as described in Chapter 9.

Table E.72. Summary of pretreatment costs for Cottage Grove.

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
Pretreatment at WTP	2	Lump Sum	Iron/Manganese	$15,897,434
Stormwater Costs	1	Lump Sum	Stormwater Costs 5% of Linear and Facility Projects	$794,872
			Subtotal	$16,692,305
			Contingency (25%)	$4,173,076
			Professional services (15%)	$2,503,846
			Total Capital	**$23,369,228**
Annual O&M Cost				
Pretreatment at WTP	1	gpm	Backwash fees, Maintenance, and FTEs	$1,543,661
			Subtotal	$1,543,661
			20 years of annual O&M	$30,873,215
			20 years of annual O&M present value (inflation + interest)	$29,456,685
			20-year costs (capital + O&M)	**$54,242,443**
			20-year present value costs (capital + O&M and inflation + interest)	**$52,825,912**

Table E.73. Summary of pretreatment costs for Woodbury.

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
Pretreatment at WTP	1	Lump Sum	Iron/Manganese	$19,783,697
Stormwater Costs	1	Lump Sum	Stormwater Costs 25% of Linear and Facility Projects	$4,945,924
			Subtotal	$24,729,621
			Contingency (25%)	$6,182,405
			Professional services (15%)	$3,709,443
			Total Capital	**$34,621,469**
Annual O&M Cost				
Pretreatment at WTP	1	WPT	Backwash fees, Maintenance, and FTEs	$1,903,877
			Subtotal	$1,903,877
			20 years of annual O&M	$38,077,537
			20 years of annual O&M present value (inflation + interest)	$36,330,456
			20-year costs (capital + O&M)	**$72,699,006**
			20-year present value costs (capital + O&M and inflation + interest)	**$70,951,926**

Table E.74. Summary of pretreatment costs for Lake Elmo Alternative 1 – Woodbury Interconnect.

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
Pretreatment at WTP	1	Lump Sum	Iron/Manganese	$3,912,937
Stormwater Costs	1	Lump Sum	Stormwater Costs 25% of Linear and Facility Projects	$978,234
			Subtotal	$4,891,171
			Contingency (25%)	$1,222,793
			Professional services (15%)	$733,676
			Total Capital	**$6,847,639**
Annual O&M Cost				
Pretreatment at WTP	1	WPT	Backwash fees, Maintenance, and FTEs	$391,799
			Subtotal	$391,799
			20 years of annual O&M	$7,835,978
			20 years of annual O&M present value (inflation + interest)	$7,476,447
			20-year costs (capital + O&M)	**$14,683,618**
			20-year present value costs (capital + O&M and inflation + interest)	**$14,324,086**

Table E.75. Summary of pretreatment costs for Lake Elmo Alternative 2 – Autonomous.

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
Pretreatment at WTP	1	Lump Sum	Iron/Manganese	$3,172,217
Stormwater Costs	1	Lump Sum	Stormwater Costs 30% of Linear and Facility Projects	$951,665
			Subtotal	$4,123,882
			Contingency (25%)	$1,030,970
			Professional services (15%)	$618,582
			Total Capital	**$5,773,435**
Annual O&M Cost				
Pretreatment at WTP	1	WPT	Backwash fees, Maintenance, and FTEs	$315,772
			Subtotal	$315,772
			20 years of annual O&M	$6,315,448
			20 years of annual O&M present value (inflation + interest)	$6,025,681
			20-year costs (capital + O&M)	**$12,088,882**
			20-year present value costs (capital + O&M and inflation + interest)	**$11,799,116**

E.3.8 Recommended Option 2 summary

Table E.76 provides a summary of estimates of the base, particle tracking, and pretreatment costs for all the improvements included in recommended Option 2 as described in previous sections.

Table E.76. Cost estimate summary table for improvements included in Recommended Option 2.

Community served	Components	Base Costs							Particle Tracking Costs					Pretreatment Costs		
		POETSs	Treated Water provided (gpm)	Capital cost ($Ms)	Annual O&M cost ($Ms)	Total 20 year costs ($Ms)	Capital and operating cost per 1,000 gal	Operating only cost per 1,000 gallons	POETSs	Treated Water provided (MGD)	Capital cost ($Ms)	Annual O&M cost ($Ms)	Total 20 year costs ($Ms)	Capital cost ($Ms)	Annual O&M cost ($Ms)	Total 20 year costs ($Ms)
Afton	POETSs only	60	17	0.243	0.060	1.387	7.75	6.39	172	0.08	0.602	0.172	3.884	N/A	N/A	N/A
Cottage Grove	2 WTPs (7100, 3200 gpm), 1 new well	138	11,850	72.744	1.590	103.082	0.83	0.24	52	2.160	7.124	0.215	11.231	23.369	1.544	52.826
Denmark	POETSs only	7	2	0.025	0.007	0.158	8.29	7.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Grey Cloud Island	POETSs only	78	11	0.126	0.078	1.614	13.52	12.47	43	0	0.151	0.043	0.971	N/A	N/A	N/A
Lake Elmo	Capital and O&M for 2,700 gpm interconnect with Woodbury	46	2,700	46.739	0.465	55.622	1.92	0.31	220	0	3.652	0.220	7.850	6.848	0.391	14.324
Lakeland, Lakeland Shores, Lake St. Croix Beach	225 service connections	1	75	1.613	0.001	1.632	2.10	0.02	0	1.080	7.991	0.227	12.328	N/A	N/A	N/A
Maplewood	Water main extension for 35 connections	11	2	0.021	0.011	0.231	10.74	9.76	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Newport	Interconnects with Woodbury and Cottage Grove	32	426	3.042	0.032	3.653	0.82	0.14	16	0	0.056	0.016	0.361	N/A	N/A	N/A
Oakdale	1 WTP (expand existing), two new wells	0	2,050	25.607	0.787	40.634	1.88	0.70	4	0	0.285	0.004	0.361	9.996	0.546	20.414
Prairie Island Indian Community	300 gpm WTP, PWS with 8" lines and tank	0	300	7.176	0.141	9.868	3.13	0.85	0	N/A	N/A	N/A	N/A	1.551	0.105	3.556
St. Paul Park	2200 gpm WTP	5	2,200	15.880	0.421	23.913	1.03	0.35	20	0	0.284	0.020	0.666	5.208	0.345	11.799
West Lakeland – Municipal System	PWS for 80% Township, 2 wells, 1 WTP, 8" & 12" lines	26	1,200	181.410	0.350	188.093	14.85	0.53	264	0	0.924	0.264	5.961	3.573	0.211	7.595
West Lakeland – POETSs	POETSs only	696	136	2.462	0.696	15.743	10.99	9.27	697	0.393	2.440	0.697	15.740	N/A	N/A	N/A
Woodbury	1 WTP (11,600 gpm)	50	15,612	141.293	1.839	176.390	1.07	0.21	27	0	0.267	0.027	0.782	34.621	1.904	70.952
Totals for West Lakeland on POETSs		**1124**	**35,381**	**316.971**	**6.128**	**433.927**	**N/A**	**N/A**	**1251**	**3.713**	**22.852**	**1.641**	**54.174**	**81.593**	**4.835**	**173.871**
Totals for West Lakeland on municipal supply		**454**	**36,445**	**495.919**	**5.782**	**606.277**	**N/A**	**N/A**	**818**	**3.32**	**21.336**	**1.208**	**44.395**	**85.166**	**5.046**	**181.466**

E.4 Recommended Option 3

E.4.1 Option summary

Recommended Option 3 is a variation of recommended Option 1 and consists of the selected community-specific alternatives identified in previous analyses presented in Appendix H and also described below for the treatment threshold of **HI ≥ 0.5**. The costs for this option have been updated compared to costs in Appendix H. This recommended option includes the same projects for each community as those presented for Option 1 in Section E.2 except for Lake Elmo and Oakdale, as described in further detail below. In addition to this section, the municipal wells requiring treatment in updated recommended Options 1–3 are listed in Section E.5 Table E.85, and the total number of existing and proposed POETSs for each community is provided in Section E.6 Table E.86.

E.4.2 Project improvements

The key project components under recommended Option 3, include:

- A regional water supplier, St. Paul Regional Water Services (SPRWS), would supply drinking water to both Oakdale and Lake Elmo, with water being conveyed to Lake Elmo through Oakdale's existing municipal water distribution system and proposed interconnects. Existing municipal groundwater supply wells in Lake Elmo and Oakdale would be taken out of service and replaced with treated water supplied from SPRWS' McCarron WTP.
- All other infrastructure improvements for Lake Elmo and Oakdale would remain the same as is described in recommended Option 1. They include extending water mains to neighborhoods currently with some non-municipal wells that are PFAS-impacted, and providing POETSs for any remaining PFAS-impacted non-municipal wells that do not already have a municipal water system line in front of their house; factors include cost or constructability constraints as described below.
- The project components for the remaining communities would be the same as those presented for recommended Option 1 in Section E.2.

Figure E.1 is a regional map that illustrates the non-municipal wells that will receive POETSs or be replaced with a connection to the distribution system according to the HI ≥ 0.5 threshold under recommended Options 1 and 3, and also shows the projected areas of PFAS impacts. Figure E.5 illustrates the infrastructure modifications necessary for the connection between Lake Elmo and Oakdale that is served by SPRWS under recommended Option 3.

E.4.2.1 SPRWS infrastructure components

According to SPRWS, the McCarron's WTP currently has 30 mgd of extra water treatment capacity. The existing McCarron's WTP is located in Maplewood between Roselawn Avenue and Larpenteur Avenue just west of Interstate 35. As part of their treatment process, SPRWS softens the water before pumping it into the distribution system. It is assumed that SPRWS's bulk water rate will cover any costs associated with future water supply improvements, WTP capacity expansion, or BPS upgrades at the plant and as such these costs are not included in this estimate.

In order to supply water to neighboring communities, SPRWS would need to implement some infrastructure changes to their existing distribution system. Discussions with SPRWS indicated that the best location to connect to their existing system would be their 10 MG Hillcrest Reservoir that is currently supplied by an existing 24-inch water main. SPRWS' hydraulic model indicates that a 30-inch water main to the Hillcrest Reservoir location would be necessary for their system to meet the MDD for both Oakdale and Lake Elmo. In order to supply water to Oakdale and Lake Elmo, a new BPS and distribution mains would also need to be installed downstream from the Hillcrest Reservoir, and will be discussed in greater detail in the Section 4.3 below.

E.4.2.2 Oakdale and Lake Elmo infrastructure improvements

As mentioned above, with the exception of water supply for Lake Elmo and Oakdale, all other infrastructure modifications in the East Metropolitan Area would remain the same as they were under recommended Option 1. The additional water supply improvements and/or modifications for this option aside from the SPRWS interconnects for Lake Elmo and Oakdale are described below.

Oakdale municipal infrastructure improvements

Improvements to Oakdale's municipal system as a result of switching to SPRWS include demolition of the existing treatment facilities, as well as sealing of the municipal wells. A detailed discussion of these improvements is included in Section E.4.3 below. The hydraulic evaluation, as described below, did not indicate the need to install any additional water distribution lines.

No neighborhoods were proposed to be connected to the existing system. However, individual homes with non-municipal wells that meet the treatment threshold and have existing distribution system lines in front of them were proposed to be connected. This is consistent with guidelines discussed in the neighborhood connections section of Section E.1.3.3. The individual home improvements for recommended Option 3 are discussed further in Section E.4.2.3.

Lake Elmo municipal infrastructure improvements

Improvements to Lake Elmo's municipal system as a result of switching to SPRWS include distribution lines, as well as sealing of existing municipal wells. A detailed discussion of these improvements is included in Section E.4.3 below.

In addition to municipal system improvements, residents with private wells or other non-municipal wells that are currently or are anticipated to be impacted by PFAS contamination will be addressed based on the guidelines discussed in the neighborhood connections section of Section E.1.3.3. The individual home improvements for recommended Option 3 are discussed further in Section E.4.2.3.

E.4.2.3 Lake Elmo and Oakdale homes on non-municipal wells

The improvements for homes with non-municipal wells under recommended Option 3 are the same as those in recommended Option 1 and are described specifically for Lake Elmo and Oakdale below. Current PFAS-impacted, non-municipal wells that meet the treatment threshold and are not connected to the municipal water system would be provided with POETSs. Non-municipal wells would be selected for treatment using the treatment threshold of HI ≥ 0.5.

Lake Elmo home connections to municipal system

For Lake Elmo, the available sample data as of October 2020 indicates that the majority of sampled non-municipal wells are currently impacted by PFAS and many have had a POETS installed or been connected to the municipal system wherever possible according to the current well advisory threshold of HI ≥ 1.0. Under the recommended Option 3 HI threshold, three existing neighborhoods comprising 86 homes on private wells would be replaced with a connection to the city's municipal water system requiring a water main extension. An additional 11 homes have private wells that meet the treatment threshold and already have water lines running in front of them, for a total of 97 homes being connected to the system. These neighborhoods and individual homes are also included in Table E.4 in the neighborhood connections section of E.1.3.3.

In addition to the 97 homes proposed to be connected as part of this option's base costs, results from the particle tracking analysis indicate that 133 additional individual homes may need to be connected to the existing distribution system in the future. These homes are included in particle tracking costs.

Oakdale home connections to municipal system
Currently 96% of the city's population is served by the existing municipal water distribution system. Therefore, no neighborhoods were proposed to be connected to the existing system. A total of four homes have private wells that meet the treatment threshold and already have water lines running in front of them to be connected to the system.

In addition to the four homes proposed to be connected as part of this option's base costs, results from the particle tracking analysis indicate that 25 additional individual homes may need to be connected to the existing distribution system in the future. These connections are included in particle tracking costs.

Lake Elmo POETSs
According to PFAS sampling data from October 2020 and MWI data, Lake Elmo has an estimated 1,386 existing non-municipal wells, of which 645 have been sampled. Based on the treatment threshold and of those sampled, a total of 18 POETSs would be installed in homes without water lines already in front of them and an additional 11 homes would keep their existing POETSs, for a total of 29 POETSs included for Lake Elmo as long-term solutions for residents with non-municipal wells.

Oakdale POETSs
Current PFAS-impacted non-municipal wells that meet the treatment threshold would be provided with POETSs that were not proposed to be connected to the municipal water system. According to PFAS sampling data from October 2020 and MWI data, Oakdale has an estimated 109 existing non-municipal wells, of which 23 have been sampled. Based on the treatment threshold and of those sampled, no wells would require a POETS. Furthermore, no wells have an existing POETS that would require future maintenance.

E.4.3 Hydraulic modeling analysis

Water Demands
Water demands were based on 2040 population projections, and the hydraulic model was run using MDD. Oakdale has a 2040 MDD of 4,861 gpm, or approximately 7.0 mgd. Lake Elmo has a 2040 MDD of 4,235 gpm, or approximately 6.1 mgd. The two communities together have an MDD of 13 mgd, as summarized in Table E.77 below.

Table E.77. Water Demands for recommended Option 3.

	ADD, mgd	Maximum Day Demand (MDD), mgd
Oakdale	3.06	7.0
Lake Elmo	2.03	6.1
Total	**5.09**	**13.1**

The hydraulic analyses focused on the sizing requirements for the transmission lines and BPS to convey water from SPRWS' Hillcrest Reservoir to Oakdale's distribution system, as well as the interconnects between Oakdale and Lake Elmo's existing distribution system. The hydraulic analyses also included a

10,140 linear foot, 30-inch diameter transmission line that would facilitate flow from SPRWS' existing system to the Hillcrest Reservoir. From the reservoir, water would be pumped and conveyed through dual 24-inch lines for redundancy east to Century Ave, where it would split north and south. A 16-inch line would convey water south to a connection along Century Ave, and another 16-inch line would convey flow north along Century Avenue and then east along 34th Street, where it would connect to the existing distribution system at three different locations, as shown in Figure E.5. In order to minimize head losses and facilitate flow through Oakdale's existing distribution system, some of the existing lines also needed to be upsized. Table E.78 below summarizes the length and diameters of proposed new lines. Existing lines that are proposed to be upsized from 6 and 8 inches under recommended Option 3 are shown in Table E.79.

Table E.78. Recommended Option 3 proposed new water line segment lengths and diameters.

Diameter (in)	Description	Length (ft)
12	New connecting lines	9,993
16	New connecting lines	2,713
24	Dual transmission mains	8,106
30	SPRWS line to Hillcrest Res.	10,140
Total (ft)		30,952
Total (mi)		5.86

Table E.79. Recommended Option 3 existing lines segments proposed to be upsized.

Existing Diameter (in)	Proposed Diameter (in)	Length (ft)
6	12	207
8	12	3,548
8	16	670
	Total (ft)	4,425
	Total (mi)	0.84

In addition to the water line modifications, three interconnects to Lake Elmo's system were included. The first interconnect upsized the existing interconnect near 40th St and Lake Jane Trail N from a 6-inch to a 12-inch diameter. The other two interconnects were also sized as a 12-inch diameter and located along Ideal Ave at 34th Street N and Stillwater Blvd. All three interconnects were located upstream of Lake Elmo's existing Inwood Ave BPS in an attempt to preserve the City's current operating procedures. The operating point of the BPS was iteratively modified to achieve system pressures consistent with what the City is currently experiencing. While it appears that the existing head on the pump created adequate system pressures, it would be necessary to increase the flow rate. This modification may require either multiple pumps operating simultaneously or modifications to the existing pumps, such as installing variable frequency drives or SCADA instrumentation, which is accounted for in the cost estimates provided. The water supply improvements based on the hydraulic modeling are included in base capital costs in Section E.2.5.1.5.

E.4.4 Groundwater modeling analysis

The groundwater model was used to evaluate the amount of "rebound" that would occur under recommended Option 3.

Rebound is the reverse of drawdown, and occurs when groundwater elevations increase after a pumping well is turned off. The condition of Oakdale and Lake Elmo municipal wells being turned off resulted in rising water levels that exceeded “static” conditions (in this case average 2016–2018 simulated groundwater elevations). Rebound shown in Table E.80 is the difference between the resulting Jordan Sandstone and Prairie du Chien groundwater elevations and the “static” groundwater elevations at each of the existing community wells.

Table E.80. Recommended Option 3 rebound analysis at existing Oakdale and Lake Elmo municipal wells.

Community	Well	Jordan Sandstone Rebound (m)		Prairie du Chien Rebound (m)	
		Wet	Dry	Wet	Dry
Oakdale	1	<1	2	<1	2
	2	2	3	2	3
	3	6	8	<1	2
	4	<1	<1	<1	<1
	5	12	18	3	6
	6	<1	<1	<1	<1
	7	<1	2	<1	2
	8	<1	<1	<1	<1
	9	17	24	4	7
	10	3	4	<1	<1
Lake Elmo	1	<1	< 1	<1	<1
	2	2	2	<1	<1
	3	<1	< 1	<1	<1
	4	4	5	<1	<1
	5	<1	< 1	<1	<1

Forward particle tracking to 2040 was conducted under wet and dry climate conditions from known PFAS sources and areas where HI ≥ 1. Particles inserted into the model travel in the direction of groundwater flow. The particle tracking results from the previous groundwater analyses described in Appendix H were incorporated along with results from updated analyses described for recommended Options 1 and 2 to determine potential future costs.

In general, shutting off Oakdale wells delayed westward migration of particles originating directly up gradient (east/northeast) of the City of Oakdale wells. Particles from the analysis in Options 1 and 2 have a further westward extent in the vicinity of Oakdale and Woodbury than particles under recommended Option 3 conditions. Rebound at the Oakdale municipal wells prevents them from capturing particles. As a result, particles stop short of Oakdale wells 5 and 7 and do not travel further west of those wells. Rebound at Oakdale wells ranges between less than 1 meter to 21 meters under wet conditions and up to 26 meters under dry conditions. The greatest amount of rebound occurs at well 9. Rebound that is less than 1 meter occurs at wells that were not pumping under current conditions (2016–2018).

Overall, turning off Lake Elmo community supply wells had a minimal impact on the movement of particles from PFAS sources and areas where HI>1. Wells 1 and 5 are down gradient from the Washington County Landfill and are within the pathway of particles originating at the landfill; however, these wells are not pumping in this option, and therefore, particles are not captured. Rebound at the

Lake Elmo wells ranges between less than 1 meter (wells 1, 3, and 5) to four meters under wet conditions and up to five meters under dry conditions. The greatest amount of rebound occurs at well 4.

Particle tracking for recommended Option 3 is shown in Figure E.10. Particles tracked in the recommended Option 3 groundwater model simulation originating up gradient to the Woodbury Tamarack well field do not travel as far west as the particles tracked for recommended Options 1 and 2. In addition, particles originating at the Woodbury 3M site reach Cottage Grove wells 11 and 12. Therefore, costs to treat those municipal wells are included in the particle tracking costs for recommended Option 3.

E.4.5 Base cost estimate breakdown

Recommended Option 3 capital costs include major infrastructure improvements, including new transmission lines, a BPS, and three interconnects between Oakdale and Lake Elmo in order to supply water from SPRWS. The capital cost estimates are split between Oakdale and Lake Elmo proportional to their 2040 MDDs of 7 MGD and 6.1 MGD, respectively, with the exception of the interconnects from Oakdale to Lake Elmo, and the BPS upgrade in Lake Elmo, which are considered costs for Lake Elmo's subtotal.

Table E.81 provides the base costs associated with SPRWS supplying both Oakdale and Lake Elmo. Tables E.82 and E.83 provide the base costs for improvements specific to Oakdale and Lake Elmo, respectively. Base costs for communities other than Lake Elmo and Oakdale remain unchanged from recommended Option 1. Base capital and O&M costs included for all the communities in recommended Option 3 are summarized in Section E.4.8 below.

O&M costs associated with SPRWS supplying Oakdale and Lake Elmo will comprise only the bulk water charges from SPRWS. SPRWS currently charges a bulk water rate of $2.14 per 100 cubic feet, and has indicated that a 25% increase would take place by 2024, resulting in a rate of $2.675 per 100 cubic feet. The annual cost for Oakdale and Lake Elmo to purchase water from SPRWS will grow over time as Oakdale and Lake Elmo grow. The overall O&M cost related to SPRWS supplying Oakdale and Lake Elmo is not calculated based on a static annual O&M cost applied over time and adjusted for interest and inflation. Instead, the annual cost was increased each year to account for increasing demands. It was assumed that the ADDs for Oakdale and Lake Elmo increased linearly between 2021 and 2040; approximately 2.55 MGD in 2021 to 3.06 MGD in 2040 for Oakdale, and approximately 0.92 MGD in 2021 to 2.03 MGD in 2040 for Lake Elmo. The bulk water rate was kept constant at $2.675 per 100 cubic feet, and each annual cost was adjusted for interest and inflation from 2021 to 2040. Annual O&M costs shown in Table E.81 to cover the bulk water charges to connect Oakdale and Lake Elmo to SPRWS are approximated averages of the annual O&M costs from 2021 to 2040, and therefore cannot be used to calculate the overall O&M cost, as was done for other communities and described in Section E.1.3.3.

The annual O&M also takes into account the expenses associated with maintaining their own wells and facilities that Oakdale and Lake Elmo will no longer have. These costs were estimated using relevant expenses reported in their 2020 annual budget, and are subtracted from the annual O&M.

Table E.81. Base costs for improvements included in Option 3 associated with SPRWS supplying Oakdale and Lake Elmo.

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
Interconnects	3	Stations	From Oakdale to Lake Elmo, $125,000 ea	$375,000
BPS Upgrades	1	Ea	Pump Upgrades to Lake Elmo BPS	$400,000
BPS	1	Stations	9000 gpm at 10 MG Hillcrest Reservoir	$5,252,700
Water distribution mains	0.84	Miles	Upsize mains	$1,762,959
Water distribution mains	3.94	Miles	Distribution mains from Hillcrest Reservoir to Oakdale	$13,529,542
30" water main (SPRWS)	1.92	Miles	Hazel Park BPS to Hillcrest Reservoir	$6,225,960
Stormwater Costs	1	Lump Sum	Stormwater Costs 30% of Linear and Facility Projects	$8,263,848
Land acquisition (site + water mains)	9.1	Acres	1/2 acre per BPS, 20 ft easements (50%)	$338,929
			Oakdale Subtotal	$18,902,105
			Lake Elmo Subtotal	$17,246,834
			Contingency (25%)	$9,037,235
			Professional services (15%)	$5,422,341
			Total Capital	**$50,608,515**
Annual O&M Cost				
Oakdale Bulk Water Cost from SPRWS	1	LS	$2.675 / 100 cu.ft. for ADD of ~2.53 MGD in 2020 with linear increase to ADD of 3.06 MGD in 2040	$3,295,689 in 2020 to $3,993,984 in 2040
Lake Elmo Bulk Water Cost from SPRWS	1	LS	$2.675 / 100 cu.ft. at ADD of ~0.86 MGD in 2020 with linear increase to ADD of 2.03 MGD in 2040	$1,123,210 in 2020 to $2,649,604 in 2040
Oakdale Reduction for well use and media costs	1	LS	Annual budgets for well maintenance and treatment-related costs	-$473,533
Lake Elmo Reduction for well use	1	LS	Calculated based on Oakdale's well maintenance costs	-$122,249
			Oakdale Subtotal	$3,171,303
			Lake Elmo Subtotal	$1,764,158
			20 years of annual O&M	$99,827,149
			20 years of annual O&M present value (inflation + interest)	$95,033,724
			20-year costs (capital + O&M)	**$150,435,663**
			20-year present value costs (capital + O&M and inflation + interest)	**$145,642,238**
			Capital and operating cost per 1,000 gal	$1.63
			Operating only cost per 1,000 gallons	$1.00

Table E.82. Base costs for improvements included in Option 3 specific to Oakdale.

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
Temporary Treatment Facility Demo	1	Lump Sum	Existing and at well 7	$500,000
Municipal Well Demo	4	Ea	$130K per well ($49K to seal well, wells 1,2,7,8)	$520,000
Stormwater Costs	1	Lump Sum	Stormwater Costs 30% of Linear and Facility Projects	$306,000
Service Laterals	4	Ea	Connect homes to existing mains ($4,000 ea)	$16,000
Oakdale City Fees for New Connections	4	Ea	City Fees include WAC ($550), Connection Fee (0), Meter ($400), and Permit ($80)	$4,120
Well Sealing	4	Ea	$2,700 per well	$10,800
			Subtotal	$1,356,920
			Contingency (25%)	$339,230
			Professional services (15%)	$203,538
			Costs for POETSs installed since 2/20/2018	$0
			Total Capital	**$1,899,688**
Annual O&M Cost				
GAC POETSs	0	POETSs	Standard household systems, $1,000 per well	$0
			Subtotal	$0
			20 years of annual O&M	$0
			20 years of annual O&M present value (inflation + interest)	$0
			20-year costs (capital + O&M)	**$1,899,688**
			20-year present value costs (capital + O&M and inflation + interest)	**$1,899,688**

Table E.83. Base costs for improvements included in Option 3 specific to Lake Elmo.

Item	Quantity	Units	Description	Total Cost (GAC)
Capital Cost				
Municipal Well Demo	3	Ea	$130K per well ($49K to seal well, wells 2,4,5)	$390,000
Neighborhood mains	2.4	Miles	Connect 86 homes	$1,900,152
Stormwater Costs	1	Lump Sum	Stormwater Costs 30% of Linear and Facility Projects	$687,046
Service Laterals	97	Ea	Connect homes to existing mains ($8,100 ea)	$785,700
Lake Elmo City Fees for New Connections	97	Ea	City Fees include WAC ($3,000), Connection Fee ($1,000), Meter ($1,540), and Permit ($0)	$537,380
Well Sealing	97	Ea	$2,700 per well	$261,900
Existing GAC POETS Removal	25	Ea	$400	$10,000
Land acquisition (water mains)	4.5	Acres	20 ft easements (50%)	$862,539

Item	Quantity	Units	Description	Total Cost (GAC)
GAC POETSs	18	POETSs	Standard household systems, $2,500 per well	$45,000
			Subtotal	$5,479,716
			Contingency (25%)	$1,369,929
			Professional services (15%)	$821,957
			Costs for POETSs installed since 2/20/2018	$27,500
			Total Capital	**$7,699,103**
Annual O&M Cost				
GAC POETSs	29	POETSs	Standard household systems, $1,000 per well	$29,000
			Subtotal	$29,000
			20 years of annual O&M	$580,000
			20 years of annual O&M present value (inflation + interest)	$553,388
			20-year costs (capital + O&M)	**$8,279,103**
			20-year present value costs (capital + O&M and inflation + interest)	**$8,252,491**

E.4.6 Cost implications of particle tracking

As shown in Figures E.1, E.10 and E.11, the particle tracking analyses indicate that additional wells may be impacted in the future under recommended Option 3. The costs due to particle tracking are the same for recommended Option 3 as in recommended Option 1 for all communities, and are summarized in Section E.4.8 below.

E.4.7 Pretreatment cost summary

There are no pretreatment costs included for Oakdale and Lake Elmo associated with being supplied by SPRWS or otherwise. All other communities have the same pretreatment costs, as discussed in their respective sections of E.2.

E.4.8 Recommended Option 3 summary

Table E.84 provides a summary of estimates of the base, particle tracking, and pretreatment costs for all the community-specific projects included in recommended Option 3, as described in previous sections.

Table E.84. Cost estimate summary table for improvements included in recommended Option 3.

Community served	Components	Base Costs							Particle Tracking Costs					Pretreatment Costs		
		POETSs	Treated Water provided (gpm)	Capital cost ($Ms)	Annual O&M cost ($Ms)	Total 20 year costs ($Ms)	Capital and operating cost per 1,000 gal	Operating only cost per 1,000 gallons	POETSs	Treated Water provided (MGD)	Capital cost ($Ms)	Annual O&M cost ($Ms)	Total 20 year costs ($Ms)	Capital cost ($Ms)	Annual O&M cost ($Ms)	Total 20 year costs ($Ms)
Afton	POETSs only	52	15	0.215	0.052	1.207	7.77	6.39	180	0	0.630	0.180	4.065	N/A	N/A	N/A
Cottage Grove	2 WTPs (7100, 3200 gpm), 1 new well	117	10,350	63.237	1.447	90.843	0.84	0.25	58	4.320	16.644	0.384	23.979	20.503	1.363	46.505
Denmark	POETSs only	4	1	0.014	0.004	0.090	8.29	7.00	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Grey Cloud Island	POETSs only	76	11	0.119	0.076	1.569	13.49	12.47	45	0	0.158	0.045	1.016	N/A	N/A	N/A
Lake Elmo	Neighborhood connections and POETSs	29	6	7.699	0.029	8.252	N/A	N/A	234	0	3.862	0.234	8.327	0	0	0
Lakeland, Lakeland Shores, Lake St. Croix Beach	225 service connections	1	75	1.410	0.001	1.429	1.84	0.02	0	1.08	8.193	0.227	12.531	N/A	N/A	N/A
Maplewood	Water main extension for 35 connections	10	2	0.018	0.010	0.201	10.66	9.76	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Newport	Interconnects with Woodbury and Cottage Grove	6	400	2.951	0.006	3.066	0.69	0.03	16	0	0.056	0.016	0.361	N/A	N/A	N/A
Oakdale	POETSs	0	2,050	1.900	0	1.900	N/A	N/A	4	0	0.285	0.004	0.361	0	0	0
Prairie Island Indian Community	300 gpm WTP, PWS with 8" lines and tank	0	300	7.176	0.141	9.868	3.13	0.85	0	N/A	N/A	N/A	N/A	1.551	0.105	3.556
SPRWS interconnect	Transmission lines, BPS, upsized lines	0	9,000	50.609	4.935	145.642	1.63	1.00	N/A	N/A	N/A	N/A	N/A	0	0	0
St. Paul Park	2200 gpm WTP	5	2,200	15.880	0.421	23.913	1.03	0.35	20	0	0.284	0.020	0.666	5.208	0.345	11.799
West Lakeland – Municipal System	PWS for 80% Township, 2 wells, 1 WTP, 8"& 12" lines	20	1,200	181.389	0.344	188.308	15.17	0.52	270	0	0.945	0.270	6.097	3.573	0.211	7.595
West Lakeland – POETSs	POETSs only	655	130	2.319	0.655	14.817	10.99	9.27	738	0	2.583	0.738	16.666	N/A	N/A	N/A
Woodbury	1 WTP (11,600 gpm)	20	11,600	125.149	1.467	153.134	1.26	0.23	30	0	0.278	0.030	0.850	25.853	1.431	53.151
Totals for West Lakeland on POETSs		**975**	**49.311**	**278.696**	**9.244**	**455.931**	**N/A**	**N/A**	**1325**	**5.400**	**32.973**	**1.878**	**68.822**	**53.115**	**3.244**	**115.011**
Totals for West Lakeland on municipal supply		**340**	**50.860**	**457.766**	**8.933**	**629.422**	**N/A**	**N/A**	**857**	**5.400**	**31.335**	**1.410**	**58.253**	**56.688**	**3.455**	**122.606**

E.5 Recommended Options 1-3 – Impacted municipal wells

Municipal wells that are proposed to be treated in the updated recommended Options 1, 2, and 3 are listed in Table E.85 below. Those wells with a "Yes" are included in the options as shown. The base columns include municipal wells that are proposed to be treated based on sampling as of first quarter 2021 or other considerations as described in Sections E.2-E.4 and included in base costs. The particle tracking (PT) columns include municipal wells with the potential to be treated based on the particle tracking analysis. Wells included only in the PT column will not be treated unless future sampling indicates they meet the treatment threshold. Wells that are grayed out are either off-line or sealed, or proposed to be sealed, and communities that are grayed out do not have municipal wells (not applicable [N/A]).

Table E.85. Municipal wells treated in recommended Options 1, 2, and 3 for the original analysis and PT.

Community	Well No.	Option 1 (HI ≥ 0.5)		Option 2 (HI ≥ 0.3)		Option 3 (HI ≥ 0.5)	
		Base	PT	Base	PT	Base	PT
Afton	N/A						
Cottage Grove	1						
Cottage Grove	2						
Cottage Grove	3	Yes	Yes	Yes	Yes	Yes	Yes
Cottage Grove	4	Yes	Yes	Yes	Yes	Yes	Yes
Cottage Grove	5	Yes	Yes	Yes	Yes	Yes	Yes
Cottage Grove	6	Yes	Yes	Yes	Yes	Yes	Yes
Cottage Grove	7	Yes	Yes	Yes	Yes	Yes	Yes
Cottage Grove	8	Yes	Yes	Yes	Yes	Yes	Yes
Cottage Grove	9	Yes	Yes	Yes	Yes	Yes	Yes
Cottage Grove	10	Yes	Yes	Yes	Yes	Yes	Yes
Cottage Grove	11		Yes	Yes	Yes		Yes
Cottage Grove	12		Yes		Yes		Yes
Cottage Grove	New W1	Yes	Yes	Yes	Yes	Yes	Yes
Denmark	N/A						
Grey Cloud Island	N/A						
Lake Elmo	2						
Lake Elmo	4						
Lake Elmo	5						
Lake Elmo	New W1*	Yes	Yes	Yes	Yes	Yes	Yes
Lake Elmo	New W2*	Yes	Yes	Yes	Yes	Yes	Yes
Lakeland	1						
Lakeland	2						
Maplewood	N/A						
Newport	1						
Newport	2						

Community	Well No.	Option 1 (HI ≥ 0.5)		Option 2 (HI ≥ 0.3)		Option 3 (HI ≥ 0.5)	
		Base	PT	Base	PT	Base	PT
Oakdale	1						
Oakdale	2						
Oakdale	3						
Oakdale	5	Yes	Yes	Yes	Yes		
Oakdale	6						
Oakdale	7						
Oakdale	8						
Oakdale	9	Yes	Yes	Yes	Yes		
Oakdale	10						
Oakdale	New W1	Yes	Yes	Yes	Yes		
Oakdale	New W2	Yes	Yes	Yes	Yes		
Oakdale	New W3	Yes	Yes	Yes	Yes		
PIIC	1	Yes	Yes	Yes	Yes	Yes	Yes
St. Paul Park	2	Yes	Yes	Yes	Yes	Yes	Yes
St. Paul Park	3	Yes	Yes	Yes	Yes	Yes	Yes
St. Paul Park	4	Yes	Yes	Yes	Yes	Yes	Yes
West Lakeland	New W1	Yes	Yes	Yes	Yes	Yes	Yes
West Lakeland	New W2	Yes	Yes	Yes	Yes	Yes	Yes
Woodbury	1						
Woodbury	2	Yes	Yes	Yes	Yes	Yes	Yes
Woodbury	3	Yes	Yes	Yes	Yes	Yes	Yes
Woodbury	4	Yes	Yes	Yes	Yes	Yes	Yes
Woodbury	5	Yes	Yes	Yes	Yes	Yes	Yes
Woodbury	6	Yes	Yes	Yes	Yes	Yes	Yes
Woodbury	7	Yes	Yes	Yes	Yes	Yes	Yes
Woodbury	8	Yes	Yes	Yes	Yes	Yes	Yes
Woodbury	9	Yes	Yes	Yes	Yes	Yes	Yes
Woodbury	10	Yes	Yes	Yes	Yes	Yes	Yes
Woodbury	11	Yes	Yes	Yes	Yes	Yes	Yes
Woodbury	12	Yes	Yes	Yes	Yes	Yes	Yes
Woodbury	13	Yes	Yes	Yes	Yes	Yes	Yes
Woodbury	14	Yes	Yes	Yes	Yes	Yes	Yes
Woodbury	15						
Woodbury	16						
Woodbury	17	Yes	Yes	Yes	Yes	Yes	Yes
Woodbury	18			Yes	Yes		
Woodbury	19	Yes	Yes	Yes	Yes	Yes	Yes
Woodbury	New W1			Yes	Yes		
Woodbury	New W2			Yes	Yes		
Woodbury	New W3			Yes	Yes		
Woodbury	New W4			Yes	Yes		
Woodbury	New W5			Yes	Yes		

Community	Well No.	Option 1 (HI ≥ 0.5)		Option 2 (HI ≥ 0.3)		Option 3 (HI ≥ 0.5)	
		Base	PT	Base	PT	Base	PT
Woodbury	New W6**			Yes	Yes		
Woodbury	New W7**			Yes	Yes		
Woodbury	New W8**			Yes	Yes		
	Total	**35**	**33**	**42**	**40**	**31**	**29**

*The two new wells shown for Lake Elmo are only applicable for the autonomous alternative, as described in Section E.2.5

**These three new wells shown for Woodbury are only applicable for Lake Elmo's interconnect alternative, as described in Section E.2.5.

E.6 Recommended Options 1-3 – Non-municipal wells and POETSs

Non-municipal wells and POETSs included in the updated recommended Options 1, 2, and 3 are provided in Table E.86 below. Explanation of the columns included in the table are as follows:

- **Total wells** – total number of wells estimated for each community. In some cases these were modified from those found in the MWI and/or sampling databases based on feedback from the community representatives.
- **Wells in MWI** – number of wells for each community indicated by the MWI geographical information system files.
- **Total sampled** – number of wells for each community that have been sampled by MDH for PFAS as of October 2020.
- **Total wells w/ POETSs** - number of wells for each community that have a POETS installed as of October 2020.
- Per each option:
  - **Wells to continue w/ POETSs** – number of wells in each community that are proposed in the respective updated recommended options to continue to rely on POETSs. Only O&M costs are included in the recommended options for these wells.
  - **Wells to receive POETSs** – number of wells in each community that are proposed in the respective updated recommended options to receive new POETSs due to the lower HI treatment thresholds. Both capital and O&M costs are included in the recommended options for these wells.
  - **POETSs in base costs** - total number of wells in each community that are proposed in the respective updated recommended options to either receive a new POETS or continue with an existing POETS, as described in the two previous columns listed above.
  - **POETSs from PT** - number of wells in each community that are included in costs for the respective updated recommended options that would receive a new POETS based on the PT results from the groundwater model. Both capital and O&M costs are included in the recommended options for these wells.

Table E.86. Summary of Non-municipal wells and POETSs discussed in recommended Options 1, 2, and 3.

Community	Total Wells	Wells in MWI	Total Sampled	Total Wells w/ POETSs	Options 1 and 3				Option 2			
					Wells to continue w/ POETSs	Wells to receive POETSs	POETSs in base costs	POETSs from PT	Wells to continue w/ POETSs	Wells to receive POETSs	POETSs in base costs	POETSs from PT
Afton	1195	808	242	39	39	13	52	180	39	21	60	180
Cottage Grove	868	868	723	68	68	49	117	58	68	70	138	52
Denmark Twp	761	515	133	0	0	4	4	0	0	7	7	0
Grey Cloud Island Twp	123	123	111	53	53	23	76	45	53	25	78	43
Lake Elmo	1386	1386	645	11	11	18	29	234	11	35	46	220
Lakeland	342	342	112	5	1	0	1	0	1	0	1	0
Lake St. Croix Beach	122	122	6	0	0	0	0	0	0	0	0	0
Lakeland Shores	44	44	16	0	0	0	0	0	0	0	0	0
St. Mary's Point*	102	102	5	0	0	0	0	0	0	0	0	0
Maplewood	615	615	59	5	5	5	10	0	5	6	11	0
Newport	134	134	57	1	0	6	6	16	0	32	32	16
Oakdale	109	109	23	0	0	0	0	4	0	0	0	4
PIIC	1	1	1	0	0	0	0	0	0		0	0
St. Paul Park	66	66	25	6	5	0	5	20	5	0	5	20
WLT – POETSs only	1393	1393	995	552	552	103	655	738	552	144	696	697
WLT – Municipal System	1393	1393	995	12	12	8	20	270	12	14	26	250
Woodbury	657	657	258	2	2	18	20	30	2	48	50	27
Total (WLT ALL POETSs)	**7918**	**7285**	**3411**	**742**	**736**	**239**	**975**	**1325**	**736**	**388**	**1124**	**1259**
Total (WLT MUNICIPAL SYSTEM)	**7918**	**7285**	**3411**	**202**	**196**	**144**	**340**	**857**	**196**	**258**	**454**	**812**

Appendix F. Recommended options supporting documentation

F.1 Unit cost estimations

F.1.1 Introduction

This section summarizes the unit costs developed for drinking water-related construction projects within Washington County, Minnesota. These costs were developed by the State of Minnesota in partnership with the work groups, primarily the Technical Drinking Water Supply Subgroup, SG1. This information was used to help determine the total estimated costs associated with conceptual projects included in this Conceptual Drinking Water Supply Plan (Conceptual Plan).

Costs were developed for the following construction projects (and described in more detail in the sections below):

- Installing water mains (Section F.1.2)
- Constructing water storage tanks or towers (Section F.1.3)
- Constructing booster pump stations (BPSs; Section F.1.4)
- Constructing buildings used for BPSs, well pump houses, and water treatment plants (WTPs; Section F.1.5)
- Drilling new municipal and non-municipal wells (Section F.1.6)
- Acquiring land (Section F.1.7).

F.1.2 Water mains

Unit costs (in dollars per foot) for the installation of water mains in Washington County were estimated to calculate the total cost, based on the distance of the water main installation project.

These unit costs were developed for varying percentages of pipe that will be aligned under roadways in both urban and rural areas; and include street reconstruction, material, labor, and permitting costs. The cost estimates for pavement removal and replacement, trench excavation and backfill, pipe, and installation costs were developed using bid tabulations from cities within Washington County along with the Washington County Municipal Water Coalition Water Supply Feasibility Assessment (Metropolitan Council, 2016). All pricing from years before 2019 was normalized to 2019 pricing using the Construction Cost Index from the Engineering News Record (ENR). Assumptions used in the analysis include:

- One-hundred percent of the total costs for street reconstruction were applied in roadway construction (or 100% under roadway pavement) where two lanes of roadway were assumed to be removed and replaced. Half of the total costs for street reconstruction were applied in roadway construction where one lane of roadway was assumed to be removed and replaced. No costs for street reconstruction were applied in any roadway construction where no lanes were assumed to be removed and replaced (e.g., in cases where right-of-way is accessible).
- Curbs, gutters, and sidewalks are to be removed and replaced for water mains in urban areas. Curb, gutter, and sidewalks were not included for water mains installed in rural areas.
- All pipe requires an 8-foot burial depth.
- Excavation protection was included for water main installation in urban and rural areas, as well as protection of existing utilities.

- Fire hydrants will be included every 300 feet.
- For pipes with diameters ranging from 4 to 8 inches, valves will be installed every 400 feet and fittings will be installed every 200 feet.
- For pipes with a 12-inch diameter, valves will be installed every 600 feet and fittings will be installed every 200 feet.
- For pipes with diameters ranging from 16 to 24 inches, valves will be installed every 800 feet and fittings will be installed every 200 feet.
- For pipes with diameters ranging from 20 to 42 inches, the costs for valves and fittings were included in the unit costs per linear foot of pipe.
- Stormwater protection and utility conflicts were taken into consideration as part of street reconstruction estimates. Bid tabulations used include stormwater protection in their estimates and $2 per linear foot was also included for erosion control.
- Engineering permits, right-of-way permits, and construction inspections were included as a percentage of total capital costs (in the 15% applied to capital costs for professional services, which also includes construction management and administration, and engineering design).

Table F.1 outlines the individual costs that were included in the total unit price per linear foot of water main installation. Table F.2 summarizes the total cost per linear foot of water main installations for varying pipe sizes. These costs are organized by pipe diameter, percentage in roadway, and the type of area where the project would occur (urban versus rural). Total water main installation capital costs can be estimated by multiplying the unit cost (in dollars per linear foot) by the approximate distance in linear feet for the project. The need for rock excavation was determined using a geographic information system (GIS) to determine where proposed water lines overlap shallow bedrock (e.g., less than 10 feet below the ground surface). In cases where proposed pipelines were located in shallow bedrock, rock excavation will be required. For watermains that require rock excavation along 100% of the pipe length, an additional cost per cubic yard was added to the linear foot cost of the watermain installation, as shown in Table F.2.

Table F.1. Individual costs included in urban and rural water main installations.

Urban	Rural
• Roadway and driveway removal/replacement • Curb, gutter, and sidewalk removal/replacement • Removal/replacement of median • Trench excavation and backfill • Excavation protection • Landscape repairs and improvements • Clearing and grubbing • Rock excavation (0%, 50%, or 100% of alignment) • Ductile iron piping, fittings, and valves • Existing sewer, water, and utility pipe removal/replacement • Pipe insulation and bedding • Other trenching costs • Additional costs including mobilization, overhead, profit, and general conditions • Labor • Engineering permits and city inspections	• Roadway and driveway removal/replacement • Trench excavation and backfill • Excavation protection • Landscape repairs and improvements • Clearing and grubbing • Rock excavation (0%, 50%, or 100% of alignment) • Ductile iron pipping, fittings, and valves • Pipe insulation and bedding • Other trenching costs • Additional costs including mobilization, overhead, profit, and general conditions • Labor • Engineering permits and city inspections

Table F.2. Unit cost summary for water main installation.

Pipe diameter (inches)	Percent in roadway (%)	0% rock excavation		Unit cost for rock excavation per CY		100% rock excavation	
		Urban cost per foot ($/LF)	Rural cost per foot ($/LF)	Urban cost for rock excavation ($/CY)	Rural cost for rock excavation ($/CY)	Rural cost per foot ($/LF)	Rural cost per foot ($/LF)
8	0	194	110	52	56	258	179
8	50	385	152			449	222
8	100	577	194			641	264
12	0	204	119	58	62	276	196
12	50	396	162			468	238
12	100	588	204			659	281
16	0	221	134	64	68	299	218
16	50	412	176			491	260
16	100	604	218			683	303
18	0	235	147	67	71	317	235
18	50	427	190			509	278
18	100	619	232			701	320
20	0	327	239	70	74	414	331
20	50	519	282			606	373
20	100	711	324			798	415
24	0	365	274	76	80	458	373
24	50	556	316			650	416
24	100	748	359			841	458
30	0	422	330	84	89	527	440
30	50	614	372			718	482
30	100	806	414			910	524
36	0	503	408	94	98	618	529
36	50	694	450			810	572
36	100	806	493			1,002	614
42	0	503	454	102	107	677	586
42	50	694	496			869	628
42	100	889	538			1,061	671
48	0	550	512	111	116	749	655
48	50	742	554			941	698
48	100	934	596			1,133	740
54	0	611	570	121	125	822	726
54	50	803	612			1,013	768
54	100	1,055	655			1,205	810
60	0	729	627	127	131	887	789
60	50	921	669			1,079	831
60	100	1,113	711			1,271	874

Annual operation and maintenance (O&M) costs for water mains were estimated to be 0.5% of the installation cost and are inclusive of general O&M costs, such as valve exercising, fire hydrant or blowoff flushings, water main repairs, and water quality sampling. Recapitalization costs are also included in yearly O&M costs at 2% of the installation cost and assume a 50-year service life. However, these O&M and recapitalization costs for the distribution system infrastructure were only included in the initial estimates provided in Appendix H. These costs were determined to not be Settlement-eligible and were not included in the final costs presented in Appendix E and the Conceptual Plan.

F.1.3 Storage tanks or towers

The approximate total unit cost (in dollars per gallon) of constructing a storage tank or tower in Washington County was estimated based on the gallons of water the tank or tower would hold.

Unit costs related to sitework and storage tank construction were estimated using a bid tabulation from studies and construction projects in Woodbury and Lake Elmo, as well as the communities of Hamburg, Freeport, and Lyon County outside of the East Metropolitan area. Details about site project-specifics were not available to assess the scope of each reference project. All pricing from years before 2019 were moved forward to 2019 pricing using the Construction Cost Index from ENR. The following assumptions and costs were used in the analysis:

- The storage tank could be constructed as a steel fluted column water tower or a steel pedestal spheroid water tower.
- Large-volume storage tanks require foundations and footings, and the level of effort is dependent on site geotechnical conditions. Reference projects were assumed to include steel (e.g., rebar) and concrete composite bases, and the collection of reference projects were assumed to cover the range of representative conditions.
- The estimated cost for the storage tank does not include all required tank equipment costs as some of this equipment may be site-specific. Examples include lift pump, yard piping, special freeze protection equipment, land, Federal Aviation Administration lighting, painted logo, mixing system inside the tank, or other elective accessories (Caldwell Tanks, Undated).
- The yard piping was assumed to be 200 linear feet of 24-inch ductile iron water main.
- The base capital cost estimate excludes soft costs such as construction management and administration, engineering design, engineering and right-of-way permits, and construction inspections. These costs were added as a percentage (15%) of the base capital costs and are referred to collectively as professional services costs.
- O&M and recapitalization costs were only included in the initial estimates provided in Appendix H and were determined to not be settlement-eligible. The following annual tank costs and assumptions were included in the initial estimates:
  - Annual tank maintenance was assumed to be 1.5% of the tank's capital cost. This includes general maintenance items often performed by operations staff, such as level sensor replacement, cathodic system adjustment, sediment removal, gasket replacements, and screening replacements.
  - Site operating costs included $2,000 for heating and $2,000 for general site maintenance. Operator costs were assumed to be $50 per hour for four hours per week.
  - Internal and external tank coatings were assumed to be removed and recoated every 20 years at $39 per square foot, which was based on five bid tabulations from the East Metropolitan area.

Eight water storage tank projects from Minnesota for the last 15 years yielded a cost per unit of capacity for a storage tank or tower that ranged from $1.89 to $6.68 per gallon, depending on the tank volume. The tank installation cost can be estimated by multiplying the unit cost (dollars per gallon) by the storage capacity (gallons). This value was added to the sitework cost of $0.15/gallon (minimum of $50,000) estimated from the above-mentioned bid tabulation to obtain an estimated total capital cost for the project. Table F.3 provides example unit cost estimates for the construction of a storage tank or tower.

Table F.3. Unit cost summary for storage tank or tower construction.

Cost per gallon ($)	Storage capacity (gallons)	Storage tank cost ($)	Sitework cost ($)	Total capital cost ($)	Annual O&M cost ($)
6.68	75,000	501,000	50,000	551,000	31,000
5.12	150,000	768,000	50,000	818,000	40,000
3.22	500,000	1,611,000	76,000	1,687,000	70,000
2.47	1,000,000	2,469,000	151,000	2,620,000	101,000
1.89	2,000,000	3,784,000	301,000	4,085,000	150,000

F.1.4 BPS

The approximate unit cost (in dollars per gallons per minute, gpm) of constructing a BPS in Washington County was estimated by calculating the total costs of a BPS was based on its gpm firm pumping capacity or flow rate.

Unit costs were prepared based on historical bids tabulated for a 2016 reference project in Lake Elmo. Many assumptions follow those outlined in the Washington County Municipal Water Coalition Water Supply Feasibility Assessment (Metropolitan Council, 2016) and the 2019 RSMeans Cost Data Book. All pricing for years before 2019 were moved forward to 2019 pricing using the Construction Cost Index from ENR. The construction cost was scaled from the reference project by applying an empirical power factor of 0.6 to the ratio of capacity:

$$Cost\ New = Cost\ Reference \times \left(\frac{Cost\ Index\ Current\ Year}{Cost\ Index\ Reference\ Year}\right) \times \left(\frac{Capacity\ New}{Capacity\ Reference}\right)^{Power\ Factor}$$

The analysis costs include:

- The reference project includes two pumps in the booster station for redundancy.
- The cost of a building and all required site work.
- O&M and recapitalization costs were only included in the initial estimates provided in Appendix H and were determined to not be settlement-eligible. The following describes the annual BPS costs and assumptions that were included in the initial estimates:
  - Assumed four hours per week for operators, with an hourly labor rate of $50 per hour.
  - Booster pumps were assumed to run 12 hours daily.
  - The motor horsepower was estimated based on the pump capacity, a supply of 50 feet of head pressure, an overall efficiency of 68%, and numbers were rounded up to the nearest standard horsepower for motors (30, 40, 50, 60, 75, 100, 125, 150, 200, 250, 300, 350, 400, 450, 500, 600, 700, 800, 900, and 1,000).
  - Pumping energy costs were assumed to be 74% of pump efficiency, using a kilowatt-hour cost of $0.072.

- The assumed equipment maintenance was 3% of capital cost.
- Additional annual maintenance costs included $2,000 for heating the building and $2,000 for miscellaneous building costs.

Table F.4 provides an example unit cost estimate for a BPS that matches the reference project. The capital cost, adjusted to 2019 using the ENR Construction Cost Index, leads to a cost of $871 per gpm of capacity. This cost includes all related sitework and assumes two pumps in the booster station.

Table F.4. Unit cost summary for BPS construction.

Pumping capacity or flow rate (gpm)	Horsepower	Annual operating cost ($)	Capital cost ($)	Cost per unit of capacity ($ per gpm)
1,200	150	82,300	1,045,400	871

F.1.5 Buildings

The approximate unit cost (in dollars per square foot) of constructing a building used for a BPS or well pump house in Washington County was estimated by calculating the total cost of a building based on the building size.

The contractor's schedule of values from St. Paul Park's granular activated carbon (GAC) WTP were used to determine the building cost.

It was estimated to cost approximately $560 per square foot to construct a building, which includes all necessary sitework. The total cost for constructing a building can be estimated by multiplying the unit cost (in dollars per square foot) by the building size (in square feet). Table F.5 provides examples of varying costs based on the building size.

Table F.5. Unit cost summary for building construction.

Building dimensions (ft)	Building cost per square foot ($)	Capital cost ($)
45 x 20	560	504,000
30 x 15	560	252,000
10 x 10	560	56,000

F.1.6 Municipal and non-municipal wells

The approximate total cost to drill a new municipal or non-municipal well in Washington County was estimated for this Conceptual Plan.

For drilling a new municipal well, the pricing came from the Washington County Municipal Water Coalition Water Supply Feasibility Assessment (Metropolitan Council, 2016) and a bid tabulation from Hastings, Minnesota, a community just outside the East Metropolitan area. Using this information, the cost to drill a new municipal well capable of supplying 800–1,200 gpm was estimated to be $2,178,000.

The construction cost was scaled from the reference project by applying an empirical power factor of 0.6 to the ratio of capacity.

$$\mathit{Cost\ New} = \mathit{Cost\ Reference} \times \left(\frac{\mathit{Cost\ Index\ Current\ Year}}{\mathit{Cost\ Index\ Reference\ Year}}\right) \times \left(\frac{\mathit{Capacity\ New}}{\mathit{Capacity\ Reference}}\right)^{\mathit{Power\ Factor}}$$

For drilling a new non-municipal well, the approximate cost was determined using a bid tabulation from West Lakeland Township. Using this information, the cost to drill a new non-municipal well capable of supplying 20 gpm was estimated to be $12,000.

Table F.6 summarizes the estimated costs to drill a new municipal or non-municipal well. The pricing includes the costs to construct a new well house and sitework. All pricing from years before 2019 were moved forward to 2019 pricing using the Construction Cost Index from ENR.

Table F.6. Unit cost summary for drilling new municipal and non-municipal wells.

Well description	Water pumping rate (gpm)	Capital cost ($)
Municipal well	800–1,200	2,178,000
Non-municipal well (single home)	20	12,000

F.1.7 Land acquisition

The approximate unit costs (in dollars per square foot) to acquire land in Washington County were estimated to calculate the total cost of land acquisition based on the lot size.

To estimate the current cost of land in Washington County, the costs of two lots per community were analyzed. The resources used in this analysis included Realtor.com, Zillow, and Metro East Commercial Real Estate Services.

Table F.7 summarizes the results of this analysis. An average cost of $3.11 per square foot was estimated based on the price per acre of each lot throughout Washington County. The total cost of the land acquisition project can be estimated by multiplying the unit cost (in dollars per square foot) by the lot size (in square feet), unless actual cost information was provided by the communities.

Table F.7. Unit cost summary for land acquisition. Information sorted by cost per square foot, from lowest to highest cost.

Lot size (acres)	Community	Cost per square foot ($ per square foot)
5.5	Denmark	0.93
4.2	Cottage Grove	1.64
3.4	St. Paul Park	1.82
3.0	Grey Cloud Island	2.04
5.1	Afton	2.12
1.3	Newport	2.18
2.6	West Lakeland Township	3.24
2.5	Oakdale	4.11
1.8	Lake Elmo	4.36
1.2	Maplewood	4.38
1.5	Lakeland/Lakeland Shores/Lake St. Croix Beach	4.41
1.4	Woodbury	6.03
	Average land acquisition cost for East Metropolitan area	3.11

F.2 Small community water system analysis

F.2.1 Introduction

This section summarizes the theoretical exercise that was performed to examine the validity of small community water systems for rural communities in the East Metropolitan area. Selected areas were analyzed to determine if drilling and treating a well to service 8 or 20 homes would create a more cost-effective solution over treating each non-municipal well individually with a GAC point-of-entry treatment (POET) system. The analysis included neighborhoods in Afton, Grey Cloud Island Township, and West Lakeland Township.

Important considerations for this analysis included how many homes could be grouped together and any associated service requirements. The 1974 Safe Drinking Water Act states that when at least 15 service connections or 25 people are served for at least 60 days a year by a single source, the water system is considered a public water system, which has associated redundancy requirements (see below). A system for eight homes with approximately three people per home is the maximum number of homes that can be grouped together and serviced by one well without redundancy requirements. When analyzing 20 homes per well, the redundancy requirements consist of two wells, a certified water operator, a backup generator, and additional water quality testing. These additional costs required for a public water system that can service 20 homes are reflected in the analyses below.

Please note that this assessment was conducted based on year 2019 costs, POET counts, assumptions, and discount rate. Based on the analysis, the concept was removed from further consideration at that time. The values identified below are provided for reference and were not updated further since that time.

F.2.2 Methods

Key steps of this analysis included identifying homes close enough to form an area to be serviced, measuring the average distances between homes with ArcGIS Earth, and determining the cost of creating a small community water system versus treating each well individually with a POET system or treatment at a municipal level. The methods are described in more detail in the sections below.

F.2.2.1 Well counts

Well data were taken from initial well counts provided by the Minnesota Pollution Control Agency (MPCA) and the Minnesota Department of Health (MDH) in 2019. Although these well counts do not match the final private well counts used in Appendix E of the Conceptual Plan, they illustrate the conclusions of this analysis with the same efficacy.

F.2.2.2 GIS analysis

The ArcGIS Earth interface was used to identify the number of homes in each community that were close enough to be considered a small community water system. For this analysis, clusters of 8 and 20 homes were considered.

F.2.2.3 Cost development

Costs were developed by utilizing unit costs from recent bid tabulations in the project area, obtaining installation quotes from private well drillers in the project area, obtaining vendor quotes for equipment, and utilizing MPCA's experience and current contracted rates for installing POET systems on private wells.

The total 20-year costs for a small community water system were calculated by summing the initial costs for drilling and equipping a well with a depth of 200–400 feet, installing 24-inch polyvinyl chloride (PVC) pipe, and installing a treatment system; as well as including the anticipated 20-year O&M costs with a 3% discount rate related to the net present value. It was assumed that 2-inch PVC piping would be used for an 8-home system and 4-inch PVC piping would be used for a 20-home system. The GAC treatment system was sized based on the gpm it would treat. The total 20-year O&M costs assume that PVC piping would last 50 years, and a recapitalization cost was estimated along with piping maintenance costs. The PVC piping service life estimate was determined from the American Society of Testing and Materials' (ASTM's) Annual Book of ASTM Standards, Volume 8.04, Plastic Pipe and Building Products (ASTM, 2006). The cost assumes that the well pump and pressure tank would need to be replaced every 10 years.

POET system costs used for individual homes/wells were assumed to be $2,500 for capital costs and $1,000 for annual O&M costs. The GAC treatment system for the wells was assumed to need maintenance and filter change-outs once yearly.

Legal expenses and administrative costs of setting up and running a small community water system were not accounted for in these cost estimates. Similarly, the legal, administrative, and ongoing well monitoring; and other indirect or overhead costs associated with managing the POET systems and carbon change-outs were also not accounted for in the cost estimates.

F.2.3 Afton

For Afton, two analyses were performed to determine if a small community water system of 8 or 20 homes would create cost savings over treating non-municipal wells with POET systems.

The first analysis was performed to calculate the total 20-year costs for grouping eight homes together in Afton to form a small community water system. Figure F.1 shows an example of four, eight-home groupings in Afton, located off 2nd and 3rd streets west of Neal Avenue. In Afton, there are many areas of opportunity to create small community water systems. The average distance between homes in Afton was calculated to be 350 feet using ArcGIS Earth. Thus, the average estimated feet of pipe required to connect eight homes in Afton would be approximately 2,800 feet.

As shown in Table F.8, grouping eight homes to create a small community water system would not provide sufficient cost savings over individual treatment with a POET system. As the number of small community water systems increases and the number of POET systems decreases, the total 20-year costs increase (Table F.8).

Figure F.1. Example of four, eight-home groupings in Afton.

Table F.8. Cost analysis for grouping eight homes in Afton.

Alternative	Groups of 8-home small community water systems	Individual homes with private wells and POET systems	Initial cost (capital)	Annual operating cost	20-year cost (capital + O&M)
1	0	1,105	2,763,000	1,105,000	24,863,000
2	10	1,025	5,653,000	1,125,000	28,153,000
3	35	825	12,878,000	1,175,000	36,378,000
4	65	585	21,548,000	1,235,000	46,248,000
5	95	345	30,218,000	1,295,000	56,118,000
6	135	25	41,778,000	1,375,000	69,278,000

A similar analysis was performed to calculate the total 20-year costs for grouping 20 homes. Figure F.2 shows an example of a 20-home grouping located off Trading Post Trail and 42nd Street in Afton. However, Afton has limited areas where 20 homes are close enough to be connected as one small community water system, and there would need to be supplemental systems with less than 20 homes per group to make this option possible. The average estimated feet of pipe required to connect 20 homes in Afton would be approximately 7,000 feet. For redundancy requirements to be met, two wells would be required along with a certified water operator, additional water quality testing, and a backup generator for one well. As shown in Table F.9, creating a small community water system of 20 homes would provide no cost savings over individual treatment with POET systems.

Figure F.2. Example of a 20-home grouping in Afton.

Table F.9. Cost analysis for grouping 20 homes in Afton.

Alternative	Groups of 20-home small community water systems	Individual homes with private wells and POET systems	Initial cost (capital)	Annual operating cost	20-year cost (capital + O&M)
1	0	1,105	2,763,000	1,105,000	24,863,000
2	10	905	18,193,000	1,535,000	48,893,000
3	25	605	41,338,000	2,180,000	84,938,000
4	35	405	56,768,000	2,610,000	108,968,000
5	45	205	72,198,000	3,040,000	132,998,000
6	55	5	87,628,000	3,470,000	157,028,000

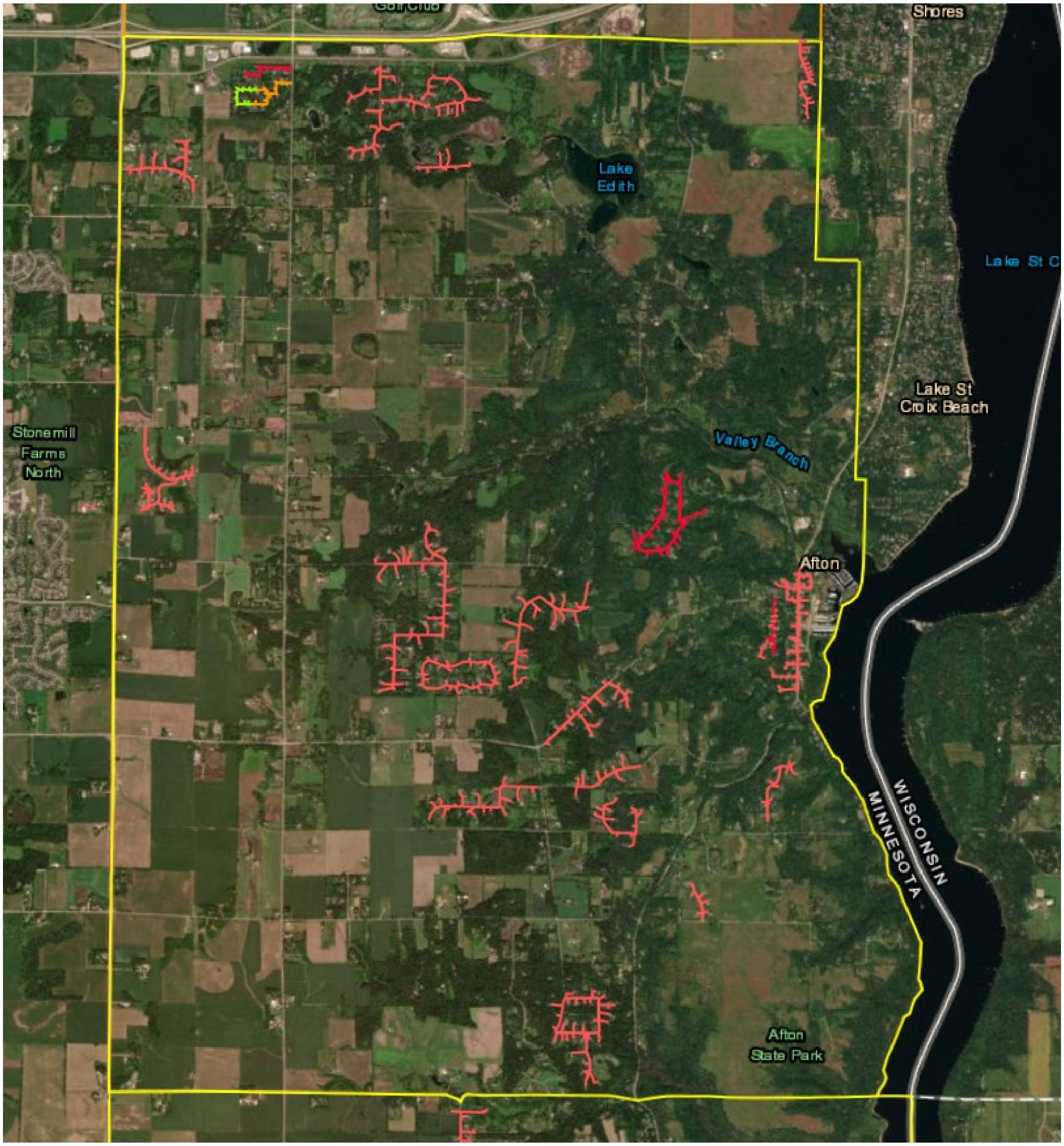
From the results above, grouping 8 or 20 homes to create a small community water system is possible but would not produce cost-saving benefits when compared to treating each home individually with a POET system. The unit costs used for the calculations are shown in Table F.10. A map of the potential small community water systems in this community is shown in Figure F.3.

Table F.10. Cost summary for Afton.

Item	Description	Source	Quantity	Units	Unit cost	Subtotal
City of Afton cost estimate for 8-home community						
20-year treatment facility capital costs						
1	2" piping installed	Washington County bid tabulations	2,800	LF	$97	$272,000
2	Capital cost POET	Wood experience	4	LS	$5,500	$22,000
3	New private well with hook-up	E.H. Renner & Sons Well Drilling MN	400	FT	$30	$12,000
4	Well pump	Wood experience	1	EA	$2,000	$2,000
5	Pressure tank	Grainger	1	EA	$1,000	$1,000
		Subtotal – 20-year treatment facility capital costs				**$309,000**
Annual O&M costs						
6	Filter maintenance cost	Estimate	4	LS	$1,000	$4,000
7	Cost to replace piping	Wood experience	1	LS	$5,500	$5,500
			Subtotal – annual O&M costs			**$10,000**
20-year O&M costs						
8	Cost to replace PVC piping	Wood experience	1	LS	$110,000	$110,000
9	Well repair costs	Estimate	1	LS	$6,000	$6,000
10	Filter maintenance cost	Estimate	1	LS	$80,000	$80,000
			Subtotal – 20-year O&M costs			**$196,000**
			Subtotal – 20-year capital + O&M costs			**$505,000**
City of Afton cost estimate for 20-home community						
20-year treatment facility capital costs						
1	4" piping installed	Washington County bid tabulations	7,000	LF	$127	$889,000
2	Capital cost GAC	Wood experience	1	LS	$660,000	$660,000
3	New well with hook-up	E.H. Renner & Sons Well Drilling MN	800	FT	$50	$40,000
4	Well pump	Wood experience	2	EA	$2,000	$4,000
5	Pressure tank	Grainger	2	EA	$1,000	$2,000
		Subtotal – 20-year treatment facility capital cost				**$1,595,000**
Annual O&M costs						
6	Annual media cost	Estimate	1	LS	$12,000	$12,000
7	Annual operating costs	Estimate	1	EA	$33,000	$33,000
8	Cost to replace piping	Wood experience	1	LS	$18,000	$18,000
			Subtotal – annual O&M costs			**$63,000**
20-year O&M costs						
9	Cost to replace piping	Wood experience	1	LS	$360,000	$360,000
10	Operating costs	Estimate	1	EA	$660,000	$660,000
11	Well repair costs	Estimate	1	LS	$8,000	$8,000
12	Filter maintenance cost	Estimate	1	LS	$240,000	$240,000
			Subtotal – 20-year O&M costs			**$1,268,000**
			Subtotal – 20-year capital + O&M costs			**$2,863,000**

EA = each, FT = feet, LF = linear feet, LS = lump sum, Wood = Wood Environment & Infrastructure Solutions, Inc.

Figure F.3. Potential small community water systems in Afton.



F.2.4 Grey Cloud Island

For Grey Cloud Island, two analyses were performed to determine if a small community water system of 8 or 20 homes would create cost savings over treating non-municipal wells with POET systems. These analyses were similar to those performed for Afton (Section F.2.3).

The first analysis was performed to calculate the total 20-year costs for grouping eight homes together in Grey Cloud Island to form a small community water system. Figure F.4 shows an example of three, eight-home groupings in Grey Cloud Island, located off Grey Cloud Island Drive west of Pioneer Road. In Grey Cloud Island, the homes are spread farther apart, with an average distance of 380 feet between them, compared to 350 feet for Afton (see Section F.2.3) and 300 feet for West Lakeland Township (see Section F.2.5). Due to the larger spacing between homes, there are only a few pockets where eight homes exist within a close-enough distance to create a small community water system. On average, 3,040 feet of pipe would be required to connect eight homes in Grey Cloud Island.

As shown in Table F.11, grouping eight homes to create a small community water system would not provide sufficient cost savings over individual treatment with a POET system. As the number of small community water systems increase and the number of POET systems decrease, the total 20-year costs increase (Table F.11).

Figure F.4. Example of three, eight-home groupings in Grey Cloud Island.

Table F.11. Cost analysis for grouping eight homes in Grey Cloud Island.

Alternative	Groups of 8-home small community water systems	Individual homes with private wells and POET systems	Initial cost (capital)	Annual operating cost	20-year cost (capital + O&M)
1	0	126	315,000	126,000	2,835,000
2	3	102	1,251,000	132,000	3,891,000
3	6	78	2,187,000	138,000	4,947,000
4	9	54	3,123,000	144,000	6,003,000
5	12	30	4,059,000	150,000	7,059,000
6	15	6	4,995,000	156,000	8,115,000

A similar analysis was performed to calculate the total 20-year costs for grouping 20 homes. Figure F.5 shows an example of a 20-home grouping located off Grey Cloud Island Drive west of Pioneer Road. The average estimated feet of pipe required to connect 20 homes in Grey Cloud Island would be approximately 7,600 feet. For redundancy requirements to be met, two wells would be required, along with a certified water operator, additional water quality testing, and a backup generator for one well. As shown in Table F.12, creating a small community water system of 20 homes would provide no cost savings over individual treatment with POET systems.

Figure F.5. Example of a 20-home grouping in Grey Cloud Island.

Table F.12. Cost analysis for grouping 20 homes in Grey Cloud Island.

Alternative	Groups of 20-home small community water systems	Individual homes with private wells and POET systems	Initial cost (capital)	Annual operating cost	20-year cost (capital + O&M)
1	0	126	315,000	126,000	2,835,000
2	2	86	3,553,000	216,000	7,873,000
3	3	66	5,172,000	261,000	10,392,000
4	4	46	6,791,000	306,000	12,911,000
5	5	26	8,410,000	351,000	15,430,000
6	6	6	10,029,000	396,000	17,949,000

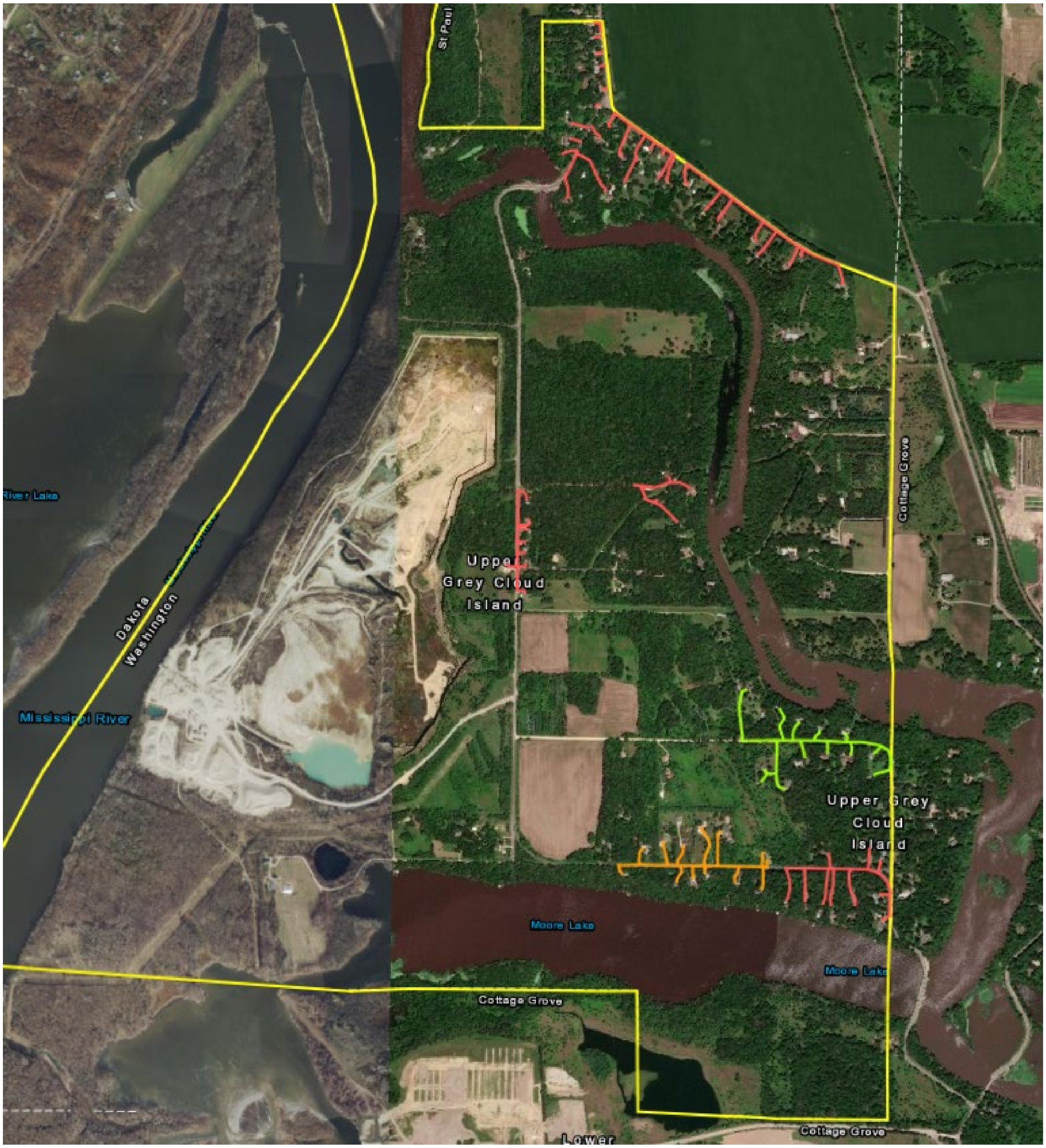
From the results above, grouping 8 or 20 homes to create a small community water system is possible but would not produce cost-saving benefits compared to treating each home individually with a POET system. The unit costs used for the calculations are shown in Table F.13. A map of the potential small community water systems in this community is shown in Figure F.6.

Table F.13. Cost Summary for Grey Cloud Island.

Item	Description	Source	Quantity	Units	Unit cost	Subtotal
Grey Cloud Island cost estimate for 8-home community						
20-year treatment facility capital costs						
1	2" piping installed	Washington County bid tabulations	3,040	LF	$97	$295,000
2	Capital cost POET	Wood experience	4	LS	$5,500	$22,000
3	New private well with hook-up	E.H. Renner & Sons Well Drilling MN	400	FT	$30	$12,000
4	Well pump	Wood experience	1	EA	$2,000	$2,000
5	Pressure tank	Grainger	1	EA	$1,000	$1,000
					Subtotal – 20-year treatment facility capital costs	**$332,000**
Annual O&M costs						
6	Filter maintenance cost	Estimate	4	LS	$1,000	$4,000
7	Cost to replace piping	Wood experience	1	LS	$6,000	$6,000
					Subtotal – annual O&M costs	**$10,000**
20-year O&M costs						
8	Cost to replace PVC piping	Wood experience	1	LS	$118,000	$118,000
9	Well repair costs	Estimate	1	LS	$6,000	$6,000
10	Filter maintenance cost	Estimate	1	LS	$80,000	$80,000
					Subtotal – 20-year O&M costs	**$204,000**
					Subtotal – 20-year capital + O&M costs	**$536,000**

Item	Description	Source	Quantity	Units	Unit cost	Subtotal
Grey Cloud Island cost estimate for 20-home community						
20-year treatment facility capital costs						
1	4" piping installed	Washington County bid tabulations	7,600	LF	$127	$965,000
2	Capital cost GAC	Wood experience	1	LS	$661,000	$661,000
3	New well with hook-up	E.H. Renner & Sons Well Drilling MN	800	FT	$50	$40,000
4	Well pump	Wood experience	2	EA	$2,000	$4,000
5	Pressure tank	Grainger	2	EA	$1,000	$2,000
					Subtotal – 20-year treatment facility capital costs	**$1,672,000**
Annual O&M costs						
6	Annual media cost	Estimate	1	LS	$12,000	$12,000
7	Annual operating costs	Estimate	1	EA	$33,000	$33,000
8	Cost to replace piping	Wood experience	1	LS	$19,000	$19,000
					Subtotal – annual O&M costs	**$64,000**
20-year O&M costs						
9	Cost to replace piping	Wood experience	1	LS	$380,000	$380,000
10	Operating costs	Estimate	1	EA	$660,000	$660,000
11	Well repair costs	Estimate	1	LS	$8,000	$8,000
12	Filter maintenance cost	Estimate	1	LS	$240,000	$240,000
					Subtotal – 20-year O&M costs	**$1,288,000**
					Subtotal – 20-year capital + O&M costs	**$2,960,000**

Figure F.6. Potential small community water systems in Grey Cloud Island.



F.2.5 West Lakeland Township

For West Lakeland Township, two analyses were performed to determine if a small community water system of 8 or 20 homes would create cost savings over treating non-municipal wells with POET systems. These analyses were similar to those performed for Afton (Section F.2.3) and Grey Cloud Island (Section F.2.4).

The first analysis was performed to calculate the total 20-year costs for grouping 8 homes together in West Lakeland Township to form a small community water system. Figure F.7 shows an example of four, eight-home groupings in West Lakeland Township, located east of Manning Avenue off 24th Street. In West Lakeland Township, there are many areas of opportunity to create small community water systems. The average distance between homes in West Lakeland Township was calculated to be 300 feet using ArcGIS Earth. Thus, the average estimated feet of pipe required to connect eight homes in West Lakeland Township would be approximately 2,400 feet.

As shown in Table F.14, grouping eight homes to create a small community water system would not provide sufficient cost savings over individual treatment with a POET system. As the number of small community water systems increase and the number of POET systems decrease, the total 20-year costs increase (Table F.14).

Figure F.7. Example of four, eight-home groupings in West Lakeland Township.

Table F.14. Cost analysis for grouping eight homes in West Lakeland Township.

Alternative	Groups of 8-home small community water systems	Individual homes with private wells and POET systems	Initial cost (capital)	Annual operating cost	20-year cost (capital + O&M)
1	0	1,314	3,285,000	1,314,000	29,565,000
2	30	1,074	10,785,000	1,344,000	37,665,000
3	60	834	18,285,000	1,374,000	45,765,000
4	90	594	25,785,000	1,404,000	53,865,000
5	130	274	35,785,000	1,444,000	64,665,000
6	160	34	43,285,000	1,474,000	72,765,000

A similar analysis was performed to calculate the total 20-year costs for grouping 20 homes. Figure F.8 shows an example of a 20-home grouping located on Morgan Avenue and Mystic Ride Avenue. The average estimated feet of pipe required to connect 20 homes in West Lakeland Township would be approximately 6,000 feet. For redundancy requirements to be met, two wells would be required along with a certified water operator, additional water quality testing, and a backup generator for one well. As shown in Table F.15, creating a small community water system of 20 homes would provide no cost savings over individual treatment with POET systems.

Figure F.8. Example of a 20-home grouping in West Lakeland Township.

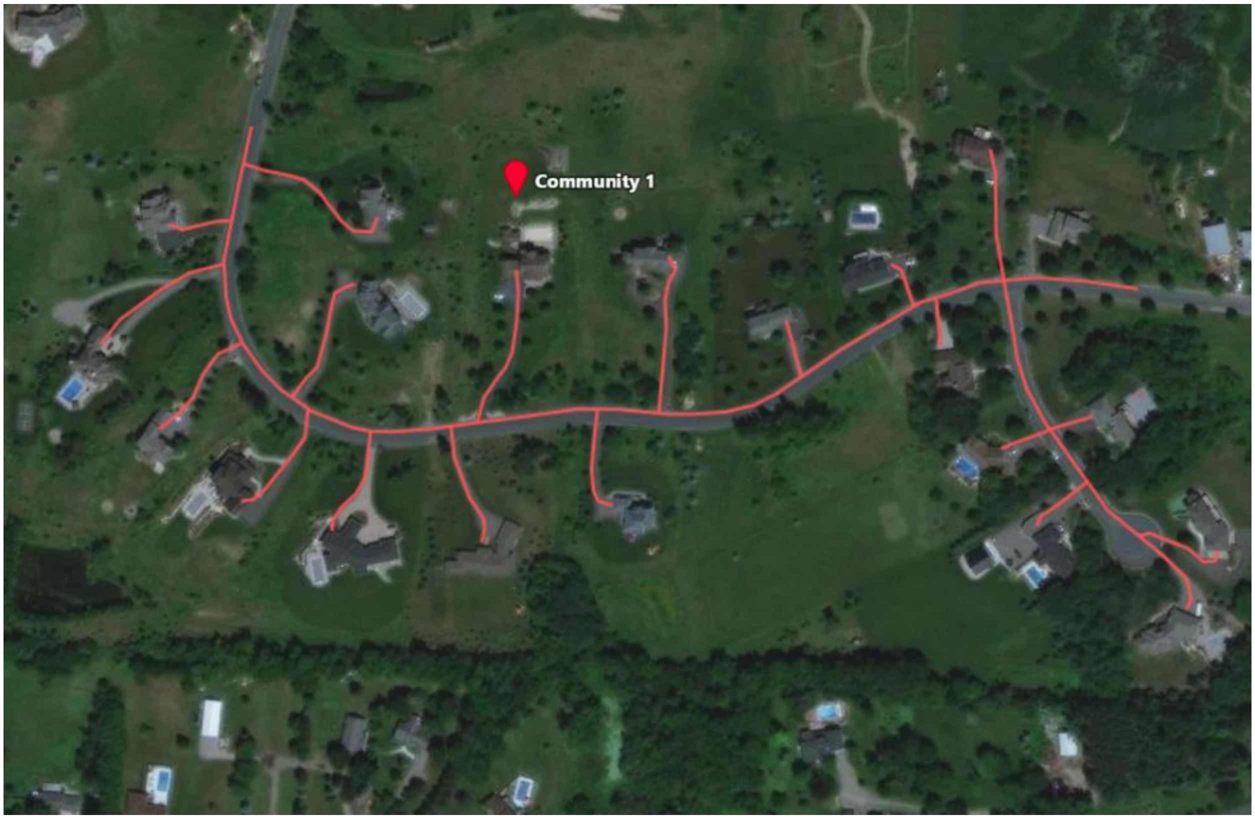


Table F.15. Cost analysis for grouping 20 homes in West Lakeland Township.

Alternative	Groups of 20-home small community water systems	Individual homes with private wells and POET systems	Initial cost (capital)	Annual operating cost	20-year cost (capital + O&M)
1	0	1,314	3,285,000	1,314,000	29,565,000
2	15	1,014	24,540,000	1,929,000	63,120,000
3	25	814	38,710,000	2,339,000	85,490,000
4	35	614	52,880,000	2,749,000	107,860,000
5	45	414	67,050,000	3,159,000	130,230,000
6	65	14	95,390,000	3,979,000	174,970,000

From the results above, grouping 8 or 20 homes to create a small community water system is possible but would not produce cost-saving benefits when compared to treating each home individually with a POET system. The unit costs used for the calculations are shown in Table F.16. A map of the potential small community water systems in this community is shown in Figure F.9.

Table F.16. Cost summary for West Lakeland Township.

Item	Description	Source	Quantity	Units	Unit cost	Subtotal
West Lakeland Township cost estimate for 8-home community						
20-year treatment facility capital costs						
1	2" piping installed	Washington County bid tabulations	2,400	LF	$97	$233,000
2	Capital cost POET	Wood experience	4	LS	$5,500	$22,000
3	New private well with hook-up	E.H. Renner & Sons Well Drilling MN	400	FT	$30	$12,000
4	Well pump	Wood experience	1	EA	$2,000	$2,000
5	Pressure tank	Grainger	1	EA	$1,000	$1,000
					Subtotal – 20-year treatment facility capital costs	**$270,000**
Annual O&M costs						
6	Filter maintenance cost	Estimate	4	LS	$1,000	$4,000
7	Cost to replace piping	Wood experience	1	LS	$5,000	$5,000
					Subtotal – annual O&M costs	**$9,000**
20-year O&M costs						
8	Cost to replace PVC piping	Wood experience	1	LS	$93,000	$93,000
9	Well repair costs	Estimate	1	LS	$6,000	$6,000
10	Filter maintenance cost	Estimate	1	LS	$80,000	$80,000
					Subtotal – 20-year O&M costs	**$179,000**
					Subtotal – 20-year capital + O&M costs	**$449,000**

Item	Description	Source	Quantity	Units	Unit cost	Subtotal
West Lakeland Township cost estimate for 20-home community						
Treatment facility capital costs						
1	4" piping installed	Washington County bid tabulations	6,000	LF	$127	$762,000
2	Capital cost GAC	Wood experience	1	LS	$661,000	$661,000
3	New well with hook-up	E.H. Renner & Sons Well Drilling MN	800	FT	$50	$40,000
4	Well pump	Wood experience	2	EA	$2,000	$4,000
5	Pressure tank	Grainger	2	EA	$1,000	$2,000
					Subtotal – 20-year treatment facility capital costs	**$1,469,000**
Annual O&M costs						
6	Annual media cost	Estimate	1	LS	$12,000	$12,000
7	Annual operating costs	Estimate	1	EA	$33,000	$33,000
8	Cost to replace piping	Wood experience	1	LS	$16,000	$16,000
					Subtotal – annual O&M costs	**$61,000**
20-year O&M costs						
9	Cost to replace piping	Wood experience	1	LS	$320,000	$320,000
10	Operating costs	Estimate	1	EA	$660,000	$660,000
11	Well repair costs	Estimate	1	LS	$8,000	$8,000
12	Filter maintenance cost	Estimate	1	LS	$240,000	$240,000
					Subtotal – 20-year O&M costs	**$1,228,000**
					Subtotal – 20-year capital + O&M costs	**$2,697,000**

Figure F.9. Potential small community water systems in West Lakeland Township.

F.2.6 Average cost per home for community water systems

Results from the 8- and 20-home small community water systems were extrapolated further to 100- and 500-home systems. This analysis was conducted for Afton and the West Lakeland Township. However, this analysis was not performed for Grey Cloud Island due to the small number of homes and large spaces between homes within the community.

In Table F.17, the average cost per home over 20 years can be estimated to further compare the cost differences between treating wells individually with POET systems or with 8–500 home small community water systems. Treating private wells individually with POET systems remain the most cost-effective option, followed by treating an 8-home, a 500-home, a 100-home, and a 20-home community.

The two most significant parameters affecting total 20-year costs include installing the GAC treatment systems and pipe. The parameter that impacts the total cost the least is the cost for drilling a new community well. Table F.18 illustrates how small community water systems progressively add costs for additional upfront capital infrastructure items.

Table F.17. Average cost per home over 20 years.

Community	Private well with POET systems	8-home community water system with treatment	20-home community water system with treatment	100-home community water system with treatment	500-home community water system with treatment
Afton	$26,000	$65,000	$149,000	$97,000	$112,000
West Lakeland Township	$26,000	$58,000	$138,000	$84,000	$81,000
Grey Cloud Island	$26,000	$70,000	$169,000	N/A	N/A

N/A = not applicable.

Table F.18. Scope of work that influences cost estimates of individual POET systems versus community water systems.

Infrastructure item	POET on existing private well	Small community water system (< 8 homes)	Medium community water system (20 homes)	Large community water system (100–500 homes)
Well	Existing	New 1 required	New 2 required	New 2 or more required
Linear infrastructure (water supply piping)	None	New	New	New
Treatment system	New	New	New	New
Building	In existing home	New structure at well (with electrical and heat)	New structure at well (with electrical and heat)	New structure at well (with electrical and heat)
Operating cost	Annual media change-out	Annual media change-out	Annual media change-out	Annual media change-out
Care and monitoring	By homeowner	By homeowner	By qualified operator	By qualified operator

F.2.7 Conclusion

The results from this analysis suggest that implementing a small community water system for any of the three communities examined – Afton, Grey Cloud Island, or West Lakeland Township – is more expensive than installing POET systems. It can be noted that the costs for a small community water system of 8 homes is less than the costs for a public water system of 20–500 homes due to redundancy requirements. However, both options require costs greater than individually treating each well with a POET system.

For all three communities, the population density and lack of existing infrastructure create conditions where the use of POET systems is the most cost-effective method to deliver safe drinking water, compared to community treatment systems of any size.

F.3 Treatment technology comparison

F.3.1 Introduction

This section provides information on various technologies available for the treatment of per- and polyfluoroalkyl substances (PFAS) in drinking water in the East Metropolitan area. The lifecycle of technology development, as presented in Figure F.10, illustrates how technologies are developed from research and development through to demonstration and validation, and ultimately to full-scale commercialization. Full-scale commercialized options to treat PFAS in drinking water are limited due to the strict requirements for technology approval and the difficulty in degrading PFAS, especially perfluorooctanesulfonic acid (PFOS) and perfluorooctanoic acid (PFOA). Examples of these rigorous standards include the National Science Foundation (NSF) International certification to meet drinking water treatment requirements that are in accordance with strict public health standards and state health department requirements for approval and/or certification of drinking water treatment technologies. Current research and development on PFAS treatment sites provide insights into promising and partially demonstrated new technologies. Research and development activities for PFAS water treatment include chemical oxidation, biological degradation, and novel sorption technologies. Although this testing may show promise, these technologies are not currently applicable to drinking water treatment applications and would still need to achieve applicable strict public health standards and state-level certifications. To date, all mature commercially available technologies for treating PFAS in drinking water rely on separation rather than degradation.

Below, information is presented on technology effectiveness, limitations, and sustainability pertaining to the following categories of drinking water treatment:

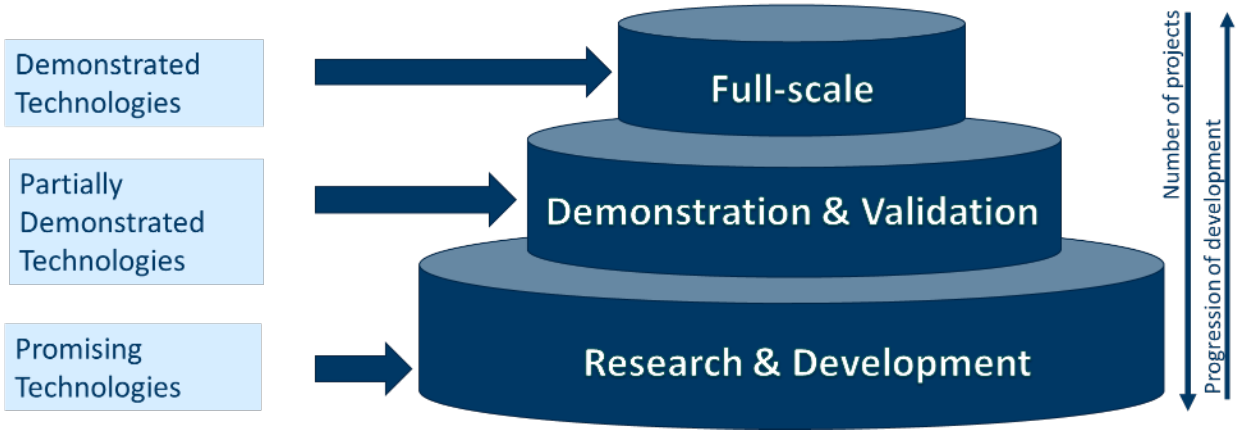
- Mature technologies that are commercially available and have been implemented at a full scale for treating PFAS in drinking water across the United States:
  - Granular Activated Carbon (GAC)
  - Ion exchange (IX)
  - Membrane (reverse osmosis [RO], nanofiltration [NF]).
- Developing technologies that have been tested at various scales for treating PFAS in drinking water but have not yet been implemented fully and are not approved for use in drinking water treatment. While these systems show promise, they currently are not considered technologies that can be readily deployed into a drinking water system:
  - Zeolite/organoclay media systems
  - Biochar systems
  - Advanced oxidation systems
  - Sonolysis treatment systems.

Technologies that are currently considered in the demonstration and validation as well as research and development stages are not considered further in this Conceptual Plan as they are not deemed appropriate for consideration at this time as they are not commercially available, and full-scale implementation is not feasible without demonstration and validation at a minimum.

Co-treatment technologies may be similar in many ways but can present several potential advantages and disadvantages regarding sustainable practices. These considerations are presented in Section F.3.2.4.

Pretreatment is an important consideration when evaluating primary treatment technologies. The presence of organic and inorganic co-contaminants can have a significant effect on the efficacy and longevity of a drinking water treatment system. For instance, the presence of organic co-contaminants can result in adsorption sites being preferentially filled while the presence of inorganic contaminants can result in significant bed fouling issues leading to premature breakthrough of target constituents. Pretreatment options should consider residuals formation, residuals disposal, and chemical consumption associated with the pretreatment step. Pretreatment variables are considered further in Tables F.21 and F.22.

Figure F.10. Lifecycle of technology development.



Source: S. Thomas, Wood, used with permission.

F.3.1.1 Key variables for consideration

When developing a drinking water system for the treatment of PFAS, many important technical and non-technical considerations need to be evaluated. Key variables are presented in Table F.19 and discussed for the various technologies presented.

Table F.19. Key treatment technology variables for consideration.

Technical	Non-technical
Final water treatment requirements	Operational costs
Pretreatment requirements	Capital costs
Co-contaminants	Ease of operation
Water hardness	System complexity
Competing ionic species	Space required
Product water generated/wastewater generated	State certifications/approvals
Disposal of media/residuals	NSF/American National Standards Institute (ANSI) certification
Performance criteria	Availability of equipment/media
System contact volume	Impact of changing regulations

F.3.2 Mature technologies

Currently, three treatment technologies for drinking water are commercially available, which include GAC, single use IX resins, and membrane processes (RO and NF). Sections F.3.2.1 through F.3.2.3 provide descriptions of these technologies, and Table F.20 provides a comparison that includes waste disposal and management, key treatment variables, sustainability evaluation factors, and other variables.

F.3.2.1 GAC

GAC is used in drinking water treatment, usually as a polishing step, to remove synthetic organic chemicals, natural organic compounds, and other compounds affecting taste and odor. GAC currently is the most widely used treatment method for the removal of PFAS compounds from drinking water.

GAC systems can be installed easily and require relatively low O&M effort. GAC is placed in packed-bed, flow-through pressure vessels, usually operated in series (lead-lag configuration), with typical empty bed contact times of 10–15 minutes per vessel for PFAS applications. Breakthrough, which is the point at which the contaminant (e.g., PFAS) is no longer captured by the treatment method and is monitored by sampling water, at a minimum, between the lead and lag vessels. When breakthrough exceeds the identified criteria, the lead vessel is taken offline and the spent GAC is removed and replaced with new (either virgin or reactivated) GAC. The spent media are disposed of offsite, typically by incineration or thermal destruction, but can also be reused by employing high-temperature thermal reactivation. Reactivated PFAS GAC is allowed for use in drinking water applications, but this should be considered with caution and in accordance with the American Water Works Association B605-13 Reactivation of Granular Activated Carbon standard. Many states do not allow its use for drinking water applications (ITRC, 2020).

GAC can be manufactured using various materials (e.g., coal [bituminous], coconut shells, wood), which all have shown some ability to remove PFAS. Re-agglomerated bituminous GAC has been demonstrated to be the most effective GAC media and is used for the majority of existing PFAS treatment systems. Media selection and lifecycle cost will depend on several factors, including PFAS and co-contaminant concentrations, media availability and pricing, and disposal options and costs.

A significant benefit of GAC is that it is widely available through a large network of providers and several vendors provide turn-key replacement services. The removal efficiency of PFAS by GAC depends on the functional group and perfluorocarbon chain length of the individual PFAS compound. Removal efficiency increases with increasing perfluorocarbon chain length. GAC is less effective for PFAS compounds with carboxylate functional groups than those with sulfonate functional groups.

Other factors that will impact the removal efficiency of PFAS by GAC include:

- Naturally occurring organic matter (NOM). NOM competes with PFAS for adsorption sites. The presence of NOM in drinking water systems will reduce the adsorption capacity for the targeted PFAS and organic chemicals to be removed.
- The presence of chlorine. Activated carbon reacts with chlorine (or other oxidants) in a reduction-oxidation reaction, which may change surface characteristics of the activated carbon and reduce treatment effectiveness.
- The presence of organic co-contaminants. Co-contaminants compete for adsorption sites. The presence of organic co-contaminants in drinking water systems will reduce the adsorption capacity for the targeted PFAS and organic chemicals to be removed.
- Particulate material that results in bed plugging and elevated bed pressure loss can result in premature media replacement.

Operations must consider the optimization of key process operational parameters, an understanding of the impacts of influent and effluent parameters, and an understanding of system capacity in terms of flow and loading to effectively manage system costs.

F.3.2.2 IX resin

IX is a widely accepted process for the removal of targeted, typically inorganic compounds. IX involves the use of resins. Most synthetic IX resins are manufactured by a process in which styrene and divinylbenzene are copolymerized. The styrene serves as the basic matrix of the resin, and divinylbenzene is used to cross-link the polymers to produce insoluble, tough resin beads. Important properties of IX resin include exchange capacity, particle size, and stability. IX resins can be considered non-regenerable (i.e., single use) when disposed of after one application or regenerable, resulting in a more expensive disposal cost than for the reactivation of GAC. Waste disposal is discussed further in Section F.3.3. IX regeneration involves backwashing the resin bed with a variety of proprietary solutions to remove and concentrate the PFAS into a smaller, liquid volume; subsequent rinses are used to purge the regenerant solution from the bed and prepare the resin bed for reuse. Regenerable resins are not currently approved for use in drinking water treatment applications in the United States and are not considered further in this Conceptual Plan.

According to several studies (Amec Foster Wheeler, 2017; McCleaf, 2017; Woodard et al., 2017; Gagliano et al., 2020), non-regenerable IX resin has the highest capacity for PFAS, followed by GAC and regenerable IX resin.

The removal efficiency of the non-regenerable IX system depends on a variety of factors, including the nature of the resin within the beads, competing ions, treatment design (e.g., empty bed contact times, size of resin beads), and physical and chemical properties of the PFAS requiring treatment. The following additional considerations are related to the use of IX for PFAS removal:

- According to a previous literature review conducted by Wood, anion exchange resins are the only effective resin for PFAS removal (Amec Foster Wheeler, 2017).
- Competing ions such as sulfate, nitrates, and heavy metals may impact the sorption capacity of the resin. Total organic carbon (TOC) in groundwater can also result in biofouling of IX resins.
- Oxidizable metal particulates (e.g., iron, manganese) and particulate materials that result in bed plugging and elevated bed pressure loss can result in premature media replacement.
- Based on the bench-scale study conducted by Wood (Woodard et al., 2017), long-chain PFAS compounds are more effectively removed than short-chain PFAS when using non-regenerable IX resin.

Many factors drive IX resin system design decisions other than removal efficiency. Compared with a GAC system, the capital costs for an IX resin system are lower. Factors such as influent and target PFAS concentration, replacement of resin, arrangement of resin vessels (lead-lag or lead-lag-standby), and strength of the resin beads will all impact the operation cost of the IX resin system and will be used to decide whether a GAC or IX system is more economical.

Operations must consider the optimization of key process operational parameters, an understanding of the impacts of influent and effluent parameters, and an understanding of system capacity in terms of flow and loading to effectively manage system costs.

F.3.2.3 Membrane processes (RO and NF)

RO and NF are forms of a membrane filtration technology that are pressure-driven and shown to be effective in the removal of PFAS. Typically, NF systems reject constituents as small as 0.001 µm, whereas RO systems reject particles as small as 0.0001 µm.

The removal efficiency for PFAS by these types of membranes is typically greater than 90% effective at removing a wide range of PFAS (U.S. EPA, 2018). The high removal rate for PFAS is primarily due to the molecular weight cut-off (MWCO) of the NF and RO membranes. MWCO is a measure of the removal characteristics of a membrane in terms of atomic weight. The typical range of MWCO levels for NF ranges from 200 to 1,000 Daltons, while for RO it is less than 100 Daltons (U.S. EPA, 2005). The molecular weight for PFOA and PFOS are 500 and 414 Daltons, respectively, meaning PFOA and PFOS can be easily removed by NF and RO systems.

The following factors will impact the performance of membrane filtration systems:

- Pressure: The operation pressure will affect the water flux across the membrane and the recovery rate. For NF membranes, the typical feed pressure ranges between 50 and 150 pounds per square inch; while for RO membranes, the typical feed pressure ranges between 125 and 1,200 pounds per square inch, depending on osmatic pressure and the required production flux.

- Temperature: The membrane filtration system performance is sensitive to changes in the feed water temperature. As the feed water temperature increases, the water flux increases linearly (which is often preferred since it will increase the recovery rate); however, the contaminant removal/rejection rate will be lowered (which is not preferred since it decreases the quality of the treated water).
- Salt concentration: For RO systems, osmotic pressure is a function of the salt concentration. As the salt concentration increases, the osmotic pressure increases. If the feed pressure remains constant, a higher salt concentration will result in a lower membrane water flux since the increased osmotic pressure offsets the feed water driving pressure.
- Recovery rate: The recovery rate is defined as the ratio between the permeate stream flow and the feed stream flow. Typically, the recovery rate for NF is typically higher than for RO systems. Systems used for drinking water applications should be able to attain 90% recovery for NF systems and 80% recovery for RO systems.

Despite its high-removal efficiency for PFAS, capital and O&M costs for membrane systems are generally high compared to sorption systems (i.e., GAC and IX resins). Other than economic factors, operational issues such as membrane fouling and rejected stream treatment usually limit the application of membrane filtration systems.

Pretreatment and posttreatment are often necessary when working with NF and RO systems. The primary objective of pretreatment is to remove or reduce the constituents that contribute to membrane fouling and make the feed water compatible with the membrane. It is expected that by pretreatment, the efficiency and life expectancy of the membrane elements will be improved. RO systems will provide a very pure water product that requires remineralization and decarbonation to provide non-corrosive drinking water.

Membrane filtration systems produce a concentrated waste stream. The concentrate from NF and RO facilities will not only contain elevated concentrations of contaminants of interest, but can also contain hardness, heavy metals, and high-molecular-weight organics. The disposal of the waste stream includes discharge to wastewater collection systems and thermal evaporation.

Table F.20. Comparison of drinking water treatment technologies.

Technology	Advantages	Disadvantages
GAC	1) GAC is the most widely used technology for PFAS removal, especially for long-chain PFAS; the removal efficiency is > 90% for long-chain PFAS. 2) Given the design and operation configuration of the fixed-bed column, it is possible to achieve very low PFAS levels in treated water. 3) Low capital and operation costs. 4) GAC can be re-activated for non-potable use or incinerated to destroy PFAS.	1) Not suitable for treating water that contains elevated levels of organic compounds and/or oxidizable metals (including iron and manganese) unless pretreatment measures are in place. 2) As carbon can react with oxidants such as chlorine, its use should be avoided after chlorine disinfection. 3) Generally not as efficient as IX for shorter-chain PFAS.

Technology	Advantages	Disadvantages
Non-regenerable IX resin	1) Non-regenerable resin has the highest sorption capacity among GAC and regenerable IX resin; the removal efficiency is > 90% for long-chain PFAS. 2) Given the design and operation configuration of the fixed-bed column, it is possible to achieve very low PFAS levels in treated water. 3) No concentrated waste stream will be produced (since no regeneration is required); however, there is a need to consider the disposal of spent resin. 4) Operation costs are expected to be significantly lower than the membrane filtration system (NF and RO).	1) Not suitable for treating water containing elevated levels of sulfates, nitrates, and oxidizable metals (including iron and manganese) unless pretreatment measures are in place. 2) Since regeneration is not feasible, the spent resin needs to be changed out once it is exhausted and disposed via incineration. Operating costs need to consider the treatment and disposal of the spent resin.
NF	1) Removal efficiency for PFAS is greater than 90%. 2) There is less of a footprint compared to traditional treatment options. 3) There are higher water recovery rates and lower operating pressures compared to RO.	1) Pretreatment is required. 2) Generally high capital costs. 3) Operation costs are high due to energy cost, cleaning cost, labor, and chemical consumption. 4) Recovery rate may be low depending on the quality of raw water. 5) Treatment for the concentrated waste stream requires evaporation and residual incineration/encapsulation at a significant cost. 3) High demand for O&M to achieve optimal treatment.
RO	1) Removal efficiency for PFAS is close to 100%, and effective for both long- and short-chain PFAS. 2) There is less of a footprint compared to traditional treatment options.	1) Pretreatment is required. 2) Generally high capital costs. 3) Operation costs are high due to energy cost, cleaning cost, labor, and chemical consumption. 4) Recovery rate may be low depending on the quality of raw water. 5) Treatment for the concentrated waste stream requires evaporation and residual incineration/encapsulation at a significant cost. 6) High demand for O&M to achieve optimal treatment.

F.3.2.4 Comparison of key treatment variables and sustainability evaluation

In the evaluation of PFAS drinking water technologies, specific treatment variables should be considered to ensure that reliability, efficiency, and long-term system economics are optimized. Sustainability considerations, including environmental impacts of the system's manufacturing, carbon emissions, and disposal methods, are also drivers to the selection of the treatment technology of choice (see Table F.21).

Table F.21. Key treatment variables and sustainability evaluation factors.

Sustainability consideration	GAC	IX	Membrane systems
Media materials	Best performing media is bituminous (less sustainable), followed by coconut and wood-based media (more sustainable).	Synthetically manufactured materials from hydrocarbons. Less media required compared to GAC.	A variety of materials are used for NF and RO membranes, including cellulose acetate, polyamide, and ceramic media. Cellulose acetate is manufactured from renewable sources, polyamide materials form hydrocarbons, and ceramics require high-temperature manufacturing processes.
Media availability	Most widely used treatment technology, and therefore more widely available.	Media widely used, but specialty media demands may out-weigh supply.	Widely used and easily procured materials.
Pretreatment requirements	Pretreatment of organic constituents that compete for adsorption sites may be required. Elevated iron or manganese may cause bed fouling due to the formation of solids and may require pretreatment.	Pretreatment of organic constituents that result in biofouling may be required. Elevated iron or manganese may cause bed fouling due to the formation of solids and may require pretreatment.	Pretreatment required to prevent membrane fouling. Use of membrane cleaning chemicals required to routinely clean membranes.
Timeline to implement	Easily implementable systems. Vessels and media are readily available.	Easily implementable systems. Vessels available but media may require lead time.	More complex implementation. Systems are generally custom-built with longer equipment lead times and onsite fabrication.
Vessel size/amount of media required	Larger media vessels (more media required) relative to IX.	Vessels sizes are approximately 25–30% that of GAC vessels.	Relatively small system footprint compared to GAC and IX systems. Equipment footprint is approximately 25-40% of that of GAC vessels. Equipment height 50% that of GAC Vessels.
Building space/footprint	Larger buildings required to house treatment system due to large vessels.	Smaller vessel sizes result in less building space than GAC.	A small building footprint is required for membrane systems, but ancillary systems for reject water management and chemical cleaning of membranes increase a system’s space requirements.

Sustainability consideration	GAC	IX	Membrane systems
Waste/disposal	Reactivation of media; destruction or disposal methods of spent media available.	Destruction or disposal methods of spent non-regenerable media available; regenerated media not applicable for drinking water applications.	Reject water represents approximately 25% of the flow and requires disposal. A critical factor in assessing a membrane system is the ability to dispose of the contaminated reject water.
Lifespan	Media in drinking water applications depend on feed water concentrations. For PFAS in the East Metro area, GAC media life can range from 6 months to several years.	Compared to GAC, media life is up to 2–3 times greater (1–3 years).	Typically RO and NF membranes have a life of 5 to 10 years in a drinking water application.
O&M	Pressurized flow-through operation. Media cost and disposal are the primary O&M costs.	Pressurized flow-through operation. Media cost and disposal are the primary O&M costs.	More complex operation due to high-pressure feed pump systems and the need to re-mineralize product water.
Adaptability	GAC is effective at removing longer-chain PFAS compounds. Shorter-chain compounds break through more rapidly. Less adaptable to future regulations due to lower effectiveness for short-chain compounds that may be regulated in the future. Adaptable to a range of flows.	IX systems lend themselves to future regulations on shorter-chain PFAS compounds as IX media are typically more effective in removing these compounds than GAC. Adaptable to a range of flows.	Highly adaptable to changing feedwater characteristics and regulations due to molecular-level rejection. Sensitive to flow changes.
Ancillary benefits	Taste and odor control where NOM is present. Removal of organic co-contaminants.		Will provide soft water (RO). Co-contaminant removal.
Other impacts			RO-generated water can have aggressive corrosion/metal leaching impacts on infrastructure and needs to be re-mineralized to reduce these impacts.

F.3.3 Waste disposal and management

F.3.3.1 Incineration

Incineration is a waste destruction process that involves the combustion of organic substances contained in waste materials. Incineration and other high-temperature waste treatment systems are termed “thermal treatment processes.” Incineration is a mature technology that has been used for a wide variety of organic wastes. Heat is applied directly to the contaminated solids or liquids to completely oxidize them, and gaseous combustion by-products are controlled to prevent atmospheric pollution. To date, the concentrated waste-generating technologies previously discussed (i.e., GAC and IX media) are often followed by incineration as a PFAS destruction step.

Incineration is one of the few technologies that can destroy PFAS; however, many questions remain as to the efficacy of combustion (ITRC, 2020). Hazardous waste incinerators are fixed facilities capable of reaching PFAS-destructive temperatures. Federal and state permits dictate the materials that may be processed; core incinerator operations (e.g., temperature, time); and control of process air, liquid, and solid wastes. Permit and design/construction similarities reduce the operational and performance differences between individual incinerators. Transportation costs, energy costs, and final disposal of process waste residues differ among incinerators. The cost of incineration has a significant impact on treatment costs.

Sustainability impacts of incineration include transporting contaminated material and the energy-intensive processing involving the combustion of fossil fuels to achieve the thermal destruction of contaminants. The only hazardous waste incinerators located in the East Metropolitan area is the 3M incinerator at the Cottage Grove Facility.

F.3.3.2 Landfill

Landfill disposal is a common method for the disposal of solids waste materials generated by water treatment and industrial residuals. PFAS treatment residuals, including single-use IX resins and non-regenerable activated carbon, can be disposed of in a secure industrial landfill. Some landfills, including municipal and hazardous waste facilities, will not accept PFAS-containing materials. Current federal regulations do not define PFAS as hazardous substances or hazardous wastes; however, this may be a consideration in the future as new regulations are passed.

The sustainability impacts of landfilling include the hauling of waste material, landfill activities (e.g., construction, backfill), as well as general emissions from landfills including contaminated leachate treatment requirements. If future federal designation of PFAS as a hazardous waste requires out-of-state transportation for landfill disposal, significant costs and secondary environmental impacts may be incurred for these waste materials.

F.3.4 Other variables

Additional considerations in the selection of a PFAS drinking water technology include regulatory requirements, industry-specific certifications, state or federal certifications, and regulatory performance for non-regulated contaminants (e.g., short-chain PFAS). Table F.22 provides a summary of additional considerations in the selection of PFAS drinking water treatment technologies.

Table F.22. Additional considerations in the selection of PFAS drinking water treatment technologies.

Additional considerations	GAC	IX	Membrane systems
NSF 61 Certification – Municipal Water Systems Certification	Specific GAC media are NSF 61 certified. Widest range of available NSF media.	Specific IX resins have NSF certification for PFAS.	RO and NF membranes are widely used in a variety of potable water applications. A wide array of membranes have NSF 61 certification.
State certification/ approval	Widely used treatment technology that is generally accepted by regulators.	Gaining acceptance with regulators as systems come online. Not currently approved by MDH for PFAS. With supporting information and demonstration (piloting), it is expected that MDH will approve.	Widely used treatment technology that is accepted by regulators. Not currently approved by MDH for PFAS. With supporting information and demonstration (piloting), it is expected that MDH will approve.

Additional considerations	GAC	IX	Membrane systems
Regulatory performance	As more short-chain PFAS compounds become regulated, GAC applicability may decrease or require post-treatment. Able to meet regulated PFAS compound criteria.	Better performance for short-chain compounds so long-term outlook may be better than GAC. Currently able to meet regulated PFAS compound criteria.	RO systems can remove 100% of PFAS compounds to below detection. High degree of regulatory confidence. Waste material compliance is uncertain. Liquid disposal is more difficult than solid phase media (GAC and IX).

F.3.5 Conclusions

In conclusion, adsorption (i.e., GAC) or IX (i.e., non-regenerable IX) are currently the technologies of choice for drinking water treatment for PFAS-contaminated drinking water compared to membrane filtration. The advantages of adsorption and IX include the relative simplicity of these technologies, low residuals production, and the high degree of effectiveness. Between these two methods for the treatment of PFAS, GAC has the widest application and low O&M costs. Currently GAC is the only approved technology for PFAS treatment of drinking water in the State of Minnesota. IX systems typically have lower capital implementation costs over GAC systems, but pretreatment requirements, the availability of suitable resins, and the disposal of exhausted resin material may be challenges or result in higher costs with these materials. The quality of the raw water needs to be considered and if the raw water has significant organic co-contaminant concentrations, GAC will lose its sorption capacity relatively quickly, resulting in increased media consumption. IX is currently undergoing a pilot project in Cottage Grove with the intent of providing MPCA with data to demonstrate its effectiveness; and inorganic co-contaminants may result in IX media life span reduction and may require pretreatment. Membrane processes do provide good removal performance results. NF and RO systems are capable of reliably rejecting 90% and 100% of the PFAS compounds, respectively, from a water stream. However, membrane systems will have higher capital and operating costs than GAC or IX systems due to the complexity of the systems and the need to manage the concentrated reject stream.

Several technologies that are in development have the potential to provide high-efficiency removal of PFAS in drinking water treatment systems. Advancements in IX technology, advanced oxidation systems, and biological treatment processes may provide further options for the treatment of PFAS in drinking water in the future.

F.4 Water treatment plant capacities

This section discusses general and community-specific assumptions and considerations made when determining various WTP capacities for applicable communities as part of the Conceptual Plan for the East Metropolitan area of Minnesota. Only the sizing of various WTPs is discussed in this section, which was used to estimate costs for PFAS treatment and pretreatment. Sections F.5, F.6, and F.7 discuss how costs for treatment were estimated.

F.4.1 General assumptions and considerations

Treatment facilities can be sized to accommodate a maximum flow somewhere between the maximum daily demand (MDD) and peak hour demand (PHD), depending on the available storage in the system. However, it is common practice to design a facility based on the MDD while simultaneously providing sufficient storage within the distribution system to cover variations in demands as well as emergency situations such as fire flow. It was assumed that each facility or combination of facilities would be sized to meet a given community's MDD. While this is fairly straightforward for communities with a single WTP proposed, planning becomes more complicated when the location of existing and proposed future supply wells requires more than one WTP. In addition, the operating well configuration under the most conservative conditions needs to be considered to ensure that a community's firm capacity can be met.

According to the recommended Ten State Standards, "The total developed groundwater source capacity, unless otherwise specified by the reviewing authority, shall equal or exceed the design maximum day demand with the largest producing well out of service" (2018). Feedback from larger communities in the East Metropolitan area, however, indicated that for O&M purposes, their firm capacity was defined as being able to meet their MDD with one of their largest wells out of service for every group of 10 wells. Therefore, for the purposes of the Conceptual Plan, the firm capacity from a water supply standpoint was defined as the ability to meet the MDD with either the single largest well out of service for communities with less than 10 municipal supply wells or the two largest wells out of service for communities with 10 or more wells. From a treatment standpoint, the WTP was considered to be able to meet the design flow with one treatment train, or pair of filters, out of service. This means two vessels can be taken out of service to allow for both unforeseeable and scheduled maintenance to occur, while keeping the facility fully operational. For the intended purposes of the Conceptual Plan, the rated capacity of a proposed treatment facility was considered the same as the firm capacity and was defined as the amount of treated flow required to meet a given community's 2040 MDD.

For the Conceptual Plan, the minimum number of municipal wells that would be selected for treatment was determined based on their PFAS concentrations in relation to the threshold defined in the three recommended options of the Conceptual Plan. The threshold was based on the health index (HI) value, which was calculated by summing the ratios of PFAS concentrations for five PFAS compounds with Minnesota drinking water criteria (PFOS, PFOA, perfluorohexane sulfonate [PFHxS], perfluorobutanoic acid [PFBA], and perfluorobutane sulfonate [PFBS]) by their respective health-based criteria concentration, as discussed in Section 2. This calculation was performed using MDH well data available as of December 2020. For some municipal wells, the HI used was a rolling average of the last four quarters of sampling. The HI thresholds used to select wells for treatment under the Conceptual Plan were 0.5 or greater for Options 1 and 3, and 0.3 or greater for Option 2. For some communities, this divides the wells into those that were routed to a WTP and those that were not. In other communities where several wells were in one area, or a "well field," the wells were not separated for treatment even though some wells may have been above and some wells may have been below the HI threshold.

Treatment facilities were sized based on several factors rather than simply the rated capacity of the supply wells. As mentioned, the HI threshold was the primary consideration for selecting which wells would be routed to a treatment facility. For supply wells located within a well field with numerous wells located in close proximity, well interference and groundwater levels needed to be considered as well, since operations could influence the movement of PFAS in groundwater. This movement could cause fluctuations in PFAS concentrations of neighboring supply wells in a given well field. In this case, all wells in the well field would be hydraulically routed to a centralized treatment facility to provide operational flexibility and ensure clean, safe drinking water even if all of the wells do not have PFAS concentrations that meet the HI threshold. In addition, existing treatment facility constraints needed to be considered for those communities with an existing WTP. For example, the existing firm capacity of the plant was considered when determining plant expansions to accommodate future wells. For those communities with more than one treatment facility, redundancy in operations needed to be considered, which could lead to a total treatment capacity greater than a community's 2040 MDD but would allow for operation flexibility should one or two wells need to be taken off-line.

The following sections discuss how the required treated flow, or WTP capacity, was determined for each community based on their 2040 MDD.

F.4.2 Cottage Grove

The City of Cottage Grove currently has 12 municipal supply wells (see Table F.23) and a 2040 MDD of approximately 9,800 gpm. Cottage Grove's firm capacity, with their two largest wells (well 10 and either well 8, 9, 11, or 12) out of service, is 10,500 gpm.

Table F.23. Cottage Grove municipal well summary.

Municipal wells	Well capacity (gpm)	HI value[a] (as of December 2020)
Wells to be taken out of service		
Well 1	600	0.59
Well 2	600	2.32
Wells routed to intermediate-pressure zone WTP (Option 1 capacity = 7,100 gpm, Option 2 capacity = 8,600 gpm)		
Well 3	800	2.43
Well 4	1,000	2.97
Well 5	1,000	1.20
Well 6	1,000	2.10
Well 7	1,000	1.23
Well 8	1,500	1.14
Well 9	1,500	0.80
Well 11 (Option 2)	1,500	0.31
Wells routed to low-pressure zone WTP (capacity = 3,200 gpm)		
Well 10	2,000	2.65
New Well 1	1,200	N/A
Wells not requiring treatment		
Well 11 (Options 1 and 3)	1,500	0.31
Well 12	1,500	0.01

a. Orange HI values meet Options 1, 2, and 3 treatment thresholds; and red HI values meet the Option 2 threshold.

Under the three recommended options, wells 1 and 2 will be taken out of service and one new well would be installed closer to the proposed WTP in the low-pressure zone near well 10. Two WTPs would be implemented – one in the intermediate-pressure zone and one in the low-pressure zone. Table F.24 shows which wells would be routed to which WTP under each option.

Table F.24. Wells routed to WTPs under Options 1 -3.

WTP	Options 1 and 3	Option 2
Low-pressure zone WTP	Well 10 and New Well 1	Well 10 and New Well 1
Intermediate-pressure zone WTP	Wells 3, 4, 5, 6, 7, 8, and 9	Wells 3, 4, 5, 6, 7, 8, 9, and 11

To meet firm capacity, it was assumed that two of the largest wells were out of service; however, to be conservative it was assumed that these two largest wells would be well 10 in the low-pressure zone and well 12 in the high-pressure zone, resulting in most of the demand being supplied by the intermediate-pressure zone WTP.

Starting with the 2040 MDD of 9,800 gpm, assuming wells 10 and 12 were out of service, and given the remaining flow available from the high- and low-pressure zones, the capacity of the intermediate-zone WTP can be determined. Under Options 1 and 3, 1,500 gpm would be available from the high-pressure zone and 1,200 gpm would be available from the low-pressure zone, resulting in a remaining required capacity of 7,100 gpm to be supplied from the intermediate-pressure zone wells. Under Option 2, well 12 was considered out of service for firm capacity and well 11 would be routed to the intermediate-zone WTP due to the HI threshold. With only 1,200 gpm available from the low-pressure zone WTP, the intermediate-pressure zone WTP would supply the remaining 8,600 gpm under Option 2.

F.4.3 Lake Elmo

The City of Lake Elmo currently has three municipal supply wells (see Table F.25) and a 2040 MDD of approximately 4,250 gpm. Lake Elmo's firm capacity with their largest well (well 4 or 5) out of service is 2,250 gpm. It should be noted that at the time of this Conceptual Plan, well 5 has not been placed into service and the exact capacity and HI value are unknown.

Table F.25. Lake Elmo municipal well summary.

Municipal wells	Well capacity (gpm)	HI value (as of December 2020)
Well 2	1,000	0.27
Well 4	1,250	0.01
Well 5	1,250	N/A
Wells routed to WTP (capacity = 2,000 gpm)		
New Well 1	1,000	N/A
New Well 2	1,000	N/A

As shown in Table F.25, the existing wells do not require treatment and for planning purposes of the Conceptual Plan it was assumed that all three wells would be operable. To meet their 2040 MDD of approximately 4,250 gpm, Lake Elmo would require an additional two wells, each with a capacity of 1,000 gpm. In a situation where Lake Elmo remains autonomous and for cost estimating, it was assumed that these wells would be located in the southern region of the city. It was also assumed that they would require treatment based on available sampling data and particle tracking analysis. As such, the WTP for those two wells would need to treat 2,000 gpm under both Options 1 and 2.

If an interconnect between Lake Elmo and Woodbury were to be implemented, additional wells would need to be installed in Woodbury's south well field for Woodbury to have sufficient capacity to supply Lake Elmo. In this case, the interconnect was assumed to be implemented as soon as possible, and Woodbury would need to ultimately supply the difference between Lake Elmo's current demand and their 2040 MDD, which is 2,700 gpm. Groundwater modeling confirmed that three additional wells could supply the water demands for Lake Elmo. As these three wells would be located in the south well field where the HI is assumed to be greater than or equal to 0.3, they would require treatment and would be routed to the proposed south WTP under Option 2, as discussed in the Woodbury section below.

Option 3 identifies St. Paul Regional Water Services as the water source for Lake Elmo. As such, a treatment evaluation was not performed for Option 3 for Lake Elmo.

F.4.4 Oakdale

The City of Oakdale currently has nine municipal supply wells (see Table F.26) and a 2040 MDD of approximately 4,900 gpm. Based on previous analyses as part of the Conceptual Plan, the recommended options include taking wells 1, 2, 6, 7, and 8 out of service and installing three new wells closer to the existing WTP location. The existing WTP capacity would be increased to accommodate flow from one or more of the three new wells, as needed to meet 2040 MDD. It was assumed that the three new replacement wells would match the capacities of wells 1, 2, and 7. Due to their locations and available sampling data, it was also assumed the three new wells would require treatment and therefore would be routed to the expanded WTP. Wells 3 and 10 are located in the northern region of the city and do not require treatment based on their HI values. Therefore, Oakdale's firm capacity with their largest well (well 9) out of service is 5,575 gpm.

Table F.26. Oakdale Municipal well summary.

Municipal wells	Well capacity (gpm)	
Wells to be taken out of service		
Well 1	925	7.95
Well 2	950	7.86
Well 6	1,400	0.008
Well 7	1,000	30.57
Well 8	1,000	30.55
Wells not requiring treatment		
Well 3	1,000	0.013
Well 10	850	0.007
Wells routed to expanded, existing facility (capacity = 4,050 gpm)		
Well 5	850	**59.33**
Well 9	1,100	**48.11**
New Well 1	925	N/A
New Well 2	950	N/A
New Well 3	1,000	N/A

a. Red HI values meet the Option 2 threshold.

However, given that wells 3 and 10 are located away from the other wells in the north and do not require treatment, the worst-case scenario with respect to WTP sizing, in which well 3 was out of service and the majority of the water supply would need to come from the WTP, would be considered. The City of Oakdale currently has a WTP that, according to city staff, can treat up to 2,000 gpm from their existing wells 5 and 9. Given these conditions, well 10 would be considered in service and the expanded WTP would need to supply the remaining demand or 4,900 – 850 = 4,050 gpm, resulting in a 2,050 gpm increase in capacity at the existing WTP or an additional four treatment trains under both Options 1 and 2.

Option 3 identifies St. Paul Regional Water Services as the water source for Oakdale. As such, a treatment evaluation was not performed for Option 3 for Oakdale.

F.4.5 St. Paul Park

The City of St. Paul Park currently has three municipal supply wells (see Table F.27) and a 2040 MDD of approximately 1,200 gpm. St. Paul Park's firm capacity with their largest well (well 4) out of service is 1,200 gpm.

Table F.27. St. Paul Park municipal well summary.

Municipal wells	Well capacity (gpm)	HI value[a] (as of December 2020)
Wells routed to WTP (capacity = 2,100 gpm)		
Well 2	600	**0.71**
Well 3	600	**1.58**
Well 4	900	**1.31**

a. Red HI values meet the Option 2 threshold.

The City of St. Paul Park has already implemented a temporary treatment facility. Currently, wells 3 and 4 are routed to the WTP, which has a total capacity of 2,200 gpm. While the total well capacity is 2,100 gpm, the capacity of 2,200 gpm for the recently implemented facility was used in the cost estimates and is sufficient to meet the anticipated 2040 MDD under Options 1–3.

F.4.6 West Lakeland Township – municipal system

Based on available sampling data, it was assumed that if West Lakeland Township were to implement a municipal water system, the groundwater supply wells would require treatment. To size the new supply wells, WTP, and distribution system, demands needed to be determined for the community. Domestic demands were used for estimating purposes and included irrigation demands for the types of properties considered under this Conceptual Plan (e.g., residential, commercial). To calculate a combined demand that included both domestic and irrigation use and was representative of the community, a per capita demand of 94 gallons per capita per day (gpcpd) was used based on Lake Elmo's historical water consumption. Normally, per person water consumption accounts for domestic and irrigation use; however, feedback received from the township indicated that residences in West Lakeland Township irrigate more than Lake Elmo residents due to larger lot sizes (2.5 acres or more).

To estimate water consumption for West Lakeland Township, domestic use of 47 gpcpd was assumed, which represents 50% of 94 gpcpd. The township currently has 1,393 residences and it was assumed that there were three people per residence. A peaking factor of 3 would then be applied to calculate a MDD for domestic use. Under these conditions, West Lakeland Township can assume a total MDD of 410 gpm for domestic use only.

To determine required irrigation demands, a representative sample of homes was used to determine the average amount of green space irrigated per residence. It was assumed that these homes would water their lawns once weekly, providing an inch of water per square foot. Rainfall data was considered to account for periods when residents would not need to irrigate their lawns. Under these assumptions, it was calculated that 803 gpm would be used daily to irrigate all lawns in West Lakeland Township.

Based on domestic and irrigation demand, the total MDD was estimated as 1,200 gpm or a per capita demand of approximately 140 gpcpd. The WTP would be sized to treat 1,200 gpm under Options 1–3. Table F.28 shows the new wells (one redundant) and WTP capacity.

Table F.28. West Lakeland Township municipal well summary.

Municipal wells	Well capacity (gpm)	HI value (As of December 2020)
Wells routed to WTP (capacity = 1,200 gpm)		
New Well 1	1,200	N/A
New Well 2	1,200	N/A

F.4.7 Woodbury

Similar to Cottage Grove, sizing Woodbury's potential WTP(s) is complicated due a variety of factors. Woodbury currently has 19 wells, as shown in Table F.29, and a 2040 MDD of approximately 19,575 gpm. Based on well capacities only, Woodbury's firm capacity with their two largest wells (well 10 and either well 8, 9, 11, or 12) out of service and well 1 out of service is 19,935 gpm.

Table F.29. Woodbury municipal well summary.

Municipal wells	Well capacity (gpm)	HI value[a] (As of December 2020)
Wells not requiring treatment – eastern well field		
Well 15	1,850	0.03
Well 16	1,980	0.19
Well 18	2,000	0.03
Wells routed to south WTP under Options 1 and 2 – Tamarack well field (WTP Option 1 capacity = 11,600 gpm; Option 2 capacity = 15,600 gpm)		
Well 1	725	2.76
Well 2	760	**0.46**
Well 3	860	**0.35**
Well 4	990	**2.23**
Well 5	940	**0.72**
Well 6	1,150	**3.46**
Well 7	1,350	**3.40**
Well 8	900	**0.38**
Well 9	1,050	**2.79**
Well 10	1,305	0.22
Well 11	1,150	**0.43**
Well 12	1,220	**0.35**
Well 13	1,530	**3.90**
Well 14	1,400	0.24
Well 17	1,500	**0.71**
Wells routed to south WTP under Option 2 – south well field (Option 1 capacity = 11,600 gpm; Option 2 capacity = 15,600 gpm)		
Well 19	2,000	**0.35**
New Well 1	800	N/A
New Well 2	800	N/A
New Well 3	800	N/A
New Well 4	800	N/A
New Well 5	800	N/A

a. Orange HI values meet Options 1, 2, and 3 treatment thresholds; and red HI values meet the Option 2 threshold.

However, there are many unknowns surrounding the Tamarack well field, which includes 15 of the 19 total wells, including the amount of water that can be produced. This is because the close proximity of the wells causes interference and reduces the effective pumping capacity of the wells, according to city engineering staff. The close proximity of these wells also causes water quality issues, as PFAS concentrations will fluctuate depending on well operations. Based on well pumping configurations provided by the city, it was estimated that the Tamarack well field could produce, on average, about 7,500 gpm, with a maximum operating capacity of 10,500 gpm. Pump test(s) would need to be performed once appropriate measures are in place to determine actual pumping rates. Furthermore, it was assumed that the eastern well field could produce 2,850–2,980 gpm, and the south well field (i.e., well 19 and the five new wells) could produce up to 6,325 gpm.

Under Options 1 and 3, the new WTP would be located in the south well field and would treat only the flow from the Tamarack well field, approximately 9,600 gpm when taking the above assumptions into consideration. Under Option 2, all wells in the south well field were assumed to require treatment and the plant capacity would increase by 6,000 gpm, for a total treatment capacity of 15,600 gpm. While the total treatment capacity of the proposed facility will remain the same, capacities of the Tamarack well field and the new southern wells are subject to change, depending on the well production capacity of the Tamarack well field.

As mentioned in Lake Elmo's section above, the option to have Woodbury supply Lake Elmo with treated water was also considered as a potential factor in WTP size for Woodbury. As stated above, if Woodbury were to supply Lake Elmo, Woodbury would need to supply Lake Elmo with 2,700 gpm. Groundwater modeling confirmed that three additional wells located in Woodbury's south well field could supply the water demands for Lake Elmo. Based on current sampling data, it was assumed that the south well field would require treatment under Option 2 only. As such, these wells would be routed to Woodbury's proposed South WTP under Option 2.

F.5 PFAS treatment plant costs

Preliminary estimates of costs associated with the installation and maintenance of water treatment systems in the East Metropolitan area were prepared as part of the Conceptual Plan. This section outlines the details and assumptions used to prepare these estimates.

To provide safe drinking water, the Conceptual Plan identified various treatment technologies for the removal of PFAS compounds, as discussed in Section F.3 – Treatment technology comparison. Under the Conceptual Plan, it was assumed for planning and budgeting purposes that GAC treatment would be the implemented treatment technology as it is the approved technology for PFAS in Minnesota; and provides a conservative cost estimate relative to IX technology, which was also included in early cost estimates (see Appendix H).

F.5.1 PFAS treatment capital costs

The cost estimate represents an approximation, or an early-stage opinion of the probable costs, that is consistent with the Conceptual Plan. Although the estimate includes uncertainty because only a percentage of the overall design effort has been completed, this would decrease in later stages of the design process. Given the level of engineering effort and the cost estimation methodology applied, the cost estimate should be considered an Association for the Advancement of Cost Engineering Class 5. Accuracy for a Class 5 cost estimate is application-specific but can be within the range of +100% to -50%.

Given the simplicity of the treatment system and local experience with construction of media treatment facilities, it is reasonable for the estimate to have an accuracy of ± 30%.

Factored cost estimates are a common tool in concept development stage projects, a technique that allows comparison of a wide range of alternatives. In this application, the cost was estimated by an empirical correlation between the cost and the plant capacity.

A variety of information sources were identified over the course of the work, including:

- Wood experience with PFAS treatment projects
- Local projects
- U.S. Environmental Protection Agency (EPA) Drinking Water Treatment Technology Unit Cost Model (EPA Cost Model).

A summary of these projects is provided in Table F.30. These costs are represented visually in a plot of cost versus capacity in Figure F.12.

A preliminary comparison of the sample PFAS projects to estimates of cost produced by the EPA Cost Model indicates the EPA Cost Model produced lower cost estimates than comparable sample projects. For sample projects where detailed costs estimates were available, equipment costs were comparable to the EPA Cost Model; however, the building costs appeared lower than the sample projects. The actual cause of the difference was unclear; however, there could be several causes, such as assumptions about building sizes without enclosed service bays or aspects required for Minnesota climate. Regardless of the difference, local projects were used as the basis for cost estimates to be conservative.

Given the wide range of plant capacities required across the different communities, which range from 300 gpm to nearly 16,000 gpm, it was necessary to use two different reference projects and power factors, to provide reasonable cost estimates (see Table F.30 and Figure F.11). The use of two reference projects (Reference Project A and Reference Project B) separates the wide range of capacity into two separate curves. The reference projects were selected with the following considerations: (1) represent projects within or as close as possible to the respective range, (2) represent typical cost projects (not lowest cost), and (3) represent a project at the low end of the capacity range so that the effect of the power factor leads to a conservative estimate of cost Figure F.19. Cost estimates produced as of December 2020 used reference projects that were dependent on capacity (see Table F.31). The following equation was used to produce the cost estimates based on the given basis of projects and power factor (*X*):

$$Cost\ New = Cost\ Reference \times \left(\frac{Cost\ Index\ Current\ Year}{Cost\ Index\ Reference\ Year}\right) \times \left(\frac{Capacity\ New}{Capacity\ Reference}\right)^{\mathbf{Power\ Factor}}$$

Similar types of plants or equipment have similar scaling factors. Generally, a commonly used scaling factor is 0.6. Most water treatment equipment ranges from 0.6 (e.g., media treatment vessels) to 0.85 (e.g., large concrete structures such as clarifiers and activated sludge basins).

For projects with a design capacity between 500 and 6,000 gpm , the cost was estimated by Reference Project A (see Table F.31). Above a capacity of 6,000 gpm, Reference Project B was used (see Table F.31). The shift between reference projects was selected so that the more conservative cost estimate was used to estimate the cost, which is depicted in Figure F.13.

The results of the PFAS treatment cost model were also presented in a different manner, as cost per unit (gpm) of treatment capacity (see Figure F.14). The results present the combined model and illustrates how the economies of scale were projected to influence the cost.

The historical Chemical Engineering Plant Cost Index (CEPCI) values used to adjust the cost for reference projects to 2020 year cost are illustrated in Figure F.15. Over the selected timeframe, the 25-year average inflation was 2.0%.

For the two reference projects, items in the scope of scale-up included:

- GAC vessels with carbon
- Chlorine addition
- Fluoride addition
- Surge tank (for backwash)
- Air compressor
- Piping
- Utilities
- Pavement
- Building
- Electrical
- Instrumentation
- Heating, ventilating, and air conditioning
- Concrete
- Earthwork.

Items excluded from scale-up included:

- Land
- Engineering
- Administration
- Contingency.

F.5.2 PFAS treatment O&M costs

A general O&M cost for each facility was estimated as 5% of the capital cost for a PFAS treatment plant. This includes items such as electricity, heating, and building and site maintenance.

F.5.3 PFAS treatment plant operators

GAC treatment for PFAS is expected to introduce additional complexity to the municipal water supply system. Additional operators required to support the PFAS treatment plant were estimated based on a trend developed using the EPA Cost Model for GAC; see Figure F.16. Operator full-time equivalent (FTE) was estimated based on the treatment plant capacity and rounded to the nearest half FTE. An FTE was based on 2,000 hours per year.

Table F.30. PFAS treatment sample projects

Plant	Location	Year of estimate	Estimate class	Capacity (gpm)	2020 cost ($)	CEPCI estimated cost ($)	CEPCI at year of estimate	CEPCI in 2020	Description	Plant Details
Woodbury temporary WTP	MN	2020	Constructed	3,800	7,740,000	7,740,000	607	607	Municipal WTP – Woodbury W4, 6, 7, 17	6 trains lead-lag columns
St. Paul Park	MN	2019	Constructed	2,100	5,180,000	5,180,000	607	607	Municipal WTP – St. Paul Park W2, 3, 4	4 trains lead-lag columns (8 vessels), Calgon Model 10 or equivalent
Bemidji (excludes Greensand components)	MN	2020	Class 3 (estimated)	1,800	3,864,000	3,864,000	607	607	Municipal WTP – Bemidji PFAS	3 trains lead-lag columns, total project also includes greensand filtration
Oakdale Prefeasibility Study (PFS) Layout 1	MN	2020	Class 4	800	3,265,000	3,265,000	607	607	Oakdale WTP PFS Study	2 trains lead-lag columns, 20,000-lb GAC bed, Calgon Model 10, ~ 4,100 ft^2 building
Oakdale PFS Layout 2	MN	2020	Class 4	1,600	5,078,000	5,078,000	607	607	Oakdale WTP PFS Study	4 trains lead-lag columns, 20,000-lb GAC bed, Calgon Model 10, ~ 5,100 ft^2 building
Oakdale PFS Layout 3	MN	2020	Class 4	1,600	4,444,000	4,444,000	607	607	Oakdale WTP PFS Study	2 trains lead-lag columns, 40,000-lb GAC bed, Calgon Model 12-40, ~ 4,400 ft^2 building
Barnstable	MA	2017	Class 4	2,100	4,920,176	4,600,000	567.5	607	Potable water treatment study	3 million gallons per day (MGD), 28,800 people
Central Sanitary Landfill	MI	2019	Class 4	80	785,000	785,000	607	607	Groundwater pump and treat	1 train lead-lag column, 5,000-lb GAC bed, 10-minute empty bed contact time (EBCT), bolt on to existing VOC treatment system
Oakdale Landfill Pump and Treat PFS	MN	2008	Class 3	55	1,129,548	1,070,000	575	607	Groundwater pump and treat	1 train lead-lag column, 20,000-lb GAC bed, also includes equalization tank, and VOC treatment (air stripper and 5,000-lb vapour phase GAC)
EPA tool	General	2016	Class 4	5,115	7,238,730	6,460,000	541.7	607	Developed with EPA Cost Model	7.365 MGD, 10-minute EBCT, lead-lag, with building
EPA tool	General	2016	Class 4	15,704	17,200,388	15,350,000	541.7	607	Developed with EPA Cost Model	22.614 MGD, 10-minute EBCT, lead-lag, with building
EPA tool	General	2016	Class 4	52,133	53,674,174	47,900,000	541.7	607	Developed with EPA Cost Model	75.072 MGD, 10-minute EBCT, lead-lag, with building
EPA tool	General	2016	Class 4	2,100	4,089,994	3,650,000	541.7	607	Developed with EPA Cost Model	2,100 gpm, 10-minute EBCT, lead-lag, with building

Figure F.12. Cost versus capacity curve for various sample projects.

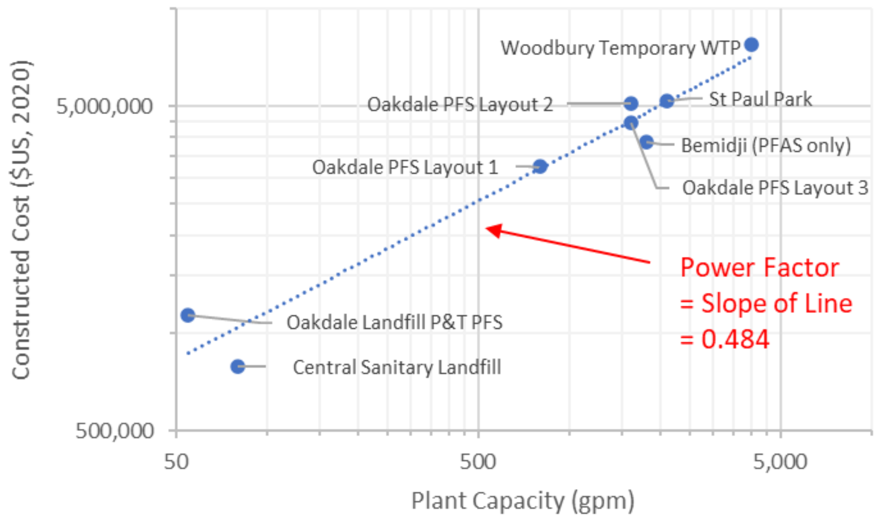


Table F.31. PFAS reference projects used for scaling cost estimates.

Suitable range of capacity	Units	Reference project A (300 to 6,000 gpm)	Reference project B (above 6,000 gpm)
Project	-	SEH Oakdale PFS Layout 2	Woodbury temporary WTP
Cost	$USD (2020)	5,078,000	7,740,000
Capacity	gpm	1,600	3,800
Power factor	-	0.60	0.85

Figure F.12. Illustration of the shift in power factor between plants with low and high capacity.

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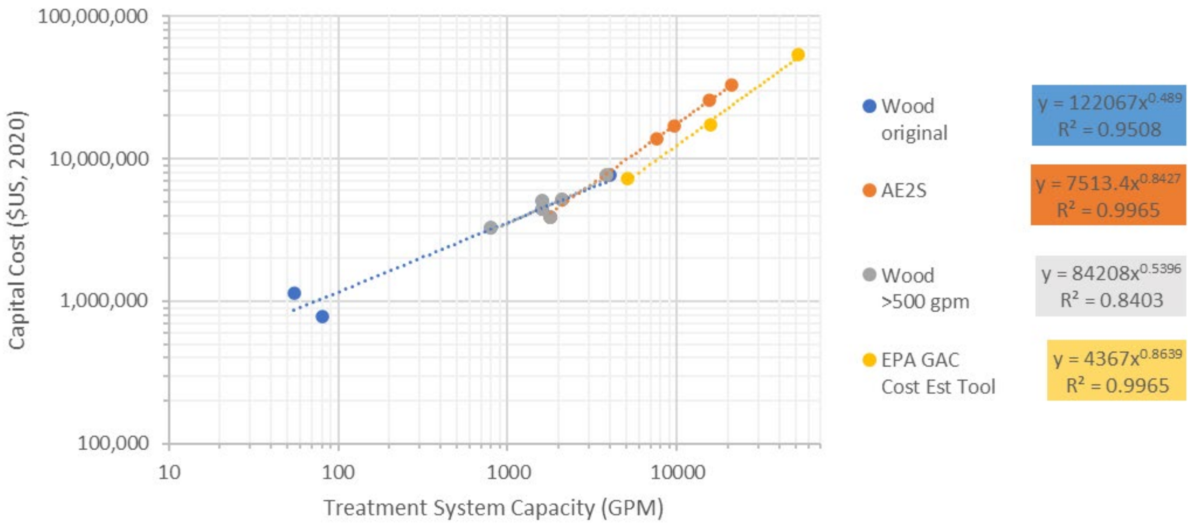

Figure F.13. Illustration of the basis for the transition between the most-conservative cost models.

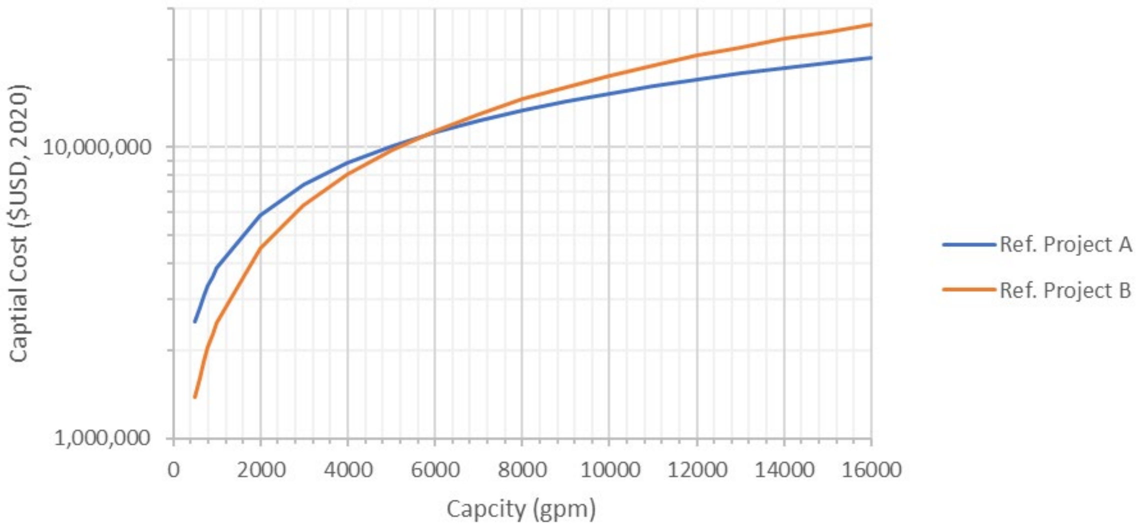

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Figure F.14. Calculated average cost per unit of capacity, using the two reference projects.

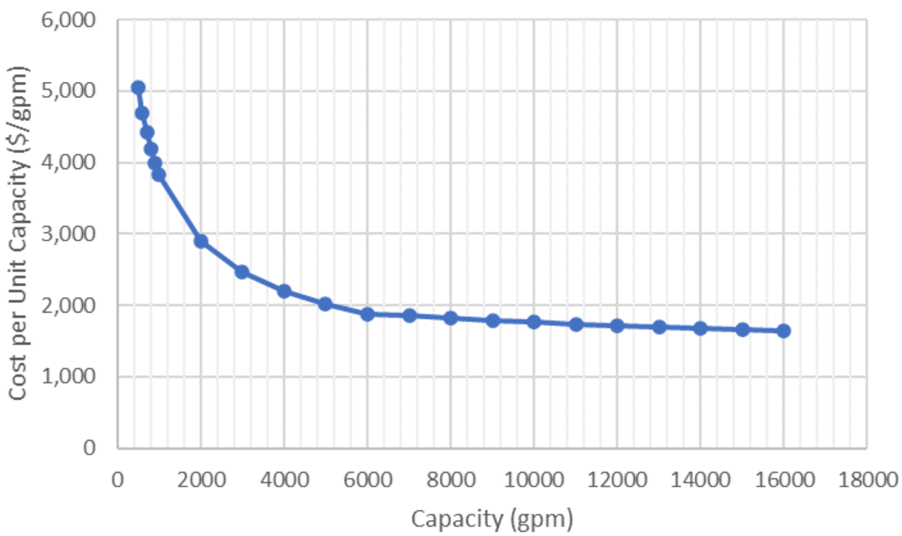
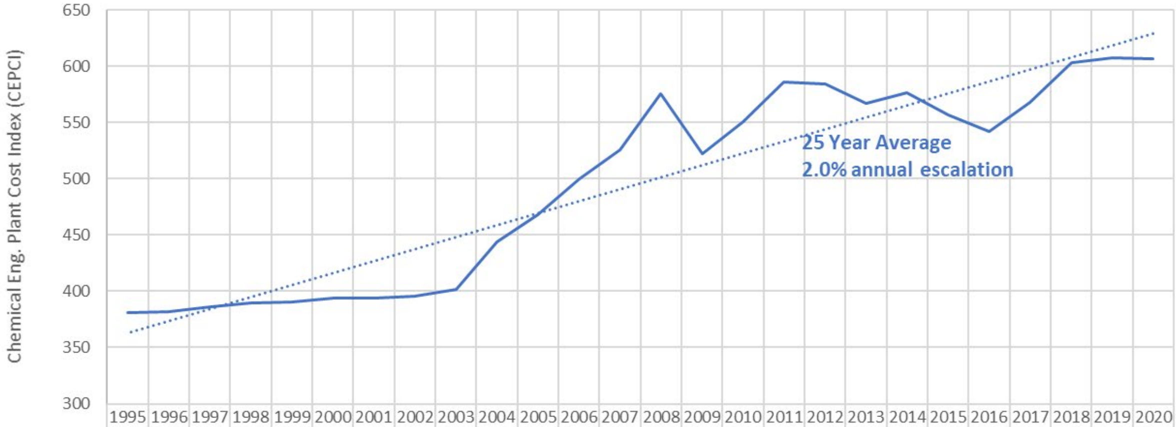
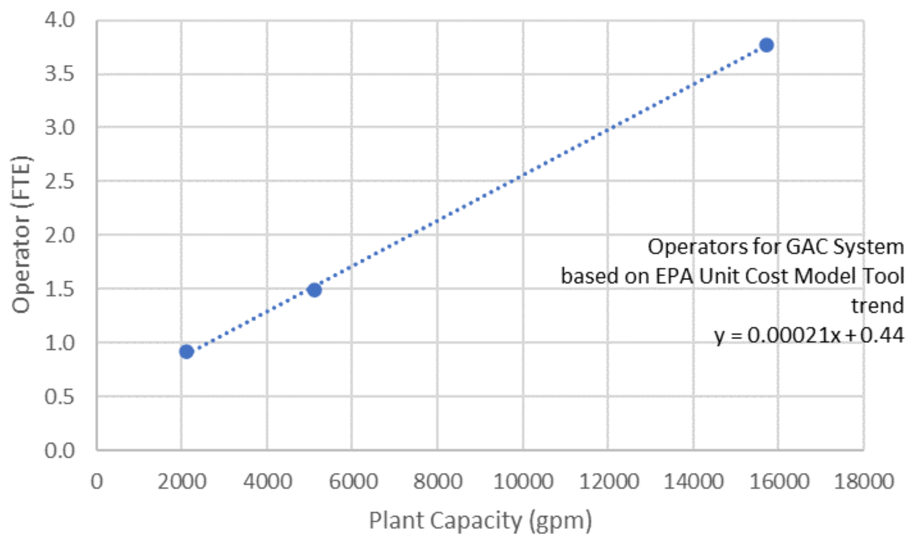


Figure F.15. Chemical Engineering Plant Cost Index trends.



	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
CEPCI	381	382	387	390	391	394	394	396	402	444	468	500	525	575	522	551	586	585	567	576	557	542	568	603	608	607

Figure F.16. Relationship between operators and capacity for PFAS treatment.



F.6 PFAS treatment operating cost

This section outlines the media consumption estimate approach for the PFAS treatment options across the range of PFAS concentrations. Groundwater quality monitoring has identified that wells demonstrate a wide range of PFAS concentrations. Media consumption for PFAS treatment was expected to be dependent on the raw water quality.

A conceptual approach to estimate the media consumption for GAC was developed, based on equilibrium GAC (i.e., media) loading capacity; see Figure F.11. This approach was based on local carbon capacity data from the Oakdale WTP, published by Hohenstein and Bachmeier (2015). Freundlich isotherms for various parameters were prepared and used to estimate the equilibrium capacity of GAC for operating conditions and equilibrium concentration; see Figure F.18 and Table F.32.

The absence of local equilibrium IX (i.e., media) loading-capacity data creates a challenge with estimating media consumption. Prior experience from pilot-scale test programs completed by Wood and other published studies have identified that IX can consistently demonstrate longer operating cycles; see Table 31. This experience was used to estimate the increased IX capacity for the East Metropolitan area, based on the available information about GAC capacity. This approach for IX capacity was deemed suitable until further information is developed via the pilot program undertaken in Cottage Grove. Available experience suggests that IX can provide a capacity that ranges from 7 to 15 times greater than GAC. For the purposes of this work, it was assumed that the IX capacity was eight times greater than GAC, a value believed to be conservative based on prior pilot programs (see Table F.33). Pilot programs were unable to demonstrate how much higher this might be, due to schedule limits that prevented operation to IX breakthrough.

Groundwater quality data indicated that PFOA was the dominant PFAS to reach loading capacity at 80% of the MDH Health-Based Value (HBV). To simplify the approach of estimating media consumption, PFOA was used as the basis for media consumption. Figure F.19 illustrates how consumption rates for GAC and IX media were estimated based on the raw water PFOA concentration.

Costs for GAC and IX media, based on the raw water PFOA concentration, were estimated; see Figure F.20. Vendor pricing for GAC and IX resin varies moderately by material, vendor, and market demand. For the purposes of this work, lifecycle costs were estimated to be \$2.75/lb (or approximately \$92.70/ft^3) for GAC and \$450/ft^3 for resin. Lifecycle costs reflect the cost to purchase virgin media as well as the cost for media disposal. Similar to the water treatment project, the disposal of treatment residues, such as GAC and IX media, is likely to be impacted by changes to waste disposal regulations. Changes to regulations are likely to impact the options and cost to manage treatment residues. U.S. EPA (2020) published interim guidance to identify and describe technologies that may control releases of PFAS waste to protect human health and the environment.

Should East Metropolitan area-specific information about the loading capacity of IX resin become available, this work could be updated. Vendor-specific experience from other projects could also be used as a resource to further refine estimates of media capacity as projects reach implementation.

An estimate of media cost by this approach is more representative compared to an estimate based on constant media consumption, as it is responsive to the PFAS (specifically PFOA) concentrations observed by communities in the East Metropolitan area. Equations used to determine carbon usage rate are shown in Figure F.21 and examples are shown in Figure F.22.

For the purpose of the Conceptual Plan, the estimate of media cost was developed with the following assumptions:

- The plant would operate at 38.5% of nameplate capacity, which corresponds to operating with a peaking factor of 2.6.
- The PFOA feed concentration to the treatment plant was estimated as the volume weighted average PFOA concentration in the wells treated.
- The PFOA concentration for each well was the average of four samples. In some instances, data came from quarterly samples from Quarter 2 in 2019 to Quarter 1 in 2020; and in other instances, data were derived from annual sampling from 2014 through 2019.
- For new wells without available data, the PFOA concentration was estimated based on data from private wells in the planned aquifer and in proximity to the proposed well.

Figure F.17. Conceptual approach to estimate GAC media consumption (Hohenstein and Bachmeier, 2015).

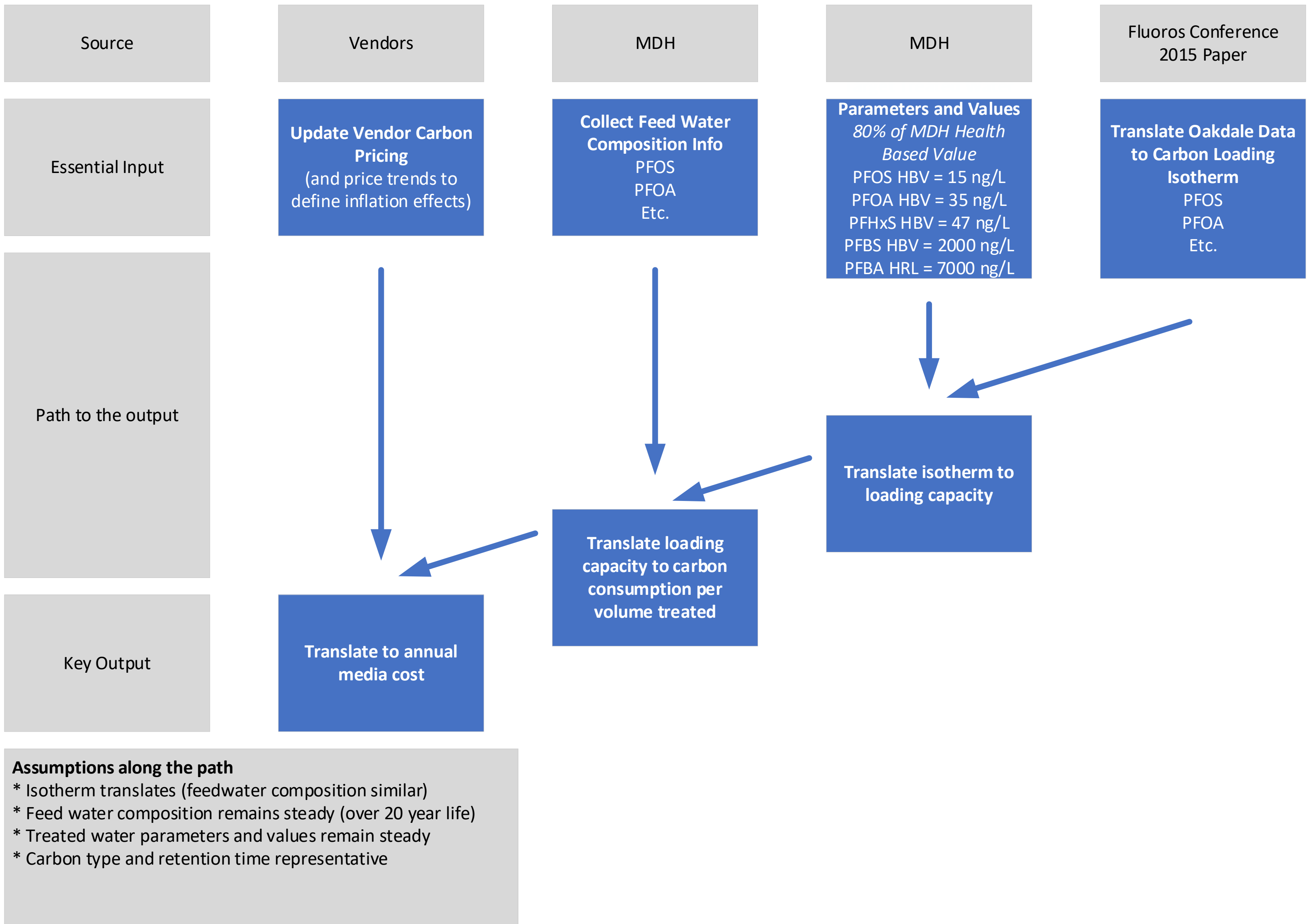


Figure F.18. Freundlich isotherms to estimate GAC loading capacity, based on data from Oakdale WTP.

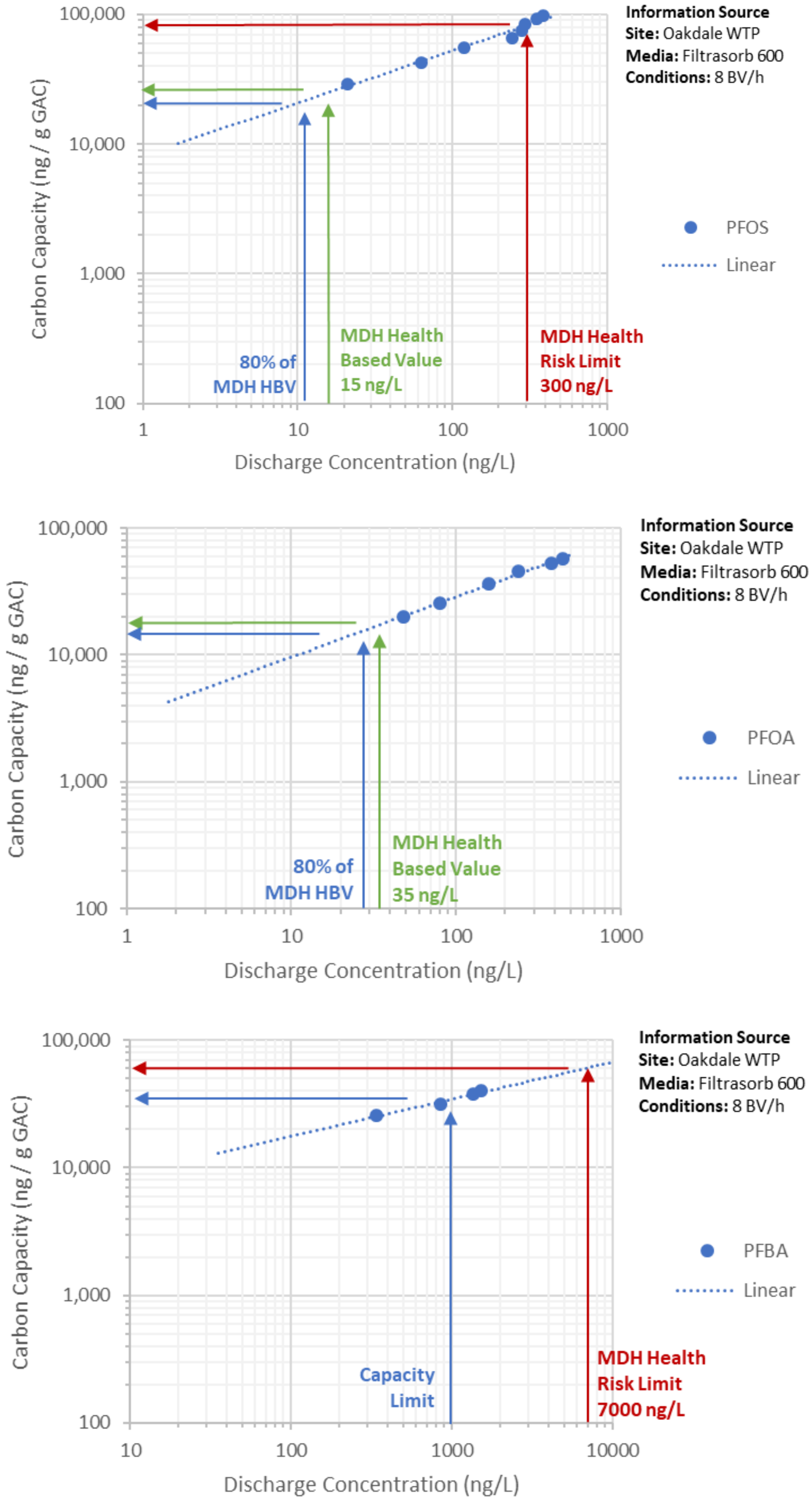


Table F.32. Estimated equilibrium GAC capacity for Filtrasorb 600 GAC based on Oakdale experience.

Parameter	MDH guidelines, 2020		Equilibrium GAC loading capacity at 80% of HBV (ng/g)
	Health Based Value (ng/L)	Health-risk limit (ng/L)	
PFBS	2,000	7,000	-
PFBA	-	7,000	35,000
PFHxS	47	-	-
PFOS	15	300	20,000
PFOA	35	-	12,500

Table F.33. Summary of pilot studies comparing GAC and IX treatment capacity.

Reference	Location	Total PFAS concentration (ug/L)	Predominant PFAS (percentage of total PFAS)	Co-contaminants	Volume treated to breakthrough[a,b,c] (as bed volume, BV) GAC	IX	Ratio IX to GAC treatment volume
Wood, 2017	Pease Air Force Base, New Hampshire	44	PFOS (45%) 6:2 FTS[d] (17%) PFHxS (15%)	Hydrocarbons	12,365 (bituminous)	> 44,000	> 4
Wood, 2019	Central Sanitary Landfill, Michigan	1.24	PFBS (52%) PFHxA (12%) PFBA (8%)	-	5,000	> 36,000 *Estimated 48,000 (PFHxA)* *Estimated 110,000 (PFOA)*	>7.2 - *Estimated* 22 PFOA
Purolite, 2017	Pilot 1	1.44	PFOS (50%) PFHxS (20%) PFOA (19%)	VOC	10,000 (coconut)	155,000	15.5
Purolite, 2017	Horsham, Pennsylvania	0.10	PFOS (37%) PFHxS (30%) PFOA (22%)	TOC	19,000 (bituminous)	> 168,000	> 8.8
Stantec, 2020	Cottage Grove Pilot	1.21	PFBA (81%) PFBS (11%) PFHxS (6%)	-	In progress	In progress	In progress

a. Unless otherwise indicated, breakthrough defined as > 35 ng/L of PFOA.

b. Pilot IX tests commonly terminated before the onset of breakthrough due to schedule limits. The volume treated at the end of the test is provided in this table. The estimated volume treated at breakthrough is shown in italics.

c. Bed volume (BV) is a term used to normalize operating data (the volume treated) relative to the design data (size of the equipment, specifically the volume of the media) so that the performance can be directly compared between different studies.

d. Fluorotelomer sulfonate (FTS) is a PFAS

Figure F.19. Estimated media consumption, based on raw water PFOA concentration.

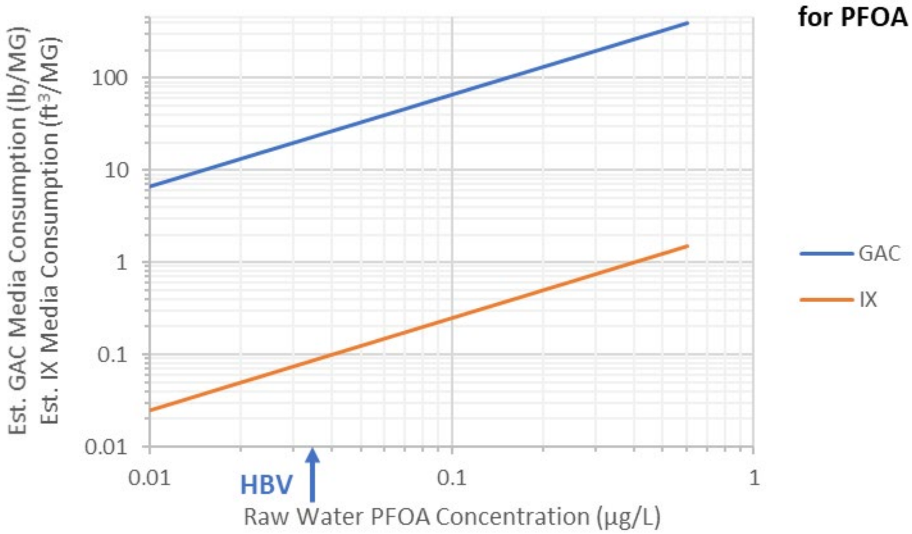


Figure F.20. Estimated lifecycle media cost, based on raw water PFOA concentration.

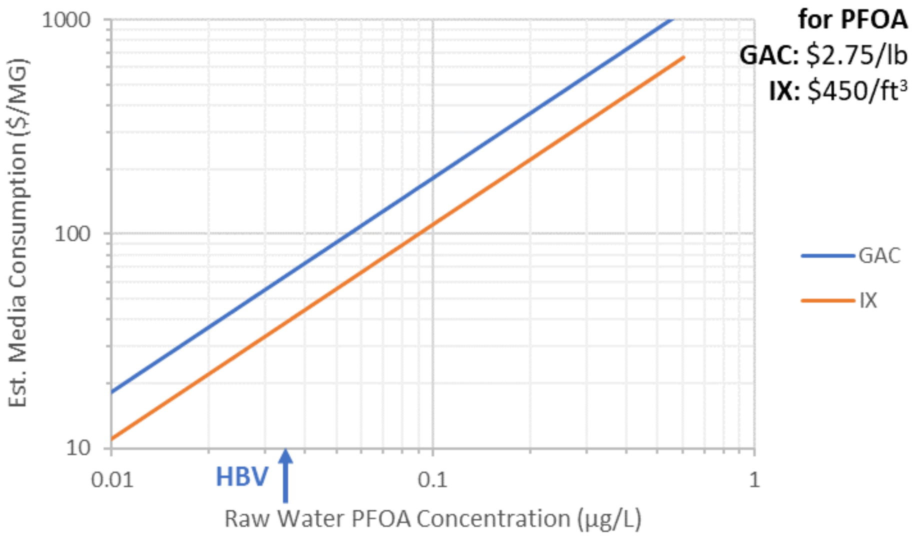


Table F.34. Municipal well groundwater quality data (data available as of September 2020).

CTU	Well Number	GIS ID	UN	Average of PFBS	Average of PFBA	Average of PFHxS	Average of PFOS	Average of PFOA	MDH HI (RA)	Comments
Cottage Grove	1	CTG-WEL-0001	208808	0.024	0.850	0.003	0.000	0.007	0.545	4 sample average
Cottage Grove	2	CTG-WEL-0002	208809	0.110	0.678	0.054	0.000	0.036	2.342	4 sample average
Cottage Grove	3	CTG-WEL-0003	208807	0.130	0.983	0.076	0.000	0.024	2.49	4 sample average
Cottage Grove	4	CTG-WEL-0004	208805	0.128	1.075	0.093	0.000	0.030	3.047	4 sample average
Cottage Grove	5	CTG-WEL-0005	208806	0.022	1.050	0.007	0.000	0.027	1.204	4 sample average
Cottage Grove	6	CTG-WEL-0006	201238	0.034	0.328	0.019	0.000	0.004	0.568	4 sample average
Cottage Grove	7	CTG-WEL-0007	201227	0.013	0.669	0.002	0.000	0.029	1.064	4 sample average
Cottage Grove	8	CTG-WEL-0008	110464	0.039	0.775	0.026	0.000	0.019	1.404	4 sample average
Cottage Grove	9	CTG-WEL-0009	165602	0.034	0.710	0.016	0.000	0.015	0.905	4 sample average
Cottage Grove	10	CTG-WEL-0010	191904	0.024	0.915	0.028	0.003	0.063	2.913	4 sample average
Cottage Grove	11	CTG-WEL-0011	655944	0.000	0.495	0.000	0.000	0.004	0.249	4 sample average
Cottage Grove	12	CTG-WEL-0012	830682	0.000	0.066	0.000	0.000	0.000	0.010	4 sample average
Lake Elmo	2	ELM-WEL-0002	603085	0.000	0.081	0.000	0.000	0.000	0.012	most recent value
Lake Elmo	4	ELM-WEL-0004	767874	0.000	0.053	0.000	0.000	0.000	0.011	most recent value
Newport	1	NEW-WEL-0001	208353	0.000	0.278	0.000	0.000	0.000	0.033	most recent value
Newport	2	NEW-WEL-0002	225904	0.000	0.470	0.000	0.000	0.000	0.056	most recent value
Oakdale	1	OAK-WEL-0001	208462	0.005	0.300	0.004	0.065	0.079	7.945	most recent value
Oakdale	2	OAK-WEL-0002	208463	0.001	0.258	0.005	0.053	0.066	7.342	most recent value
Oakdale	3	OAK-WEL-0003	208454	0.000	0.102	0.000	0.000	0.000	0.014	most recent value
Oakdale	5	OAK-WEL-0005	127287	0.023	1.250	0.047	0.675	0.413	57.970	4 sample average
Oakdale	7	OAK-WEL-0007	463534	0.022	1.125	0.042	0.323	0.313	30.568	most recent value
Oakdale	8	OAK-WEL-0008	572608	0.011	0.598	0.016	0.250	0.195	28.216	most recent value
Oakdale	9	OAK-WEL-0009	611059	0.032	1.275	0.063	0.505	0.430	47.480	4 sample average
Oakdale	10	OAK-WEL-0010	773389	0.000	0.042	0.000	0.000	0.000	0.007	most recent value
St. Paul Park	2	SPP-WEL-0002	208418	0.000	1.150	0.000	0.000	0.018	0.871	4 sample average
St. Paul Park	3	SPP-WEL-0003	208804	0.006	0.910	0.001	0.000	0.041	1.409	4 sample average
St. Paul Park	4	SPP-WEL-0004	431603	0.005	1.225	0.003	0.000	0.033	1.324	4 sample average
Woodbury	1	WDB-WEL-0001	208420	0.000	0.170	0.002	0.009	0.030	1.701	used 4 sample average
Woodbury	2	WDB-WEL-0002	208422	0.000	0.228	0.000	0.000	0.000	0.04	most recent value
Woodbury	3	WDB-WEL-0003	208423	0.000	0.210	0.000	0.002	0.012	0.376	most recent value
Woodbury	4	WDB-WEL-0004	208005	0.000	0.305	0.002	0.005	0.025	1.109	used 4 sample average
Woodbury	5	WDB-WEL-0005	150353	0.000	0.240	0.001	0.000	0.006	0.426	most recent value
Woodbury	6	WDB-WEL-0006	151569	0.001	0.435	0.004	0.020	0.046	2.759	used 4 sample average
Woodbury	7	WDB-WEL-0007	433281	0.000	0.403	0.004	0.018	0.042	2.508	used 4 sample average
Woodbury	8	WDB-WEL-0008	509051	0.000	0.275	0.000	0.000	0.000	0.040	most recent value
Woodbury	9	WDB-WEL-0009	463539	0.000	0.355	0.002	0.012	0.035	1.840	used 4 sample average
Woodbury	10	WDB-WEL-0010	541763	0.000	0.288	0.000	0.000	0.000	0.043	most recent value
Woodbury	11	WDB-WEL-0011	563000	0.000	0.185	0.000	0.000	0.004	0.431	most recent value
Woodbury	12	WDB-WEL-0012	596646	0.000	0.245	0.000	0.000	0.000	0.036	most recent value
Woodbury	13	WDB-WEL-0013	593657	0.018	0.335	0.068	0.027	0.016	3.772	used 4 sample average
Woodbury	14	WDB-WEL-0014	611094	0.000	0.255	0.000	0.000	0.000	0.039	most recent value
Woodbury	15	WDB-WEL-0015	676415	0.000	0.203	0.000	0.000	0.000	0.031	most recent value
Woodbury	16	WDB-WEL-0016	706811	0.000	0.327	0.000	0.000	0.000	0.050	most recent value
Woodbury	17	WDB-WEL-0017	759572	0.000	0.190	0.001	0.002	0.015	1.186	used 4 sample average
Woodbury	18	WDB-WEL-0018	786210	0.000	0.110	0.000	0.000	0.000	0.021	most recent value
Woodbury	19	WDB-WEL-0019	805361	0.000	0.220	0.000	0.000	0.003	0.323	most recent value
Lakeland	1	LKD-WEL-0001	420985	0.000	0.006	0.000	0.000	0.000	0.002	used 1 sample 2018
Lakeland	2	LKD-WEL-0002	533517	0.000	0.006	0.000	0.000	0.000	0.002	used 1 sample 2018

MDH HI color key

Dark blue	0<HI<0.01
Light blue	0.01<HI<0.25
Green	0.25<HI<0.5
Yellow	0.5<HI<0.75
Orange	0.75<HI<1.0
Red	1.0<HI

Table F.35. Media consumption and design criteria for PFAS treatment.

Community	Treatment Alternatives	Media consumed (GAC; $/year)	IX ($/year)	Feed PFOA (weighted average) (ug/L)	Water produced[a] (MG/year)	Nameplate capacity (gpm)	GAC consumption (lb/year)	GAC consumption (lb/MG)	Notes
Lake Elmo	Alternative 1 – all plants	928	563	-	-	-	337	-	
	WTP 1	928	563	0.000	1,112	5,500	337	0.3	
	Alternative 2 – all plants	11,318	6,868				4,116	-	
	WTP 1	928	563	0.001	708	3,500	337	0.5	
	WTP 2	10,390	6,305	0.014	404	2,000	3,778	9.3	
Oakdale	Alternative 1 – all plants	478,209	290,196	-	-	-	173,894	-	
	WTP 1	122,456	74,311	0.330	202	1,000	44,529	220.3	
	WTP 2	0	0	0	374	1,850	0		
	WTP 3	355,753	215,885	0.251	773	3,825	129,365	167.5	1,875 gpm expansion
	Alternative 2– all plants	471,715	286,255	0.263	975	4,825	171,533	175.6	2,875 gpm expansion
	Existing plant for wells 5 and 9	305,630	185,468	0.422	394	1,950	111,138	281.7	Existing WTP 1,950 gpm
Newport	Alternative 1	-	-	-	364	1,800	-		
St. Paul Park	Alternative 1	26,579	16,129	0.034	425	2,100	9,665	22.7	
Cottage Grove	Alternative 1 – all plants	113,095	68,631	-	-	-	41,125	-	
	Alternative 1 – WTP 1	3,479	2,111	0.003	606	3,000	1,265	2.1	
	Alternative 1 – WTP 2	10,687	6,485	0.024	243	1,200	3,886	16.0	
	Alterative 1 – WTP 3	45,420	27,563	0.068	364	1,800	16,516	45.4	
	Alternative 1 – WTP 4	53,510	32,472	0.023	1,274	6,300	19,458	15.3	
	Alternative 2 – all plants	108,531	65,861	-	-	-	39,466	-	
	Alternative 2 – WTP 1	42,915	26,043	0.064	364	1,800	15,605	42.9	
	Alternative 2 – WTP 2	65,616	39,818	0.019	1,880	9,300	23,860	12.7	
	Alternative 3 – all plants	8,294	5,033	-	-	-	3,016	-	
	Alternative 3 – WTP 1	8,294	5,033	0.037	121	600	3,016	24.9	600 gpm at Well 2
Prairie Island Indian Community	Alternative 1	779	473	0.021	20	100	283	14.2	
West Lakeland	Alternative 1	11,875	7,206	0.040	162	800	4,318	26.7	
Woodbury	Alternative 1	97,154	58,957	0.011	4,839	23,935	35,329	7.3	
	Alternative 2	68,095	41,323	0.019	1,934	9,565	24,762	12.8	
	Alternative 3	68,095	41,323	0.019	1,934	9,565	24,762	12.8	

a. Water produced based on a peaking factor of 2.6 (i.e., 38.5% utilization of nameplate capacity).

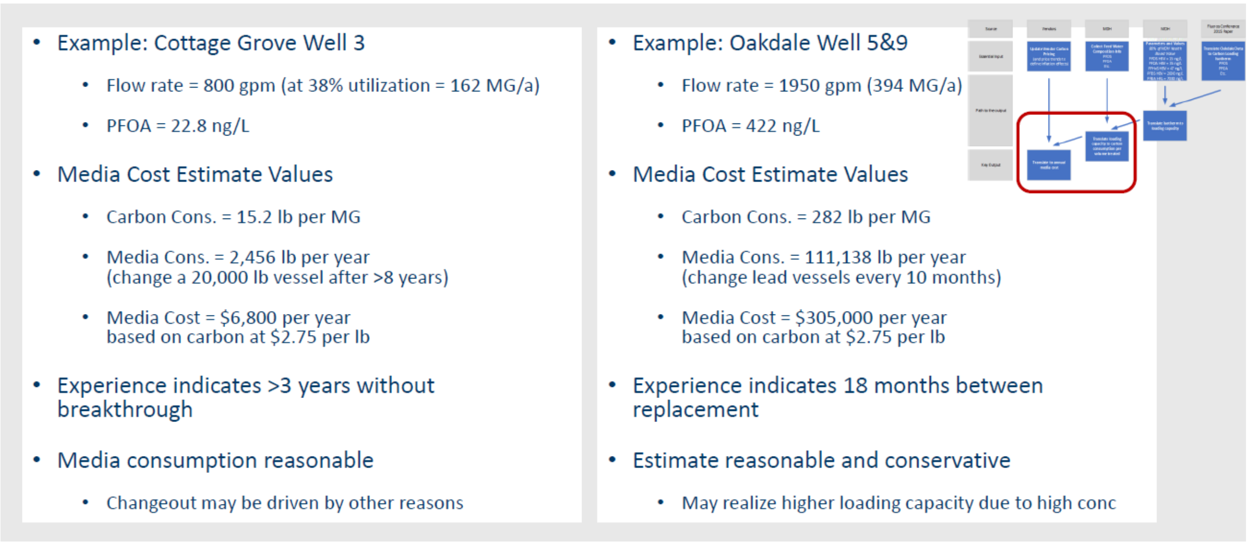
Figure F.21. Equations used to estimate the carbon usage rate.

$$Carbon\ Consumption = \frac{PFOA\ Concentration}{GAC\ Loading\ Capacity}$$

$$Annual\ Media\ Consumption = \frac{WTP\ Capacity}{Peaking\ Factor} * Carbon\ Consumption$$

$$Annual\ Media\ Cost = Annual\ Media\ Consumption * Media\ Lifecycle\ Cost$$

Figure F.22. Examples of estimated carbon usage rate.



F.7 Pretreatment contingency

Experience from the Cottage Grove pilot project has indicated that the presence of suspended solids and/or the oxidation of dissolved iron and manganese can contribute to the slow accumulation of solids on the surface and within the media bed. This action can lead to several symptoms, including early media change-out due to pressure drop (instead of PFAS breakthrough), and early media change-out due to the potential loss of media adsorption capacity (via blockage of media pores).

Symptoms from suspended solids represent a design consideration for GAC (and IX) media treatment, and a variety of tools are available to manage both the symptom and root cause, including:

- Capability to manage based on design criteria
  - Water quality (iron, manganese, total suspended solids, PFAS)
  - Media adsorption capacity and expected lifespan
  - Media particle size
  - Potential for aeration/oxidation prior to GAC
  - Hydraulic loading (x gpm/ft^2) in GAC vessels
  - Ability to utilize backwash capabilities to manage suspended solids

- Eliminate or manage via dedicated equipment
  - Surface wash equipment in the GAC vessel to manage solids without disturbance of the entire bed
  - Iron and manganese control via oxidation and filtration to manage solids before GAC treatment
  - Polyphosphate for iron sequestration to prevent iron precipitation
- Manage via operational controls
  - Accommodate media change-out before PFOA breakthrough.

Given the very long media life expected for some of the PFAS treatment systems, it may also be necessary to include controls to manage the iron and manganese before GAC treatment.

Dedicated equipment to provide pretreatment for iron and manganese control via oxidation and filtration was considered the most-conservative treatment process from a budgeting perspective, and was estimated as the basis for contingency pretreatment.

F.7.1 Pretreatment capital costs

A cost model was developed to estimate the capital cost of an iron and manganese treatment system. To be consistent with the Ten State Standards (2018), the treatment equipment considered 10-foot diameter, vertical sidewall filtration vessels, with a hydraulic loading of 4 gpm per square foot. The equipment cost was based on budgetary pricing for pre-engineered filtration vessels, with an equipment count that included redundancy as N + 1, with N equal to the calculated number of vessels. Building space requirements were estimated based on the space for the required number of units with clearances of 4 feet on the front and back, as well as 3 feet on each side. A precast backwash surge tank to manage backwash from the filtration vessels was included at a rate of 1 per 6 filters. Piping included 150 feet of 8-inch sewer lines and 100 feet of 6-inch yard piping to the backwash tank. The building cost was estimated to be $470 per square foot, including installation cost, project burdens (engineering, administration, construction management, and contractor profit), and all services and materials within the building (electrical, mechanical, instrumentation and controls,). This value was based on 2019 project bid tabulations for the St. Paul Park WTP. The cost does not include land acquisition, which has been included as a separate cost item in Appendix E.

The cost model estimated value, checked against data from several reference projects and provided by communities, is summarized in Table F.36.

Table F.36. Reference projects used as a check on pretreatment cost model estimations.

Project	Description	Capacity (gpm)	Reference value ($)	Cost model estimated value ($)	Type of cost
Stantec – unnamed	Estimated based on $1.62/MG of capacity	1,200	1,780,000	1,963,137	Equipment and building
Faribault WTP	2019/2020, filters for iron and manganese	6,944	9,717,732	9,293,977	Equipment and building
AE2S Mounds View WTP2	2020/2021, 1,000 gpm, WTP rehabilitation	1,000	1,325,875	1,273,000	Equipment only
AE2S Mounds View WTP3	2020/2021, 1,000 gpm, WTP rehabilitation	1,000	1,210,908	1,273,000	Equipment only

Project	Description	Capacity (gpm)	Reference value ($)	Cost model estimated value ($)	Type of cost
AE2S - Woodbury Option 1	Option 2, 9,600 gpm	9,600	12,700,000	12,452,857	Equipment and building
AE2S - Woodbury Option 2	Option 2, 15,600 gpm	15,600	19,400,000	19,783,697	Equipment and building
Bemidji	2019/2021 – first phase filter for iron and manganese	1,800	1,250,000	1,740,000	Equipment only

Changes from earlier Conceptual Plan estimates in September 2020 were based on feedback from community meetings and relate to:

- Equipment sizing and count based on design hydraulic loading (changed from 5.5 to 4.0 gpm per ft^2) to be consistent with Ten State Standards (2018)
- Subsequent increase in the building footprint due to a change in the equipment count
- Consideration for O&M costs.

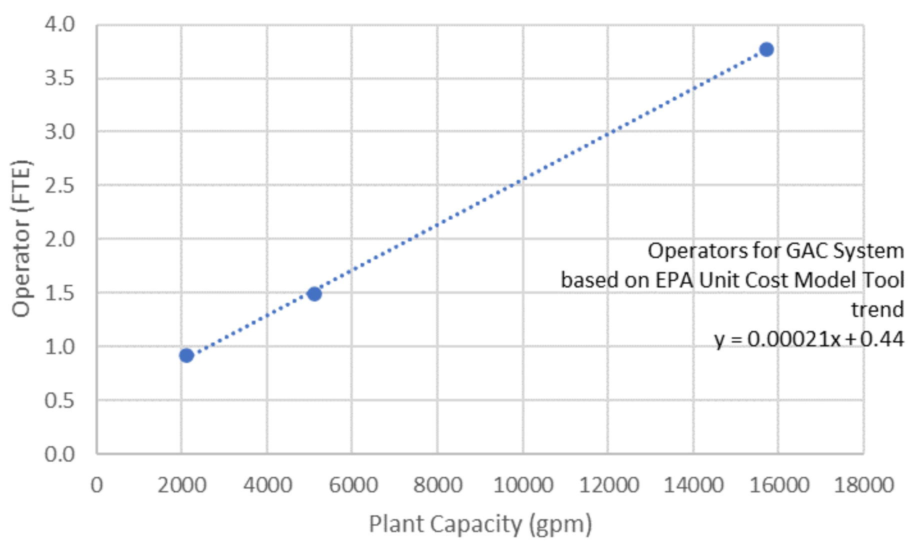
F.7.2 Pretreatment O&M costs

A general O&M cost for each facility was estimated at 5% of the capital cost for pretreatment, and includes items such as electricity, heating, and building and site maintenance.

F.7.3 Pretreatment plant operators

Pretreatment via greensand filtration is expected to introduce additional complexity to the municipal water supply system. Additional operators required to support the pretreatment plant were estimated based on the trend developed using the EPA Cost Model for GAC; see Figure F.16. Operator FTEs were estimated based on treatment plant capacity and rounded to the nearest half of an FTE. An FTE was based on 2,000 hours per year.

Figure F.23. Relationship between operators and capacity for PFAS treatment.



F.7.4 Pretreatment backwash water

The control of iron and manganese by oxidation and filtration requires backwash to remove the suspended solids collected by filtration media. The water consumed in this process represents an additional demand on water supply wells, and disposal of wastewater via the municipal wastewater treatment facility would result in sewer use charges.

The volume of water used for backwash and sewer use charges were estimated based on 5% of finished water demand as backwash. This backwash volume is equivalent to a 20-minute backwash at 15 gpm/ft^2 every 24 hours of operation, and represents rates prescribed by the Ten State Standards (2018). Sewer use rates were estimated to be $3.35 per 1,000 gallons based on Woodbury commercial utility rates. These sewer use rates represent the Metropolitan Council 2021 published wastewater charge of 2.47860 per 1,000 gallons, plus an additional 35% to operate and maintain the sewage collection systems at a municipal level.

Figure F.24 provides an example of the pretreatment capital and O&M cost calculations described above.

Figure F.24. Example pretreatment calculation.

East Metro MN Water System Project
Wood Environment & Infrastructure Solutions
Pretreatment Costs for Iron Removal **Date** May 5, 2021

Assumptions
Design hydraulic loading of 4 gpm/ft2, 10' pressure filter vessel treats up to 315 gpm
Redundancy based on N+1
Building size based on footprint vessel includes 4 ft clearance on front and back, 3 ft clearance on each side
Precast backwash surge tank quantity based on 1 per N=6 filters
150 ft of sewer line is required to reach the street, 100 ft of yard piping

Item No.	Item Description	Cost Basis and Year	Unit	Quantity	Unit Cost	Total Cost	Notes
Items require additional install and burdens							
1	Iron Removal Equipment	Evoqua PTI Series Multimedia Filter	EA	24	$235,000	$5,640,000	
2	Precast Backwash Equipment	2019	LS	4	$85,000	$340,000	
3	Backwash Discharge Sump Pumps	2019	LS	4	$13,000	$52,000	
Items carry install and burden cost in unit cost							
4	Building Costs	Costs per St. Paul Park GAC WTP, Mar 2019.	SF	6,912	$470	$3,248,640	incl. install & burden for equipment
5	6" DI Yard Piping	Cottage Grove Bid Tab No. N14.115258	LF	100	$48	$4,785	incl. install & burden
6	8" PVC Sewer Piping	Cottage Grove Bid Tab No. N14.115258	LF	150	$57	$8,552	incl. install & burden
					Equipment Only Subtotal - Iron Removal	**$6,032,000**	
					Equipment & Building Costs Subtotal - Iron Removal	**$9,293,977**	
				Installation Costs		$0	included in Item 4
				Project Burdens (Eng., Admin, Contractor Profit)		$0	included in Item 4
					Capital (Installed) Costs - Iron Removal	**$9,293,977**	
				Contingency	25%	$2,323,494	
					Capital Costs + Contingency - Iron Removal	**$11,617,471**	
					Avg. Captical Cost per Unit Capacity ($/gpm)	**$1,338**	

O&M

Item No.	Item Description	Cost Basis and Year	Unit	Quantity	Unit Cost	Total Cost	Notes
1	Backwash Water	5% of treated water as backwash at $3.35/1000 gal	EA	1	$3.35	$235,129	5% water as backwash
2	Building Costs	O&M at 5% of equipment cost	EA	1	5%	$464,699	O&M at 5% of equip. & bldg. capital
3	Operators	scaled based on capacity (FTE=0.00021*gpm+0.44)	EA	1.89824	$104,000	$197,417	FTE=0.00021*gpm+0.44
					Annual Operating Costs Subtotal - Iron Removal	**$897,245**	

Life Cycle Cost

Item No.	Item Description	Cost Basis and Year	Unit	Quantity	Unit Cost	Total Cost
	Captial (not including contingency)			1	$9,293,977	$9,293,977
	O&M			20	$897,245	$17,944,900
					Life Cycle Cost - Iron Removal	**$27,238,877**

Summmary of Design Criteria

Cost Basis and Year	Units	Value	Reference
Nameplate Design Capacity	gpm	6,944	design
Installed Capacity (with redundancy)	gpm	7,540	calculated
Hydraulic Loading	gpm/ft2	4	GLUMRB (2018) §4.3.2
Style of Filter Units		vertial side wall	GLUMRB (2018) §4.3.2
Filter Dimensions - Diameter	ft	10	design
Capacity per Filter	gpm	314	calculated
Number of Filter Units, with redundancy (N+1)	No.	24	calculated
Number of Backwash Surge Tanks (1 per N=6 filters)	No.	4	calculated
Footprint per vessel	ft2 / unit	288	calculated
Building Footprint	ft2	6,912	calculated
Water for Backwash	% of ADD	5%	design
Peaking Factor	-	2.6	design
Water for Backwash	gpm	134	calculated
Backwash Water	1000 gal/a	70,188	calculated
Backwash Water	gpm	134	calculated

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