Final Report

March 2026

Appendix C: Project 1007 Remedial Investigation Report

Project 1007 Feasibility Study
Minnesota Pollution Control Agency

MINNESOTA POLLUTION
CONTROL AGENCY

Prepared for:

Katy Bock
Minnesota Pollution Control Agency
520 Lafayette Road
Saint Paul, MN 55155

Prepared by:

AECOM
800 LaSalle Avenue, Suite 1100
Minneapolis, MN 55402
aecom.com

Quality Information

Prepared by	Prepared by	Prepared by
Hanna Temme Environmental Engineer	Ben Kroll Geologist	Josh Schultz Geologist

Verified by	Approved by
Daryl Beck Account Manager	Drew Tarara Project Manager

Minnesota Pollution Control Agency
520 Lafayette Road North | Saint Paul, MN 55155-4194 |
651-296-6300 | 800-657-3864 | Or use your preferred relay service. | Info.pca@state.mn.us
This report is available in alternative formats upon request, and online at www.pca.state.mn.us.
Document number: c-pfc1-27c

Contents

Figures

In-Text Tables

Attachments

Acronyms and Abbreviations

3M	3M Company
Abresch	Abresch Dump Site
AECOM	AECOM Technical Services, Inc.
AGWC	Anna's Grove Wetland Complex
amsl	above mean sea level
ATSDR	Agency for Toxic Substances and Disease Registry
Barr	Barr Engineering Co.
BERA	Baseline Ecological Risk Assessment
bgs	below ground surface
BS	beta site
CDWSP	Conceptual Drinking Water Supply Plan
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
Clean Harbors	Clean Harbors Environmental Services
CSM	conceptual site model
DHI	DHI Water & Environment, Inc.
DO	dissolved oxygen
EGLE	Michigan Department of Environment, Great Lakes, and Energy
EPA	U.S. Environmental Protection Agency
FEP	fluoroethylenepropylene
ft	feet
ft/d	feet per day
FS	Feasibility Study
GAC	granular activated carbon
Geoprobe	Geoprobe® Direct Push Drill Rig
gpm	gallons per minute
HBV	Health-Based Value
HDPE	high-density polyethylene
HFPO-DA	hexafluoropropylene oxide dimer acid
HI	Hazard Index
HRL	Health Risk Limit
HSA	Hollow Stem Auger
IAWC	Ideal Avenue Wetland Complex
IDW	investigation-derived waste
in	inches
Kh	horizontal hydraulic conductivity
LEPR	Lake Elmo Park Reserve
MCES	Metropolitan Council Environmental Services
MCL	Maximum Contaminant Level

MDEQ	Michigan Department of Environmental Quality
MDH	Minnesota Department of Health
MDNR	Minnesota Department of Natural Resources
MGS	Minnesota Geological Survey
MnDOT	Minnesota Department of Transportation
MPCA	Minnesota Pollution Control Agency
MS/MSD	matrix spike/matrix spike duplicate
MW	monitoring well
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
ng/L	nanograms per liter
ODS	Oakdale Disposal Site
ORP	oxidation-reduction potential
OW	observation well
PDC	Prairie du Chien
PFAS	per- and polyfluoroalkyl substances
PFBA	perfluorobutanoic acid
PFBS	perfluorobutane sulfonic acid
PFHxA	perfluorohexanoic acid
PFHxS	perfluorohexane sulfonic acid
PFOA	perfluorooctanoic acid
PFOS	perfluorooctane sulfonic acid
ppm	part per million
PTFE	polytetrafluoroethylene
PVC	polyvinyl chloride
PW	pumping well
PZ	piezometer
QA/QC	Quality Assurance/Quality Control
RI	Remedial Investigation
SAL	single aquifer location
SDSVs	site-specific sediment screening values
SML	surface microlayer
SOP	Standard Operating Procedure
SRV	Residential/Recreational Soil Reference Value
SSV	Swimming Screening Value
TOC	Total Organic Carbon
Traut	Traut Companies
ug/kg	micrograms per kilogram
USCS	Unified Soil Classification System
USGS	U.S. Geological Survey
VAP	vertical aquifer profile
VBWD	Valley Branch Watershed District

VOCs	volatile organic compounds
WC	Washington County
WCL	Washington County Landfill
WQC	Water Quality Criteria

1 Introduction

On behalf of the Minnesota Pollution Control Agency (MPCA), AECOM Technical Services, Inc. (AECOM) prepared this Remedial Investigation (RI) Report as required by the 2018 Agreement and Order (Settlement) between the State of Minnesota and the 3M Company (3M). Under the first and highest priority (Priority 1) of this Settlement, the MPCA and the Minnesota Department of Natural Resources (MDNR) use the Settlement funding to enhance the quality, quantity, and sustainability of drinking water for residents and businesses affected by per- and polyfluoroalkyl substances (PFAS) in the East Metropolitan Area. As of the publishing of this report, the Settlement includes the East Metropolitan Area communities of Afton, Baytown Township, Cottage Grove, Denmark Township, Grey Cloud Island, Hastings, Lake Elmo, Lakeland, Lakeland Shores, Maplewood, Newport, Oakdale, Prairie Island Indian Community, Saint Paul Park, West Lakeland Township, and Woodbury. The Settlement also requires that the MPCA conduct a source assessment, presented herein as the RI and Feasibility Study (FS) regarding the role of the Valley Branch Watershed District (VBWD) project known as Project 1007 in the transport and fate of PFAS in the environment. The RI is submitted as Appendix C of the FS.

Project 1007 is a flood relief project constructed in 1987 by the VBWD to prevent homes from flooding in the landlocked sub-watershed known as the Tri-Lakes area in Lake Elmo, MN, which includes Lake De Montreville, Lake Olson, and Lake Jane. The Project 1007 conveyance system directs water from the Tri-Lakes area to the St. Croix River and consists of a series of open channels, pipes, dams, storm sewers, and existing surface water bodies. The RI and FS study area (Site) includes the entire length of the Project 1007 conveyance system and the Project 1007 Corridor, which includes the adjacent areas hydraulically and/or hydrogeologically connected to the Project 1007 conveyance system (**Figure 1**).

The source assessment required by the Settlement (referred to as the RI) included an extensive hydrologic and hydrogeologic investigation of the Project 1007 conveyance system and the system of surface water bodies and groundwater aquifers that are adjacent to and hydraulically connected with Project 1007. Investigations and data collection were completed between August 2019 and October 2024. The RI was intended to assess the following:

- How the Project 1007 conveyance system interacts with the hydraulically complex surface water and groundwater systems in the area.
- How the Project 1007 conveyance system contributes to the movement of PFAS from known primary historical source areas of PFAS, including the Oakdale Disposal Site (ODS) and the Washington County Landfill (WCL).
- The movement of PFAS through preferential flow paths to areas downstream and/or downgradient of source areas.

PFAS migration from source areas has resulted in PFAS concentrations that exceed the Minnesota Department of Health (MDH) Health Risk Limits (HRLs) and Health-Based Values (HBVs) and U.S. Environmental Protection Agency (EPA) Maximum Contaminant Levels (MCLs) in private and municipal drinking water wells within the Site. As directed by Priority 1 of the Settlement, the content of this RI was used to inform the conclusions and recommendations provided in the FS. The FS, in turn, will be used to aid decision makers in selecting an appropriate remedy for the Site.

This RI is intended to support previous Settlement-related initiatives including the completion of the Conceptual Drinking Water Supply Plan (CDWSP) and the development of long-term Priority 1 goals. Long-term Priority 1 goals intended to be addressed by the FS include:

- Provide clean drinking water in sufficient supply to residents and businesses to meet current and future needs under changing conditions (e.g., climate variability and population growth) and the evolving health-based standards (such as updated MDH HBVs, HRLs, and Hazard Index [HI])
- Protect and maintain groundwater quality
- Minimize long-term cost burdens for affected communities

This RI was prepared in general accordance with the EPA documents Interim Final Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA (EPA, 1988). Threshold, balancing, and modifying FS criteria are in accordance with the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), Title 40 of the Code of Federal Regulations (CFR) Part 300.

2 Site Background

PFAS are man-made chemicals known to persist in the environment for long periods of time, which has earned them the informal moniker “forever chemicals.” Their stability is characteristic, and they are resistant to break down by both biological and non-biological processes. The 3M facility in Cottage Grove, MN, has produced commercial products containing PFAS since the early 1950s. Liquid and solid waste generated during the PFAS production process were disposed of at two historical locations, ODS and WCL, within the Site. Both disposal sites have current and historical connections to surface water and groundwater within the Project 1007 conveyance system, as well as hydraulic and/or hydrogeologic connections to the Project 1007 Corridor.

2.1 Project 1007

The Project 1007 conveyance system is a flood relief project constructed in 1987 by the VBWD to prevent homes from flooding in the landlocked Tri-Lakes sub-watershed in Lake Elmo, MN. The conveyance system, which consists of a series of open channels, pipes, dams, storm sewers, and existing surface water bodies, directs water from the Tri-Lakes area to the St. Croix River by providing a continuous hydrologic connection from the northwest to the southeast extent of the Site. The construction of the Project 1007 conveyance system altered the path and volume of surface water flowing through the Site.

Under normal flow conditions, the Project 1007 conveyance system (**Figure 2**) transports water as follows:

- Water is initially discharged from the Tri-Lakes to Raleigh Creek at Tablyn Park.
- Water is transported along Raleigh Creek into Eagle Point Lake.
- From Eagle Point Lake, water is discharged into a 22-inch diversion pipe at the Eagle Point Lake Dam. The diversion pipe runs along the lakebed of Lake Elmo and discharges water east of Lake Elmo.
- Water discharged from Eagle Point Lake via the diversion pipe combines with Lake Elmo outflow water, then continues eastward into Horseshoe Lake.
- From Horseshoe Lake, surface water is discharged through a series of pipes and channels towards the West Lakeland storage ponds.
- Surface water in the West Lakeland storage ponds and the connecting channels drains to the south where it enters a series of pipes and a single stormwater pond that run along the Minnesota Department of Transportation (MnDOT) Interstate-94 storm sewer system until the water discharges into the St. Croix River.

There is variability in these flow conditions depending on rainfall and snowmelt. **Figure 2** shows the Project 1007 conveyance system, connected surface water bodies that make up the Project 1007 Corridor, and surrounding surface water features. **Section 2.4** provides further details related to the major water bodies**.**

2.2 Oakdale Disposal Site

ODS is one of the two primary source areas of PFAS in the Project 1007 Corridor. Raleigh Creek begins near ODS and flows through the former disposal area. The operational footprint of ODS consisted of three disposal areas, Eberle Dump Site (approximately 2 acres), Brockman Dump Site (approximately 5 acres), and Abresch Dump Site (Abresch) (approximately 55 acres). From the mid-1940s until early 1960s, the three areas received PFAS-containing waste with the Abresch Dump Site receiving most of the waste. For the purposes of this report, ODS primarily refers to the Abresch Dump Site, which is further subdivided into four areas of focus, as presented on **Figure 3**: the North Area, Central Area, Isthmus Area, and Southeast Area. These focus areas are defined as follows:

- The North Area consists of the portion of the Site north of County Highway 14.
- The Central Area is bordered to the north by County Highway 14, to the east and southwest by wetlands, and to the west by Granada Avenue North.
- The Isthmus Area is the narrow strip of land, approximately 100 to 300 feet wide and bordered to the east and west by wetlands, that connects the Central Area to the Southeast Area.
- The Southeast Area is bordered to the northeast by wetlands, to the east by Hadley Avenue North, to the south by wetlands and the railroad, and to the west by wetlands.

Raleigh Creek flows through Abresch from the North Area, southward through the Central Area, then along the eastern edge of the Isthmus Area, until it exits Abresch from the Isthmus Area extending eastward toward Hadley Avenue North. The wetlands located throughout Abresch connect to Raleigh Creek to various extents depending on flow conditions.

Waste disposal methods at ODS included, but were not limited to, shallow burial of loose waste; trench burial of waste-containing drums, pails, and barrels; and open burning. Following the detection of volatile organic compounds (VOCs)-impacted shallow groundwater in the 1980s, portions of the disposal areas were excavated, contaminated bulk solids were transported offsite to 3M Chemolite for incineration, and 39 multi-aquifer wells were sealed (ATSDR, 2008). Excavated contaminated soils were aerated onsite for the removal of VOCs and then land-spread at Abresch. Additionally, approximately 1,000 tons of ash from the incineration of the removed bulk solid waste were returned to Abresch and land-spread. In 1985, a 12-well pump-out system was installed at Abresch to provide vertical gradient control and containment of VOCs.

In 2004, 3M notified the MPCA and MDH that PFAS-containing waste was disposed of at ODS, which resulted in the State requesting that 3M sample groundwater from wells at the site for PFAS (MPCA, 2008). The results of that sampling confirmed the presence of PFAS in the groundwater at Abresch and led to a broader effort to characterize the extent of the PFAS contamination in surface water, groundwater, and soil. On May 22, 2007, 3M entered into a Settlement Agreement and Consent Order with the MPCA to conduct further remedial investigation and response actions to address PFAS impacts. In 2008, as part of a remedial action response, the pump-out system was expanded to 20 wells to further control shallow contaminants at the site. The extracted water was treated with granular activated carbon (GAC) prior to discharge to the Metropolitan Council Environmental Services (MCES) sewer system. Additionally, approximately 28,000 cubic yards of soil were excavated from the North Area and disposed of offsite. The soil selected for removal, which was limited to a portion of the North Area, included all soils down to 4 feet below ground surface (bgs) with perfluorooctane sulfonic acid (PFOS) concentrations greater than 1 part per million (ppm) and selective removal of soils to the water table with PFOS concentrations greater than 6 ppm (Barr, 2022). **Figure 3** depicts the extent of the soil excavation conducted in the 1980s and the 2000s along with the approximate locations of land-spreading activities.

In 2010, the construction of a new groundwater treatment facility was completed, and the facility was connected to the expanded pump-out well network. Since 2011, annual site-wide PFAS groundwater and surface water sampling activities have been conducted at locations in and surrounding Abresch. In 2020 and 2021, 3M completed additional investigative activities including the installation of additional groundwater monitoring wells, surface water and sediment sampling, characterization of surface water flow and surface water to groundwater interaction, and geologic and hydrogeologic modeling. In December 2024, 3M submitted an updated ODS conceptual site model (CSM) to the MPCA (Barr, 2024).

PFAS-containing materials related to historical disposal were in direct contact with the surface and subsurface for over 50 years before PFAS-specific remedial actions began to address impacts in 2008. In 2008, PFAS impacts were documented beyond the Abresch boundaries toward the south and southwest in bedrock aquifers used for drinking water. Although the intent of the groundwater extraction remedial activities was to limit the offsite migration of PFAS impacts, a review of analytical and hydrogeologic data indicates two dominant PFAS migration pathways remain.

First, Raleigh Creek continues to flow intermittently through Abresch, exiting ODS at Hadley Avenue and flowing eastward toward the confluence with the Project 1007 conveyance system at Tablyn Park. PFAS analytical data for surface water collected from 2006 to 2025 indicate this surface water flow path is an ongoing and historical surface water PFAS migration pathway. The surface water flow path is also the source for groundwater impacts downstream of ODS via surface water to groundwater infiltration. Second, the existing groundwater extraction system is in the unconsolidated Quaternary Aquifer and does not capture PFAS-impacted groundwater in deeper bedrock aquifers. In 2024, the system consisted of 20 active pumping wells with an average combined pumping rate of approximately 62 gpm (Weston, 2026). A downward vertical gradient between the unconsolidated Quaternary Aquifer and the Platteville Formation has been observed in the Southeast Area of Abresch and in wells southwest of Abresch, suggesting incomplete hydraulic capture (Barr, 2024).

2.3 Washington County Landfill

The WCL is the second source of PFAS in the Project 1007 Corridor. WCL is located south of Lake Jane and west-northwest of Sunfish Lake. From 1971 to 1974, WCL accepted PFAS-containing waste from 3M, including wastewater treatment plant sludge, incinerator scrubber sludge/ash, and iron oxide sludge (ATSDR, 2008). The landfill was closed in 1975, and a clean soil cap was placed on the landfill. In 1981, VOCs and heavy metals were detected in groundwater monitoring wells located onsite and in nearby offsite domestic wells (ATSDR, 2008). This resulted in the installation of an onsite groundwater extraction and remediation system in 1983. The treatment system operated by extracting and spraying VOC-contaminated groundwater onto the surface of the landfill to volatilize the VOCs (ATSDR, 2008). Sprayed water infiltrating back into the ground created a mounding effect in the water table underneath the landfill, which may have influenced groundwater flow conditions and allowed the migration of PFAS-impacted water in all directions, including to the east toward adjacent surface water bodies. In 1988, under a permit issued by the VBWD for the purposes of gradient control, WCL began directly discharging untreated groundwater into Project 1007 via a stormwater sewer connection. Records indicate that the annual volume discharged ranged from 50 to 80 million gallons (ATSDR, 2008). As a result, PFAS-impacted waters from WCL were directly discharged to the Project 1007 conveyance system, contributing to PFAS impacts downstream. The piped connection was reportedly sealed off in 1995. **Figure 4** depicts the configuration of WCL and the historical connection to Project 1007.

In 2004, the MPCA and MDH learned that PFAS-containing waste had historically been disposed of at WCL, triggering the sampling of surface water, groundwater, surface sediment, and soil. In response to elevated PFAS concentrations in all sampled media, spray irrigator use ceased and extracted groundwater was discharged further south into an area of more permeable soils as an interim step. The movement of the discharge location reduced the mounding of the water table, allowing groundwater to return to normal flow conditions (MPCA, 2008). In 2012, reconstruction of the landfill with a triple-liner and a leachate collection and removal system was completed. Contaminated waste was removed prior to the triple-liner installation and then re-placed in the newly lined portion of the landfill, effectively containing the PFAS-containing waste onsite and preventing further infiltration to groundwater from PFAS-impacted media (URS, 2013). Some impacted soil may remain beneath the triple-liner, and PFAS impacts could possibly continue to migrate from these soils into the Quaternary and deeper aquifers beneath the landfill.

Recent groundwater sampling results indicate PFAS-impacted shallow groundwater exists in the subsurface below the former landfill footprint and continues to migrate southeast and east towards Sunfish Lake and Lake Elmo, both of which are groundwater-fed surface water bodies. Additionally, the presence of PFAS impacts in deeper aquifers east, south, and southeast of WCL suggests impacted shallow groundwater has migrated vertically into bedrock aquifers.

2.4 Major Waterbodies

2.4.1 Tri-Lakes

The Tri-Lakes, which refer to Lake De Montreville, Lake Olson, and Lake Jane, are hydrologically connected lakes fed by shallow groundwater. The approximate total surface area of the lakes is 400 acres, and the lakes are used predominantly for recreational purposes, including swimming, boating, and fishing. The surrounding area can be characterized as mostly residential use and limited agricultural use. Lake Jane is accessible to the public via a boat launch located on the southeastern edge of the lake, and Lake De Montreville is accessible to the public via a boat launch on the northwest side of the lake; there is no public boat access to Lake Olson.

The Tri-Lakes serve as the headwaters of the Project 1007 conveyance system, as shown on **Figure 2**. Lake Olson and Lake Jane have control structures to allow lake lowering operations in response to high precipitation or snowmelt runoff. The connection between the Tri-Lakes and Raleigh Creek via the Project 1007 conveyance system is referred to as the Tri-Lakes discharge. The Tri-Lakes discharge is piped south to an outlet north of 34th Street North, where it continues to the south passing through channels, small wetlands, and Beutel Pond until the confluence with Raleigh Creek at Tablyn Park. As previously mentioned, and shown on **Figure 4**, between 1988 and 1995, groundwater from WCL was directly discharged into the Project 1007 conveyance system near the corner of 37th Street North and Irwin Avenue North in Lake Elmo.

2.4.2 Sunfish Lake

Sunfish Lake is approximately 50 acres in size and is used primarily for recreational purposes, including canoeing, fishing, and swimming. Surrounding land use includes predominantly residential and public park properties with some agricultural land located on the southern margin of the lake. Though there are no public boat launches, the lake can be accessed by the public via Sunfish Lake Park. Residential properties border the lake to the north and northeast.

Sunfish Lake, located southeast of WCL as shown on **Figure 5**, is a groundwater-fed, landlocked lake. As an inferred flow-through lake, groundwater discharges to the lake on the north side, flows through the lake as surface water, and infiltrates from the lake back to the subsurface on the south side. Though the lake does not have a direct surface connection to the Project 1007 conveyance system, shallow groundwater that discharges into the lake on the northern margin of the lake is downgradient of WCL. Water infiltrating from Sunfish Lake to shallow groundwater likely flows south and discharges into Lake Elmo, which is immediately south of Sunfish Lake. **Figure 5** shows the surface water/groundwater interaction between WCL, Sunfish Lake, and Lake Elmo.

2.4.3 Raleigh Creek

Raleigh Creek is an intermittent stream that trends roughly west to east, beginning with its headwaters northwest of ODS and ending with its discharge into Eagle Point Lake. Raleigh Creek is a modified naturally occurring stream and its primary use within the Project 1007 system is to convey stormwater runoff. Its comparatively undeveloped environment provides habitat for urban wildlife. Land use around the creek includes commercial, residential, public, and undeveloped. **Figure 6** depicts Raleigh Creek and the key current and historical hydrologic features along the creek.

Raleigh Creek begins immediately northwest of ODS and then flows from west to east through a series of wetlands and ponds at ODS, as shown on **Figure 6**. After flowing through ODS, Raleigh Creek continues eastward through a series of ponded and stream channel–connected wetlands where interaction with shallow groundwater provides baseflow that typically results in perennial flow, except during winter months and drought conditions.

From ODS to 31st Street North, Raleigh Creek flows roughly west to east through three channelized wetland complexes referred to as the Upper Raleigh Creek Wetland Complexes and shown on **Figure 7**. The Upper Raleigh Creek Wetland Complexes likely experience groundwater-fed flow during periods of low flow and infiltrate surface water to shallow groundwater during periods of high flow. The Upper Raleigh Creek Wetland Complexes are all bordered by commercial properties and undeveloped land.

Downstream of the Upper Raleigh Creek Wetland Complexes, Raleigh Creek continues south-southeast through a primarily residential area with incised channels until it drains into a fourth ponded wetland complex located immediately west of Ideal Avenue, formerly referred to as Ideal Avenue Wetland Complex (IAWC) and currently referred to as Anna's Grove Wetland Complex (AGWC). AGWC comprises an inlet channel, two ponds, and an outlet channel. AGWC is bordered by residential properties to the west, north, and south. Prior to the development of residential properties around AGWC in the 1990s, water storage and ponding was generally confined to the southwest portion of the wetland complex. In the early 2000s, during reconstruction of Ideal Avenue, a culvert/flood control structure was installed at the outlet of AGWC above the wetland elevation. This increased water storage within AGWC and reduced downstream flooding. As a result, water does not flow downstream of AGWC except when water levels exceed the elevation of the culvert. The residential development along this portion of Raleigh Creek in conjunction with the construction of the flood control structures appears to have increased water storage in the wetland complex, allowing for the creation of two ponds that regularly hold water. The increase in water storage that occurs in AGWC during wet conditions likely facilitates increased infiltration from these ponds.

Downstream of AGWC, flow is generally absent of groundwater baseflow in Raleigh Creek from Ideal Avenue to Tablyn Park such that it can be classified as an ephemeral creek. This portion of Raleigh Creek typically contains flowing water following spring snowmelt and precipitation events. When flowing, this portion of the creek continues west to east until the confluence with the north to south flow path of the Tri-Lakes discharge carried by the Project 1007 conveyance system. As a result of the consistent flow from the Tri-Lakes discharge into the Project 1007 system, flow downstream of the confluence is more regular than in the intermittent portion of Raleigh Creek. This portion of Raleigh Creek, referred to as post-confluence Raleigh Creek, continues to the southeast towards the Lake Elmo Park Reserve (LEPR) where it flows into the northwestern inlet of Eagle Point Lake, as shown on **Figure 8**. The ephemeral portion of Raleigh Creek is bordered predominantly by residential properties, while post-confluence Raleigh Creek is bordered by residential properties and public park properties, including Tablyn Park and LEPR.

2.4.4 Eagle Point Lake

Eagle Point Lake is located within LEPR. The lake is accessible to the public and primarily used for canoeing, fishing, and other recreational shore-based activities. Eagle Point Lake is approximately 119 acres in size but can vary significantly depending on lake elevation given that lake levels are very responsive to precipitation (Barr, 2015). The edges, inlets, and outlet of Eagle Point Lake are predominantly shallow wetlands.

The primary surface water input to Eagle Point Lake is Post-Confluence Raleigh Creek, as shown on **Figure 8,** which is the combined flow of the Tri-Lakes discharge and Raleigh Creek and typically flows during spring and summer months. Another input to Eagle Point Lake is Farney Creek, which flows west to east and drains to the northwest inlet of Eagle Point Lake. Farney Creek is downstream of a constructed dam and is regularly dry because of its dependence on precipitation. Additionally, during periods of high surface water elevations, water from Goose Lake is pumped into the southeastern corner of Eagle Point Lake. Pumping is conducted to mitigate flooding on 10th Street North, which crosses through the northern portion of Goose Lake.

Surface water from Eagle Point Lake exits through a series of channels and small ponds on the eastern side of the lake via Eagle Point Lake Dam, as shown on **Figure 8**. At Eagle Point Lake Dam, a 22-inch-diameter pipe diverts outflow from Eagle Point Lake along the bottom of Lake Elmo before discharging into a channel immediately east of Lake Elmo Avenue N and south of 20th Street N. This drainage pathway was constructed as part of Project 1007 to improve water quality and control flooding in Lake Elmo. When water levels in Eagle Point Lake exceed an elevation of 896.5 feet above mean sea level (amsl), water flows through a secondary outlet structure that discharges directly into Lake Elmo. Prior to the construction of the Project 1007 conveyance system, Eagle Point Lake drained directly to Lake Elmo (Barr, 1986). **Figure 8** shows the hydrologic flow paths and relevant Project 1007 infrastructure associated with Eagle Point Lake.

In addition to the movement of surface water, Eagle Point Lake is an inferred flow-through lake, wherein shallow groundwater discharges into the lake on the north and west sides, flows through the lake as surface water, and infiltrates from the lake back to the subsurface on the south and east sides. The exact nature of groundwater discharge to Eagle Point Lake, including the volume of the groundwater discharge and the contributing aquifers, is not fully understood.

2.4.5 Lake Elmo

Most of Lake Elmo is located within LEPR. It has a total area of approximately 284 acres and a maximum recorded depth of 137 feet (Barr, 2015). Land use in the surrounding area consists of public property (western and southern lakeshores within LEPR) and private residential (northern and eastern lakeshores). Recreational activities at Lake Elmo primarily include canoeing, swimming, fishing, and boating, making it the most routinely accessed lake in the Project 1007 Corridor.

Upstream surface water flow into Lake Elmo occurs during high-flow conditions, when water from Eagle Point Lake flows through a secondary outlet structure at the Eagle Point Lake Dam, as shown on **Figure 8**. Like Eagle Point Lake, Lake Elmo is a flow-through lake wherein groundwater is discharged to the lake and surface water infiltrates from the lake into the subsurface.

Sunfish Lake, located upstream of Lake Elmo, and shown on **Figure 5**, is likely connected to Lake Elmo by shallow subsurface groundwater infiltration and subsequent shallow groundwater discharge. Lake Elmo is situated within a deep bedrock valley that facilitates a potential hydraulic connection between Lake Elmo surface water and deeper bedrock aquifers, including the Jordan Aquifer (Berg, 2019). The bedrock valley is discussed in greater detail in Section 2.5.2. Although the exact nature of the groundwater discharge to Lake Elmo is not fully understood, nearly constant outflow from Lake Elmo was recorded during extreme drought conditions in 1987 and 1988 and indicates that groundwater discharges to Lake Elmo (Barr, 2015). The combination of high conductivity of surficial sediments, an absent bedrock aquitard, and the fractured bedrock zone underlying and adjacent to the bedrock valley would allow for surface water infiltration from the lake into the Jordan Aquifer.

As described in Section 2.4.4, the Eagle Point Lake discharge pipe was constructed as part of the Project 1007 flood mitigation infrastructure project to reduce water levels and improve water quality in Lake Elmo. When water levels in Lake Elmo exceed an elevation of 896.5 feet amsl, water flows through a secondary outlet structure that discharges into a channel immediately east of Lake Elmo Avenue N alongside the 22-inch pipe discharge from Eagle Point Lake. The combined discharges then flow east-southeast through a series of channels, pipes, and small ponds and discharges into Horseshoe Lake (Barr, 1986). **Figures 5 and 8** show the hydrologic flow paths and relevant Project 1007 infrastructure associated with Lake Elmo.

2.4.6 Horseshoe Lake

Horseshoe Lake is in the City of Lake Elmo and West Lakeland Township and has a total area of approximately 76 acres. The land use of the surrounding western portion of the lake is predominantly characterized as private recreational land associated with a golf course, while the eastern portion is undeveloped (Barr, 2015).

The sole surface water input to Horseshoe Lake is the combined outflow of Eagle Point Lake and Lake Elmo, which flows east from Lake Elmo through a series of channels, piles, and golf course ponds before it discharges into Horseshoe Lake, as shown on **Figure 9**. Surface water exits Horseshoe Lake through a control structure installed at the northeastern lobe, which redirects flow through a series of pipes and channels to the southeast towards the West Lakeland Ponds (Barr, 1986). Horseshoe Lake has a control structure to allow lake lowering operations in response to high precipitation or snowmelt runoff. Prior to the construction of Project 1007, Horseshoe Lake received much less surface water input, and based on a review of historical imagery, the lobes were regularly disconnected water bodies during dry conditions. Following the completion of Project 1007, the lake holds water year-round and the outflow from the lake is continuous. The occurrence and nature of surface infiltration from the lake is not fully understood.

2.4.7 West Lakeland Ponds

The West Lakeland Ponds refers to three ponds located in West Lakeland, herein referred to as North Pond, Middle Pond, and South Pond. The three ponds have a combined area of approximately 26.8 acres and primarily serve water management and flood mitigation purposes. Of the three ponds, South Pond is the largest, as shown on **Figure 9**. The ponds are surrounded by residential properties and are used for recreational purposes, including canoeing (Barr, 2015).

A review of historical aerial imagery and VBWD records indicates these ponds held little to no water during average periods of precipitation prior to the completion of Project 1007 and were regularly dry, except for North Pond. North Pond was a gravel pit prior to its flooding (Barr, 2015). As part of the construction of Project 1007 in 1987, water from Eagle Point Lake, Lake Elmo, and Horseshoe Lake was directed via a series of pipes and channels to the West Lakeland Ponds (Barr, 1986). Additionally, the outlet from North Pond was deepened and widened, channels were constructed between the ponds, and the outlet from South Pond was connected to the MnDOT I-94 storm sewer system. Following the completion of Project 1007, the West Lakeland Ponds and their connecting channels served to control the inflow of runoff from Project 1007 and mitigate flooding risks in the area. Most of the sediment deposits resulting from surface runoff and erosion occur in the North Pond, reducing the infiltration capacity of that pond while the infiltration capacity of the Middle and South Ponds is preserved. According to a 1985 seepage study (Barr, 2015), the total seepage rate of the three ponds was measured between 3.5 and 5 cubic feet per second. Additionally, sinkholes have been reported by residents along the channel between the North and Middle Ponds (Barr, 2015). The high seepage rate of the ponds and the occurrence of sinkholes in their corresponding channels points to rapid surface water infiltration to the subsurface.

Currently, surface water flows north to south through the ponds and connecting channels before being piped eastward along I-94 towards the St. Croix River (Barr, 1986). Prior to Project 1007 construction, surface water in the West Lakeland Pond area flowed southward through a series of wetlands and streams, which ultimately drained to Lake Edith and the Valley Branch Creek System. **Figure 9** shows the hydrologic flow paths and relevant Project 1007 infrastructure associated with Horseshoe Lake and the West Lakeland Ponds. **Figure 10** depicts the Valley Branch Creek System and Lake Edith in relation to the Project 1007 flow path.

2.4.8 Other Disconnected Water Bodies

Several perched water bodies with no outlets to the surrounding watershed are present in the central portion of the Project 1007 Corridor. These water bodies include Goose Lake (except when manually discharged as described in Section 2.4.4), Margaret Lake, Downs Lake, Friedrich's Pond, Browns Pond, Legions Pond, and an unnamed pond in LEPR. Apart from pumping during flood events, these water bodies are not connected via surface water to the main Project 1007 flow path. The source of water in these water bodies is predominantly overland flow and discharge of shallow groundwater. **Figure 11** shows the locations of these water bodies in relation to the Project 1007 flow path.

Lake Edith and the Valley Branch Creek System are also disconnected from the Project 1007 Corridor but were historically connected to the discharge from Lake Elmo as described in Section 2.4.7.

There are several additional surface water bodies of interest that are not directly connected to the Project 1007 Corridor, as shown on **Figure 2**. The exact hydrologic nature of these surface water systems is not fully understood. The primary inputs to these water bodies are believed to be a combination of rainwater via overland flow and discharge of shallow unimpacted groundwater.

These water bodies were added to the sampling plan as part of the expansion of the Site, which occurred in 2021 and is described subsequently in Section 3.2.3. The water bodies include:

- Wetlands and ponds south and southwest of ODS – all predominantly intermittent water bodies located downgradient (but not downstream) of ODS
- Beaver Lake and Tanners Lake
- The Greenway Corridor Area – includes Armstrong Lake, Wilmes Lake, Markgrafs Lake, Colby Lake, and interconnected wetlands
- Battle Creek Lake – includes the connected downstream Battle Creek
- Carver Lake – includes downstream Fish Creek

2.5 Geology and Hydrogeology

A series of geological maps and cross-sections produced by the Minnesota Geological Survey (MGS) indicate that the geology of the East Metropolitan Area consists of Precambrian basement rock situated below Cambrian and Ordovician stratigraphy that are subsequently overlain by unconsolidated Quaternary glacial sediments, as presented in **Table 2.5** below, in stratigraphic order from youngest to oldest (MGS, 2016). These units are described in the following sections.

Table 2.5: Site Stratigraphy (Geologic Atlas of Washington County, 2016)

Symbol	System	Lithostratigraphic Unit		Description
Quat	Quaternary	Undifferentiated Units		Unconsolidated glacial and alluvial deposits vary in composition. Thickness varies from absent where bedrock outcrops to over 100 feet in filled bedrock valleys.
Od	Ordovician	Galena Group	Decorah Shale (aquitard)	Grayish-green shale interbedded with thin beds of fossiliferous limestone. The maximum preserved thickness is approximately 40 feet (ft).
Opvl		Platteville and Glenwood Formations	Platteville Limestone (aquifer)	Tan to gray fossiliferous limestone and dolostone. Commonly burrowed, mottled, and fossiliferous. Generally, 30 to 35 ft thick.
Ogwd			Glenwood Shale (aquitard)	Grayish-green to brownish-gray, sandy shale. Generally, 3 to 7 ft thick.
Os		St. Peter Sandstone	Upper St. Peter Sandstone, Tonti Member (aquifer)	White to tan, fine- to medium-grained, quartzose sandstone. Generally, 100 to 140 ft thick.
			Lower St. Peter Sandstone, Pigs Eye Member (aquitard)	White to gray feldspathic shale and siltstone interbedded with coarser-grained sandstone. Generally, 10 to 40 ft thick.
Ops		Prairie du Chien Group	Shakopee Dolostone with Sand (aquifer)	Light brown, thin- to medium-bedded dolostone, sandy dolostone, sandstone, and shale.
Opo			Oneota Dolostone (generally a vertical aquitard)	Yellowish-gray to light brown, medium to thick-bedded dolostone.
Cj	Cambrian	Jordan Sandstone (aquifer)		White to yellow, very fine- to coarse-grained, friable, quartz sandstone characterized by two coarsening-upward sequences consisting of two interlayered facies.
Cs		St. Lawrence Shale (aquitard)		Light gray to yellowish-gray and pale yellowish-green, dolomitic, feldspathic siltstone with interbedded, very fine-grained sandstone and shale. Generally, 35 to 45 ft thick.
Ctc		Tunnel City Group (aquifer)		Consists of two formations, the Mazomanie and the Lone Rock Formations. The Mazomanie is white to yellowish-gray, fine- to medium-grained, cross-stratified, friable, quartz sandstone. The Lone Rock underlies and intertongues with the Mazomanie. The Mazomanie is pale yellowish-green, very fine- to fine-grained glauconitic, feldspathic sandstone and siltstone with thin shale partings. The Tunnel City is generally 160 to 180 ft thick.
Cw		Wonewoc Sandstone (aquifer)		Light gray, fine- to coarse-grained, moderately to well sorted. The upper portion is the coarsest-grained and the unit gets progressively finer-grained toward the base. Generally, 45 to 75 ft thick.
Ce		Eau Claire Shale (aquitard)		Yellowish-gray to pale olive-gray, fine- to very fine-grained sandstone, siltstone, and shale. Ranges from 80 to 100 ft thick.
Cm		Mt. Simon Sandstone (aquifer)		Yellowish-brown to grayish-orange-pink to light gray, medium- to coarse-grained quartz sandstone. Interbedded shale, siltstone, and very fine-grained feldspathic sandstone are common. Thin quartz-pebble conglomerate is present throughout and is especially abundant near the base of the formation. Maximum thickness appears to be 280 ft.

2.5.1 Quaternary Geology and Hydrogeology

The Site is underlain by unconsolidated Quaternary-aged glacial and alluvial deposits of varying thickness.

Early Pleistocene glacial till in the Pierce Formation is intermittently present at the southern extent of the Site in the Woodbury area. It is characterized by well-compacted, yellowish-brown to dark gray loam with gravel and associated with relatively shallow depth to bedrock (within about 10 feet).

Late Pleistocene glacial till, outwash, and ice-walled lake plain deposits in the Cromwell Formation associated with the Superior lobe underly much of the Site. The glacial till consists of unsorted, reddish-brown to brown, gravelly loamy sand to gravelly sandy loam. It is typically 8 to 56 feet thick and found in hummocky topography. The glacial outwash consists of bedded sand, gravelly sand, and gravel in low hills typically found at lower elevations than the till. It can be over 100 feet thick in filled bedrock valleys. Ice-walled lake plain deposits consist of laminated fine-grained sand, silt, and clay plateaus that are as large as 1.5 miles in diameter and up to 60 feet higher in elevation than surrounding terrain. Large ice-walled lake plain deposits are found northeast of Lake Elmo and south of Horseshoe Lake.

Glaciofluvial terrace deposits associated with glacial St. Croix River consist of very coarse- to very fine-grained sand, mainly gravelly sand, and are present on the eastern edge of the Site. The modern alluvial sediment deposits of rivers and streambeds consist of very coarse- to very fine-grained sediments. These deposits are present along Raleigh Creek, Valley Branch Creek, and the modern St. Croix River. Modern lacustrine deposits consist of very fine-grained organic matter to organic-rich silty clays and sand. These deposits are found in and around the lakes and wetlands of the Site.

Groundwater flow within the surficial sediments generally follows surface topography.

2.5.2 Bedrock Geology and Hydrogeology

Encountered bedrock units are discussed in this section in stratigraphic order from shallowest to deepest. **Figure 12** shows the mapped extent of the first encountered bedrock units within the Site. Additionally, the hydrogeologic features of the St. Peter Tonti and Pigs Eye Members, the Prairie du Chien (PDC) Group, and the Jordan Aquifer are discussed in this section. The hydrogeologic characteristics of bedrock units vary significantly throughout the Project 1007 Corridor due to the presence and competency of overlying aquifers and aquitards, depth from first encountered bedrock, proximity to buried bedrock valleys (extent shown in **Figure 13**), position relative to the regional bedrock groundwater divide, and impact of the Cottage Grove Fault. The bedrock groundwater divides tend to be within relatively large areas of shallow gradient potentiometric surfaces. The potentiometric surfaces and the approximate location of groundwater divides for the Platteville Aquifer, St. Peter Aquifer, Shakopee Aquifer, and the Jordan Aquifer are shown on **Figures 14 through 17.**

2.5.2.1 Galena Group and Platteville and Glenwood Formations

The shallow-most bedrock formation, the Decorah Shale of the Galena Group, functions as an aquitard and is intermittently present, predominantly as erosional remnants in the western portion of the Site. Of note, the northern portion of ODS is underlain by the Decorah Aquitard, inhibiting vertical groundwater movement from the Quaternary aquifer(s). Once the Decorah Aquitard pinches out to the south near Radio Drive, the Quaternary units are hydrogeologically connected to the Platteville Limestone Aquifer. Continuing from west to east, the Platteville Aquifer is present throughout the western portion of the Site until the unit thins and pinches out roughly between Interstate-694 and Inwood Ave near AGWC. East of this pinch out, the Platteville and Glenwood formations are only intermittently present as erosional remnants. Based on review of available groundwater gauging data, groundwater flow within the Platteville Aquifer is dictated by the presence of a regional groundwater divide trending north to south roughly along the western edge of ODS. West of this divide, groundwater flows to the south-southwest, while east of the divide, groundwater flows to the east, as shown on **Figure 14**. The

Glenwood Shale Aquitard, which always underlies the Platteville Aquifer, acts as a barrier to vertical groundwater movement from shallow aquifers to underlying aquifers. As a result, groundwater east of the groundwater divide flows horizontally until the Platteville-Glenwood Formations pinch out, and vertical flow to the underlying St. Peter Sandstone Aquifer is uninhibited.

2.5.2.2 St. Peter Sandstone

The St. Peter Sandstone is subdivided into two members, the upper Tonti Member and the lower Pigs Eye Member. The Tonti Member behaves as an aquifer. The Pigs Eye Member, which is the lowermost 10 to 40 feet of the St. Peter Sandstone, is finer-grained and less permeable than the Tonti Member, and as result, is thought to behave like a vertical aquitard. However, leakage can occur through the Pigs Eye Member due to the presence of small fractures in the sandstone resulting in secondary porosity. Additionally, the function of the Pigs Eye Member as an aquitard is not consistent due to variation in lithology and proximity to the top of the bedrock surface, where increased fracturing is expected.

A groundwater divide within the St. Peter Aquifer trends roughly north to south along Ideal Avenue, resulting in horizontal groundwater flow west of the divide to the south-southwest and groundwater flow east of the divide to the east-southeast. Available groundwater gauging data indicates the potentiometric peak in the St. Peter Aquifer occurs immediately below the eastern edge of the Platteville Aquifer, as shown on **Figure 15**. According to the MGS, the pinch out of the Platteville Aquifer and underlying Glenwood Aquitard may result in a cascade of groundwater to flow downward into the St. Peter Aquifer, resulting in the observed potentiometric peak in this location (MGS, 2016). This secondary input of groundwater to the St. Peter Aquifer elevates the water table enough that groundwater flow is to the south-southeast, despite the relative dip of the geologic unit being to the west. Continuing eastward along the Project 1007 Corridor, the St. Peter Sandstone begins to pinch out in and around Eagle Point Lake, after which the unit is present intermittently and predominantly as erosional remnants. Thicker occurrences of the St. Peter Sandstone are present northeast and south of the Project 1007 Corridor.

2.5.2.3 Prairie du Chien Group

Underlying the St. Peter Sandstone is the PDC Group. The PDC Group comprises the Shakopee Formation, which is considered an aquifer, and the lower Oneota Dolostone, which is considered a vertical aquitard. The Oneota Aquitard can be heavily fractured and leaky. The extent to which the Oneota Aquitard functions as a barrier to the underlying Jordan Sandstone Aquifer is not well understood. Where the PDC Group is the first encountered bedrock, predominantly east of Eagle Point Lake, increased fracturing and transmissivity is expected in the Shakopee Aquifer. Where the Shakopee Aquifer is absent, the Oneota Aquitard is the first encountered bedrock and is expected to have enhanced fracturing. The absence of the Shakopee Aquifer is most prevalent along the shallow bedrock valley branch (**Figure 13**).

Groundwater in the PDC Group flows to the southwest on the west side of the regional groundwater divide and to the southeast on the east side of the regional groundwater divide, as shown on **Figure 16**. The groundwater divide trends from north to south just west of Eagle Point Lake. The PDC Group is present throughout the Site until the Cottage Grove Fault, where deeper formations are uplifted and the PDC has eroded away.

2.5.2.4 Jordan Sandstone

Underlying the Oneota Aquitard is the Jordan Sandstone, which is considered an aquifer. The Jordan Aquifer is present across the entire Site except east of the Cottage Grove Fault, where deeper formations are uplifted and the Jordan formation has been eroded away. The formation is the first encountered bedrock along the center of the deeper bedrock valley and in limited areas around the Cottage Grove Fault. The lowermost 20 feet of the Jordan Sandstone is described as grading into a very fine-grained sandstone with lenses of siltstone and shale, resulting in lower permeability and possible retardation of vertical flow.

Groundwater flow within the Jordan Aquifer is defined by a regional groundwater divide trending roughly north to south just west of Eagle Point Lake, as shown on **Figure 17**. West of the divide, groundwater flow is south-southwest-west, and east of the divide, flow is east-southeast. Based on available gauging data, groundwater within the Jordan Aquifer east of Lake Elmo appears to have an east-northeasterly flow direction.

2.5.2.5 Deeper Units

Underlying the Jordan Aquifer is the St. Lawrence Shale, which is considered a vertical aquitard. Though vertical leakage can occur through a formation via small fractures and secondary porosity, the St. Lawrence Aquitard generally has a much lower vertical hydraulic conductivity in comparison to the Oneota and St. Peter Pigs Eye Member Aquitards. As a result, the St Lawrence Aquitard likely inhibits most vertical groundwater movement from the overlying aquifers. Underlying the St. Lawrence Aquitard is the Tunnel City Group, which comprises the Mazomanie Formation (aquifer) and the Lone Rock Formation (aquitard). The Tunnel City Group is stratigraphically followed by the Wonewoc Sandstone Aquifer, the Eau Claire Shale Aquitard, and finally the Mt. Simon Sandstone Aquifer. Limited groundwater gauging data are available for aquifers stratigraphically below the Jordan Aquifer. However, the stratigraphic dips of the bedrock units suggest the presence of a north-to-south-trending groundwater divide roughly between Eagle Point Lake and Lake Elmo. Horizontal groundwater flow west of the divide is expected to be to the south-southwest, and east of the divide flow is expected to the east-southeast.

As with the Jordan Aquifer, these formations are not the first encountered bedrock at the Site until east of the Cottage Grove Fault where uplift occurred, exposing older units. Groundwater flow across the fault is not fully understood.

2.5.2.6 Buried Bedrock Valley

Lake Elmo is situated within a buried bedrock valley, which is mapped as trending roughly north to south through the center of the Site and with depths up to 400 feet bgs. The bedrock valley is a narrow, deeply incised paleochannel, which eroded through the PDC and most of the Jordan bedrock units and filled in with glacial and alluvial sediments. An additional shallow bedrock valley branch extends from the deeper bedrock valley at the southeastern edge of Lake Elmo toward Horseshoe Lake and then southward toward the West Lakeland Ponds. Both valleys play a key role in the surface and groundwater migration pathways as they expose deeper bedrock aquifers to surficial sediments and surface water bodies. **Figure 13** shows the approximate extents of the mapped bedrock valleys.

3 Field Investigations Completed

The source area assessment phase of the work, as required in the Settlement, consisted of a site-wide sampling effort of multiple media types. This assessment included surface water, foam formed on surface water, surface sediment, groundwater, and soil. To supplement the publicly available data from the existing network of monitoring locations in the surface and subsurface, AECOM identified and sampled from 165 unique surface sampling locations and completed the installation of 105 monitoring wells at the Site. Media sampling was paired with regular groundwater level measurements, regular surface water level and flow measurements, and aquifer parameter testing. The subsequent sections provide an overview of the rationale, sampling events, and methods employed to conduct surface water, sediment, groundwater, subsurface, and hydrologic and hydrogeologic field investigations.

3.1 Laboratory Analytical Methods

Samples were submitted to various laboratories throughout the investigation. This section summarizes the laboratory analytical methods used by each laboratory for each sampled media.

3.1.1 Non-PFAS Analytical Methods

Other non-PFAS analytical data were collected during this investigation including total dissolved solids, total suspended solids, turbidity, alkalinity, anions, metals, and sulfate. Additional analysis including VOCs, BOD, nitrate/nitrite, phosphorus, and pH were collected at the request of the VBWD. These were analyzed by Pace analytical. Besides total organic carbon (TOC) in sediment, these data were not used to develop the CSM as they do not correlate with the PFAS data and are not included in this report. TOC was analyzed by Pace analytical and is discussed further in this report.

3.1.2 QA/QC

Quality Assurance/Quality Control (QA/QC) samples were collected for validation purposes. These samples included duplicates (1 for every 10 samples collected), matrix spike/matrix spike duplicates (MS/MSDs) (1 for every 20 samples collected, and equipment rinsate blanks on equipment that came into direct contact with samples. All samples and equipment blanks were packed on ice and shipped to SGS AXYS in Sidney, British Columbia for analysis of 33 PFAS compounds (MLA-110 Method).

3.1.3 PFAS Analytical Methods

EPA Method 1633 was used for quantitative PFAS analysis of water, sediment, foam, and soil. Because the investigation spanned the development of EPA Method 1633, the method was originally called MLA-110 by SGS AXYS. MLA-110 became EPA Method 1633 in 2024. A majority of the samples collected were submitted to SGS AXYS, with the exception of samples collected in 2020, which were submitted to ALS Laboratories. The number of analytes included in the method expanded as the method was developed. Higher detection limits were occasionally observed, especially for foam samples, because dilution was required to quantify high PFAS concentrations. The lab also diluted high-turbidity aqueous samples.

3.2 Surface Water Investigations

Surface water bodies under investigation per the Settlement are located within an approximately 120-square-mile area across the cities of Oakdale, Woodbury, Lake Elmo, Afton, and West Lakeland Township. These cities are part of the Valley Branch, Ramsey-Washington Metro, Rice Creek, Browns Creek, and South Washington Watersheds. Thirty-four surface water sampling events were completed from August 2019 through October 2024, as detailed in the following sections. AECOM-collected surface water sample locations are shown on **Figures 18 through 22**.

Surface water sampling was completed to identify potential PFAS and other contaminants in surface water bodies within the Settlement area. One hundred thirty-eight unique surface water locations were sampled, which encompassed lakes, ponds, wetlands, streams, and stormwater channels. Select surface water sampling locations throughout the Project 1007 Corridor were repeatedly sampled, and sampling was completed seasonally to understand how various flow conditions might affect the concentrations of PFAS in surface water.

3.2.1 Surface Water Sampling Methods

Surface water sampling methods followed AECOM's Standard Operating Procedure (SOP) for Surface Water, Sediment, and Foam Sampling for PFAS (AECOM, 2020), which is included as **Attachment A-1**. This SOP follows the Michigan Department of Environmental Quality (MDEQ) and Michigan Department of Environment, Great Lakes, and Energy (EGLE) sampling guidance for surface water, sediment, and foam (MDEQ, 2018a; MDEQ, 2018b; MDEQ, 2018c; EGLE, 2019).

Surface water samples from streams were collected from the center of the stream channel (centroid of flow). A telescoping dipper was the preferred collection tool, and wading into the surface water body was necessary for some samples depending on the width of the stream. When personnel entered the water to collect a sample, they entered the water body downstream of the sample location to maintain sample integrity. All wetted equipment parts were PFAS-free materials without polytetrafluoroethylene (PTFE) and fluoroethylenepropylene (FEP). Personnel avoided water-resistant/fluorinated clothing, used powderless nitrile gloves, and followed PFAS-clean handling procedures per EPA/MPCA guidance. Bulk-water grabs were collected from the 0- to 6-inch interval below the water surface with a target of 3 inches below surface to avoid potential enrichment at the air–water interface; sampling depth and the presence/absence of foam were documented for each sample. In shallow (<6 inches) water, samples were collected as deep as practical below the surface while avoiding surface films. Sample forms are included as **Attachment B-1**.

During the 2019 baseline event and the winter 2020 quarterly event, described in subsequent sections, where an adequate water column was present in some lakes and larger ponds, an additional sample was collected from the 18- to 21-inch depth interval by submerging the sample bottle with the opening face down to approximately 19 to 20 inches. The bottle was then opened at depth and rotated so that it could fill before being lifted to the surface. Results from these sampling events indicated that PFAS concentration variation was not significant with depth, which is described further in Section 4.1.1. Therefore, there was no need for additional variable depth measurements. All subsequent surface water samples targeted the first 0 to 6 inches of the water column.

Where multiple open water samples from lakes and larger ponds were required to assess variation of PFAS within a single water body, the use of a boat was necessary for sample collection. For these locations, a small canoe or kayak was used to access the sampling location. Field personnel followed the same sampling procedure as for surface water samples by using a telescoping dipper over the side of the boat. The potential for sample contamination was reduced by paddling the boat by hand into the headwind, if present, and extending the telescoping dipper for sample collection in front of the path that the boat took.

Sampling locations from the network of storm sewers required access via a manhole cover. AECOM personnel attached a decontaminated stainless-steel bucket securely to a string, lowered the bucket into the opened manhole until it filled with water, then returned the bucket to the surface and transferred the water to sampling bottles.

3.2.2 Surface Water Sampling Events

This section describes the various types of surface water sampling events (baseline sampling, quarterly sampling, and trigger-event sampling) completed from August 2019 through October 2024. **Table 3.2.3** of Section 3.2.3 provides details including dates, areas of investigation, and number of samples collected for each sampling event.

3.2.2.1 2019 Baseline Sampling Event

The first step in developing the CSM was collecting baseline surface water data along the Project 1007 conveyance system and adjacent water bodies in the Project 1007 Corridor. This initial sampling event was referred to as the 2019 baseline sampling event. Sample locations included historically sampled surface water locations, previously unsampled inlet and outlet locations from water bodies along the flow path, and previously unsampled locations selected to provide sampling coverage along the entire Project 1007 conveyance system (AECOM, 2019a). Targeted water bodies included the Tri-Lakes (Lakes De Montreville, Olson, and Jane), the Tri-Lakes discharge, Raleigh Creek (Pre- and Post-Confluence), Eagle Point Lake, Lake Elmo, Horseshoe Lake, the West Lakeland Ponds and Channels, and the St. Croix River.

Surface water samples were collected between August 12 and August 15, 2019, from 34 discrete locations, as shown on **Figures 18 through 21**. Surface water samples were collected from the 0- to 3-inch depth interval. Where adequate water depth was available, an additional water sample was collected from the 18- to 21-inch depth interval. This additional sample was collected to assess PFAS concentration variation within the water column. The four St. Croix River samples were collected from the 18- to 21-inch depth interval.

On the second day of sampling (August 13, 2019), approximately 4 inches of rain fell across portions of the Valley Branch Watershed and thus increased flow within the Project 1007 conveyance system. As a result, the sampling plan was modified to include additional sampling from locations that had been dry prior to the rain event and resampling of locations with observed increased flow. A replicate sample was also collected from Post-Confluence Raleigh Creek to compare concentration variability when flow is present and absent across the intermittent portion of Pre-Confluence Raleigh Creek. Most locations in the 2019 baseline sampling event were sampled after the rainfall event. On November 21, 2019, two additional samples were collected along the channel downstream of the mixing of the Lake Elmo and Eagle Point Lake discharge pipes, corresponding with samples collected during the drilling of a well nest in the vicinity. One of these locations was already sampled during the August event and was resampled to compare with the further downstream location. Based on the results of the baseline sampling event, sampling locations were selected for subsequent sampling events considering observed changes in PFAS concentrations within the corridor. Each area of the corridor was included in subsequent sampling events as described below.

3.2.2.2 Routine Sampling Events

Following the 2019 baseline sampling event, sampling events typically fell into one of two categories: quarterly sampling and trigger-event sampling.

The locations sampled provided for an even geographical distribution of samples across the Site, and the timing of each sampling event was selected to develop an understanding of seasonal and meteorological effects on the hydrological conditions of the Site and the relation to PFAS migration. Additionally, where gaps in hydrologic or analytical data were identified, new locations were added to the sampling plan to better characterize the distribution, accumulation, and transport of PFAS across the Site. The surface water sampling typically spanned single, short-duration events that were not influenced by the Trigger-Event conditions described below.

Quarterly Sampling: Quarterly sampling events began in the winter of 2020. Quarterly sampling events monitored fluctuations in PFAS concentrations across seasons and over time and as such were scheduled for January (winter), April (spring), July (summer), and October (autumn). Following a review analytical data and continued development of the CSM, sample locations were added and adjusted to address gaps in data and changes in hydrologic conditions. Sample locations were also removed when seasonal variation was determined to be insignificant, the locations were deemed redundant, or when PFAS concentrations were relatively low. Additional sample locations were added in 2021 following the decision to expand the extent of the Site.

Trigger-Event Sampling: In addition to quarterly sampling, several sampling events were completed to assess fluctuations in PFAS concentrations in response to a trigger event. The following conditions were identified as a trigger event:

- Changed site hydrologic conditions, specifically as precipitation events with greater than 1 inch of rainfall over a 24-hour period or greater than 2 inches of rainfall in a 12-hour period.
- Observed flow in Pre-Confluence Raleigh Creek between Ideal Avenue and the confluence following a rain event. These flow conditions represent a surface water connection from ODS to the Project 1007 conveyance system via Raleigh Creek.
- Instances of rapid snowmelt.
- Extended periods of dry conditions.

The first trigger event targeted surface water locations that had visual changes in flow after a rainfall. Subsequent trigger events included additional surface water locations to assess all key water bodies within and adjacent to the Project 1007 Corridor. To further develop an understanding of surface water to groundwater connections, the trigger events were expanded to include shallow groundwater samples for the high-rain trigger event in August 2021 and the snowmelt trigger events in 2022 and 2023.

As with quarterly sampling, sample locations were added, removed, and moved to address gaps in data or when flow conditions restricted sampling. Surface water locations for the quarterly events and trigger events are depicted on **Figures 18 through 21**. **Figure 22** depicts the surface water locations added because of the expansion of the Site in summer 2021. The Site was expanded to assess surface water bodies outside of the Project 1007 Corridor to evaluate potential connections between PFAS-impacted groundwater and other surface water bodies and to identify potential additional sources within the Site.

3.2.3 Surface Water Sampling Summary

Table 3.2.3 summarizes the sampling plan for each quarterly and trigger event following the 2019 baseline sampling event through October 2024.

Table 3.2.3: Surface Water Sampling Events

Sampling Event	Date(s)	Areas of Investigation	No. of Locations
2019 Baseline Surface Sampling Event	8/12–15/2019; 11/21/2019	Tri-Lakes, Tri-Lakes Discharge, Pre- and Post-Confluence Raleigh Creek, Eagle Point Lake, Lake Elmo, Horseshoe Lake, West Lakeland, St. Croix River	56
2019 Baseline High-Rain Event	8/14/2019	Pre- and Post-Confluence Raleigh Creek, West Lakeland	17
Winter 2020 Quarterly Event	2/24–26/2020	Tri-Lakes Discharge, Pre- and Post-Confluence Raleigh Creek, Eagle Point Lake, Lake Elmo, Horseshoe Lake, West Lakeland, Valley Branch Creek	19
2020 Baseline Data-Gap Event	4/23–24/2020	Post-Confluence Raleigh Creek, Lake Elmo	2

Sampling Event	Date(s)	Areas of Investigation	No. of Locations
April 28–29, 2020 High-Rain Event	4/28–29/2020	Tri-Lakes Discharge, Pre- and Post-Confluence Raleigh Creek, Eagle Point Lake, Lake Elmo, Horseshoe Lake, West Lakeland, Valley Branch Creek	13
Spring 2020 Quarterly Event	5/4–14/2020	Sunfish Lake, Tri-Lakes Discharge, Pre- and Post-Confluence Raleigh Creek, Eagle Point Lake, Lake Elmo, Farney Creek, Brown's Pond, Goose Lake, Horseshoe Lake, West Lakeland, Valley Branch Creek	38
May 18, 2020 High-Rain Event	5/18/2020	Tri-Lakes Discharge, Pre- and Post-Confluence Raleigh Creek, Eagle Point Lake, Lake Elmo, Horseshoe Lake, West Lakeland, Valley Branch Creek	12
June 29, 2020 High-Rain Event	6/29–7/6/2020	Tri-Lakes Discharge, Pre- and Post-Confluence Raleigh Creek, Eagle Point Lake, Lake Elmo, Farney Creek, Goose Lake, Horseshoe Lake, West Lakeland, Valley Branch Creek	15
Summer 2020 Quarterly Event	7/28–31/2020	Sunfish Lake, Tri-Lakes Discharge, Pre- and Post-Confluence Raleigh Creek, Eagle Point Lake, Lake Elmo, Horseshoe Lake, Farney Creek, Friedrich's Pond, West Lakeland, Valley Branch Creek	30
August 26, 2020 Dry Event	8/26/2020	Tri-Lakes Discharge, Pre- and Post-Confluence Raleigh Creek, Eagle Point Lake, Lake Elmo, Horseshoe Lake, West Lakeland, Valley Branch Creek	12
September 1–4, 2020 Rain Event	9/1–4/2020	Tri-Lakes Discharge, Pre- and Post-Confluence Raleigh Creek, Eagle Point Lake, Lake Elmo, Legion Pond, Downs Lake, Horseshoe Lake, West Lakeland, Valley Branch Creek	15
Fall 2020 Quarterly Event	9/15–28/2020	Sunfish Lake, Tri-Lakes Discharge, Pre- and Post-Confluence Raleigh Creek, Eagle Point Lake, Lake Elmo, Brown's Pond, Horseshoe Lake, West Lakeland, Valley Branch Creek	50
Fall 2020 Coverage Event	10/8/2020; 10/13/2020; 11/18/2020	Stormwater Inputs to Raleigh Creek, Margaret Lake, Park Pond	6
Winter 2021 Quarterly Event	3/2/2021	Stormwater Inputs to Raleigh Creek, Pre-Confluence Raleigh Creek, Eagle Point Lake, Horseshoe Lake, West Lakeland, Valley Branch Creek	11
Spring 2021 Quarterly Event	4/16/2021	Sunfish Lake, Tri-Lakes Discharge, Pre- and Post-Confluence Raleigh Creek, Eagle Point Lake, Lake Elmo, Horseshoe Lake, West Lakeland, Valley Branch Creek	19
April 22, 2021 Disconnected Raleigh Creek Event	4/22/2021	Post-Confluence Raleigh Creek, Eagle Point Lake	3
Summer 2021 Quarterly Event	7/13–22/2021	Stormwater Inputs to Raleigh Creek, Sunfish Lake, Tri-Lakes Discharge, Pre- and Post-Confluence Raleigh Creek, Eagle Point Lake, Lake Elmo, Horseshoe Lake, West Lakeland, Valley Branch Creek, Disconnected Small	48

Sampling Event	Date(s)	Areas of Investigation	No. of Locations
		Water Bodies and Wetlands South-Southwest of ODS as a result of Site domain expansion, Beltline Interceptor, Beaver Lake, Tanners Lake, Greenway Corridor Area, Battle Creek Lake, Carver Lake	
August 30, 2021 Rain Event	8/30/2021	Stormwater Inputs to Raleigh Creek, Pre- and Post-Confluence Raleigh Creek, Eagle Point Lake, West Lakeland, Disconnected Small Water Bodies and Wetlands South-Southwest of ODS, Greenway Corridor Area	15
September 2021 BERA Addendum	9/21–24/2021; 9/27–28/2021	Raleigh Creek Wetland Complexes, Eagle Point Lake	13
Fall 2021 Quarterly Event	10/27–29/2021	Sunfish Lake, Pre-Confluence Raleigh Creek, Eagle Point Lake, Horseshoe Lake, West Lakeland, Valley Branch Creek, Disconnected Small Water Bodies and Wetlands South-Southwest of ODS, Beaver Lake, Tanners Lake, Greenway Corridor Area, Battle Creek Lake, Carver Lake	29
November 18, 2021 Eagle Point Lake Low Water-Level Event	11/18/2021	Eagle Point Lake	3
Winter 2022 Quarterly Event	1/26–28/2022	Eagle Point Lake, Lake Elmo, Horseshoe Lake	4
March 28–29, 2022 Snowmelt Event	3/28–29/2022	Pre-Confluence Raleigh Creek, Eagle Point Lake, Lake Elmo, Horseshoe Lake, Disconnected Small Water Bodies and Wetlands South-Southwest of ODS	14
Spring 2022 Quarterly Event	4/18–21/2022	Sunfish Lake, Pre-Confluence Raleigh Creek, Eagle Point Lake, Lake Elmo, Horseshoe Lake, West Lakeland, Disconnected Small Water Bodies and Wetlands South-Southwest of ODS	22
Summer 2022 Quarterly Event	7/18/2022	Sunfish Lake, Pre-Confluence Raleigh Creek, Eagle Point Lake, Lake Elmo, Horseshoe Lake, West Lakeland, Disconnected Small Water Bodies and Wetlands South-Southwest of ODS	18
Fall 2022 Quarterly Event	10/24–25/2022	Sunfish Lake, Pre-Confluence Raleigh Creek, Eagle Point Lake, Lake Elmo, Horseshoe Lake, West Lakeland, Disconnected Small Water Bodies and Wetlands South-Southwest of ODS	20
Winter 2023 Quarterly Event	1/25/2023	Eagle Point Lake, Beltline Interceptor Area, Horseshoe Lake, West Lakeland, Small Disconnected Water Bodies South-Southwest of ODS, Eagle Point Lake Outlet, Pre-Confluence Raleigh Creek	8
March 29–30, 2023 Snowmelt Event	3/29–30/2023	Pre-Confluence Raleigh Creek, Eagle Point Lake, Lake Elmo, Sunfish Lake, West Lakeland, Golf Course	11

Sampling Event	Date(s)	Areas of Investigation	No. of Locations
Spring 2023 Quarterly Event	4/19–24/2023	Pre-Confluence Raleigh Creek, Eagle Point Lake, Lake Elmo, Horseshoe Lake, Beltline Interceptor Area, Disconnected Small Water Bodies and Wetlands South-Southwest of ODS	17
Summer 2023 Quarterly Event	7/17/2023	Pre-Confluence Raleigh Creek, Eagle Point Lake, Lake Elmo, West Lakeland, Beltline Interceptor Area	12
Fall 2023 Quarterly Event	10/23/2023	Sunfish Lake, Pre-Confluence Raleigh Creek, Eagle Point Lake, Eagle Point Lake Outlet, Lake Elmo, West Lakeland, Small Disconnected Water Bodies and Wetlands South-Southwest of ODS, Beltline Interceptor Area	14
Winter 2024 Quarterly Event	01/24/2024	Lake Elmo and Eagle Point Lake Discharge, Battle Creek	3
Spring 2024 Quarterly Event	05/06–07/2024	Washington County Landfill, Pre-Confluence Raleigh Creek, West Lakeland, Lake Elmo and Eagle Point Lake Discharge, Small Disconnected Water Bodies and Wetlands South-Southwest of ODS, Battle Creek	11
Summer 2024 Quarterly Event	07/15–16/2024	Tri-Lakes, Washington County Landfill, Pre-Confluence Raleigh Creek, Eagle Point Lake, Lake Elmo and Eagle Point Lake Discharge, West Lakeland, Small Disconnected Water Bodies and Wetlands South-Southwest of ODS, Battle Creek	18
Fall 2024 Quarterly Event	10/14–15/2024	Tri-Lakes, Washington County Landfill, Pre-Confluence Raleigh Creek, Eagle Point Lake, Lake Elmo and Eagle Point Lake Discharge, West Lakeland, Small Disconnected Water Bodies and Wetlands South-Southwest of ODS, Battle Creek	18

Winter 2020 Quarterly Event: Nineteen surface water samples were collected from 19 discrete locations. Sampling locations were selected to target key water bodies within, and adjacent to, the Project 1007 Corridor. Access to sampling locations was limited by freezing conditions and lack of flow prior to snowmelt. The water bodies sampled include Raleigh Creek, the Tri-Lakes discharge, Eagle Point Lake, Lake Elmo, waterways downstream of mixing of Eagle Point Lake and the Lake Elmo discharge, Horseshoe Lake, the West Lakeland ponds and channels, and the Valley Branch Creek System. During this sampling event, surface water samples were also collected at locations where foam and surface microlayer (SML) samples were collected, as discussed in Section 3.3.

2020 Baseline Data-Gap Sediment Event: As part of the baseline data-gap sediment event, which is discussed in further detail in Section 3.4, three co-located surface water samples from two discrete locations were collected where foam and SML were sampled.

April 28 – 29, 2020 High-Rain Event: This sampling event was conducted following 24 hours of precipitation when approximately 0.75 inch of rain fell across the Project 1007 Corridor. Seventeen surface water samples were collected from 13 discrete locations. Four locations from Pre-Confluence and Post-Confluence Raleigh Creek were sampled a few hours after rainfall on April 28th and again approximately 24 hours after rainfall on April 29th to assess changes in PFAS concentrations immediately downstream of ODS along Raleigh Creek over time following precipitation. The nine other locations within the Project 1007 conveyance system were sampled only once, approximately 24 hours following rainfall, due to their locations downstream of ODS. One sample was collected from the Valley Branch Creek System to assess potential PFAS impacts.

Spring 2020 Quarterly Event: Thirty-eight surface water samples were collected from 38 discrete locations. Sampling locations were selected to target previously sampled key water bodies and expanded to include water bodies that were inaccessible in the previous quarterly event due to frozen conditions. Additional sample locations included channelized wetlands along the Tri-Lakes discharge, Pre-Confluence Raleigh Creek, the AGWC ponds, Sunfish Lake, Browns Pond, Farney Creek, Goose Lake, and additional portions of Eagle Point Lake, Lake Elmo, and the Valley Branch Creek System. During this sampling event, surface water samples were also collected at co-located foam and SML sample locations as discussed in Section 3.3.

May 18, 2020 High-Rain Event: Twelve surface water samples were collected from 12 discrete locations following 2 inches of rainfall over a 24-hour period. Based on a review of analytical data from the 2019 baseline surface sampling event (sampled 8/12/, 8/13, and 8/15), the number of sample locations from the West Lakeland Ponds was reduced due to redundancy and an additional location was added at the outlet of AGWC. The surface water sample from the Valley Branch Creek System was collected further downstream of its previous location because of the presence of foam. A foam sample was collected from the initial sample location in the Valley Branch Creek System, as described in Section 3.3.

June 29, 2020 High-Rain Event: Sixteen surface water samples were collected from 15 discrete locations following 4 inches of rainfall over a 24-hour period. Due to the generally site-wide high surface water levels, Goose Lake began to flood into portions of 10th Street North, which was remedied by pumping Goose Lake water into Eagle Point Lake during the first week of July 2020. To capture pre-pumping conditions, surface water samples were collected from Goose Lake and near the outlet of the discharge hose from Goose Lake in Eagle Point Lake. The latter location was sampled again once pumping began on July 6, 2020, to compare pre-pumping and post-pumping PFAS concentrations; a foam sample was also collected at this location once pumping began. Foam was observed in Farney Creek for the first time during this event, which prompted the collection of surface water and foam samples.

Summer 2020 Quarterly Event: Thirty surface water samples were collected from 30 discrete locations, primarily from previously sampled key water bodies. A review of analytical data from previous sampling events resulted in the removal of eight sampling locations due to redundancy of coverage. Additionally, Goose Lake and Brown's Pond were removed from the sampling plan due to low PFAS concentrations. First-time surface water samples were collected from the Tri-Lakes discharge upstream and downstream of the historical connection to the WCL discharge. In addition, co-located surface water and foam samples were collected from Friedrich's Pond prior to the pond being pumped into Eagle Point Lake to mitigate flooding.

August 26, 2020 Dry Event: Twelve surface water samples were collected from 12 discrete locations following nearly 2 months of no precipitation for comparison of high-flow to low-flow conditions.

September 1–4, 2020 Rain Event: Eighteen samples were collected from 13 discrete locations following 0.75 inch of rainfall over a 24-hour period. All 13 locations were sampled within 24 hours of the rainfall, and five locations were sampled again 72 hours later to assess the change in PFAS concentrations over time following a rain event. A second sampling location along Post-Confluence Raleigh Creek was added to better assess the change in PFAS concentrations along this stretch of Raleigh Creek in response to rain events.

Additional samples were collected from the Legion Pond and Downs Lake for the first time on September 4, 2020 to determine if they were impacted. This was completed at the request of MPCA based on concerns from residents.

Fall 2020 Quarterly Event: Twenty-seven surface water samples were collected from 27 discrete locations, primarily from previously sampled key water bodies. Brown's Pond was added back to the sampling plan to assess fluctuation in PFAS concentrations under low-flow conditions. The locations from the Tri-Lakes discharge added in the summer 2020 Quarterly Event were removed from the sampling plan due to low PFAS concentrations. Additionally, co-located surface water samples were collected where foam was sampled.

Concurrently with the fall 2020 Quarterly Event, additional surface water, sediment, foam, and ecological samples were collected as part of the 2020 Baseline Ecological Risk Assessment (BERA). The sampling plan and results of this investigation are summarized in the final report (AECOM, 2021a).

Fall 2020 Additional Samples: On October 8 and 13, 2020, seven surface water samples were collected from four discrete locations. The sampled locations were selected to assess potential additional PFAS inputs to Raleigh Creek at the request of MPCA. These were collected from ditches and manholes with stormwater that flows into Raleigh Creek immediately downgradient of the discharge from ODS via a ditch along Hadley Avenue. During the initial sampling attempt on October 8, one of the locations had no flow and could not be sampled. As a result, the four locations were resampled on October 13 following rainfall. Additionally, on November 18, 2020, first-time surface water samples were collected from Margaret Lake and an unnamed pond south of Margaret Lake. One sample was collected from each water body.

Winter 2021 Quarterly Event: Twelve surface water samples were collected from 12 discrete locations, primarily from previously sampled key water bodies. Access to the originally planned sampling locations was limited by freezing conditions and lack of flow prior to snowmelt. An additional sample was collected from a stormwater input to Raleigh Creek cross-stream of the outlet from ODS. New sampling locations were also added in the Valley Branch Creek System to assess any contribution resulting from groundwater discharge to the creek downstream of the Cottage Grove Fault. These locations were sampled over four quarters (Winter 2021, Spring 2021, Summer 2021, and Winter 2021) to support this groundwater discharge assessment.

Spring 2021 Quarterly Event: Nineteen surface water samples were collected from 19 discrete locations. Based on a review of analytical data from previous sampling events, the number of sampling locations was reduced, and the sampling frequency was reduced from quarterly to annually for several locations due to redundancy in coverage or a lack of observed seasonal fluctuation in PFAS concentrations. The sampling plan for surface quarterly sampling was limited to focus on seasonal variation in Pre-Confluence Raleigh Creek and the wetland complexes along the creek, Eagle Point Lake, and the West Lakeland Ponds. Additionally, sampling locations were included to monitor fluctuations in PFAS concentrations resulting from surface water to groundwater interactions, which were suspected to be influenced by seasonal factors. The Valley Branch Creek System was sampled to continue gathering data to assess any contribution resulting from groundwater discharge to the creek downstream of the Cottage Grove Fault.

April 22, 2021, Disconnected Raleigh Creek Event: On April 22, 2021, three surface water samples were collected from three locations from Post-Confluence Raleigh Creek and Eagle Point Lake to compare to those collected in the previous spring 2021 quarterly event. These locations, which were downstream of the confluence of Raleigh Creek and the Tri-Lakes discharge, were selected to evaluate variation in PFAS concentrations when Raleigh Creek is not connected to the rest of the Project 1007 Corridor.

Summer 2021 Quarterly Event: Forty-eight surface water samples were collected from 48 discrete locations. Of these, 24 discrete locations were sampled within the Project 1007 Corridor, adjacent waterbodies, and the Valley Branch Creek System. This sampling event included additional locations limited to annual sampling, including the previous sampled stormwater inputs to Raleigh Creek. Due to low-flow conditions, surface water samples were not collected from the westernmost Pre-Confluence Raleigh Creek location or along Raleigh Creek downstream of Ideal Avenue.

Prior to the summer 2021 quarterly event, the original Site area was expanded to address data gaps identified in the development of the surface water–groundwater model, specifically to better evaluate the southward movement of PFAS compounds in groundwater from the ODS and Eagle Point Lake areas. Given the importance of understanding any interactions between surface water and groundwater throughout the Site, the sampling plan was modified to include 24 additional surface water sample locations from water bodies in these new areas. Targeted waterways included the disconnected wetlands and ponds south and southwest of ODS, Beaver Lake, the Greenway Corridor Area, Tanners Lake, Battle Creek Lake, Carver Lake, and Fish Creek. The selected sampling locations consisted of previously sampled locations and inlets and outlets of key waterways. Some of the identified locations were dry at the time of attempted sampling because of low precipitation observed during Summer 2021.

August 30, 2021, Rain Event: Fifteen surface water samples were collected from 15 discrete locations following approximately 3 inches of rainfall in a 24-hour period. Following a review of the trigger-event data collected in 2020, surface water sampling within and adjacent to the Project 1007 Corridor was reduced to eight locations, which were selected to focus on areas of suspected infiltration. These included the wetlands along Raleigh Creek, Eagle Point Lake, and the West Lakeland ponds. This sampling event was the first trigger event that included the collection of shallow groundwater samples alongside each surface water sample.

Surface water locations, which were experiencing dry or low-flow conditions during the 2021 summer quarterly sampling event were revisited for sampling later on in the season during more typical flow conditions. The revisited locations included four surface water samples immediately south and southwest of ODS and one surface water sample from the Greenway Corridor area. Additionally, first-time sample locations included one surface water sample from a previously dry wetland complex northwest of Tanners Lake and one surface water sample from a stormwater input to Raleigh Creek.

September 2021 BERA Addendum: Surface water, sediment, foam, and ecological samples were collected within wetlands located in upper Raleigh Creek between September 21 and 24, 2021, and within wetlands located in Eagle Point Lake on September 27 and 18, 2021, as part of the 2021 BERA Addendum. The sampling plan and results of the investigation are summarized in the final report (AECOM, 2022a). Surface water, sediment, and foam analytical data from the investigation are also included in this RI.

Fall 2021 Quarterly Event: Twenty-nine surface water samples were collected from 29 discrete locations. Of these, 15 samples were within the Project 1007 Corridor and adjacent waterbodies, in addition to the Valley Branch Creek System. Continued review of analytical data from previous sampling events resulted in the further reduction of sampling frequency for select locations within the Project 1007 Corridor and adjacent water bodies due to a lack of observed seasonal fluctuation in PFAS concentrations.

November 18, 2021, Eagle Point Lake Low Water-Level Event: After observing elevated PFAS concentrations in several Eagle Point Lake samples collected during the 2021 ecological vegetation sampling event in support of the BERA Addendum, four surface water samples were collected from four discrete locations within Eagle Point Lake to assess variation in PFAS concentrations throughout the lake during low water-level conditions. Two foam samples were also collected from the southeastern portion of the lake.

Winter 2022 Quarterly Event: In January 2022, access to surface water sample locations was significantly limited by freezing conditions and lack of flow. As a result, only four surface water samples were collected: one sample each from the Lake Elmo and Eagle Point Lake discharge pipes, one sample from the combined flow of the discharge pipes, and one sample from the discharge outlet of Horseshoe Lake. Locations in the Valley Branch Creek System were removed from the sampling plan due to low PFAS concentrations and no observed seasonal fluctuations.

March 28–29, 2022, Snowmelt Event: Fourteen surface water samples were collected from 14 discrete locations following spring snowmelt. Sampled locations included Raleigh Creek, Eagle Point Lake, the discharges from Eagle Point Lake and Lake Elmo, and Horseshoe Lake. As part of the expanded sampling, the wetlands and channels south and southwest of ODS were sampled to assess high-flow conditions. First-time surface water and co-located foam samples were collected from Battle Creek. Similar to the August 30, 2021, high-rain event, the primary objective of sampling in the Project 1007 Corridor and adjacent water bodies was to evaluate surface water–groundwater interactions, supplemented by collecting select shallow groundwater samples.

Spring 2022 Quarterly Event: Thirty-two surface water samples were collected from 28 discrete locations. Twenty-six samples at 22 locations were within the Project 1007 Corridor and adjacent waterbodies. To better understand the observed variation of PFAS concentrations in Eagle Point Lake, sampling of Eagle Point Lake was expanded to include seven portions of the lake: the inlet, the outlet, the center, the eastern lobe, the southeastern lobe, the southwestern lobe, and the western edge. These locations also included four samples collected at varying distances in Eagle Point Lake from the shoreline to assess the influence of wave action on PFAS concentrations in the littoral zone. Six locations, including a new location from Battle Creek, were sampled from the expanded portion of the Site. Foam was also observed and sampled from Battle Creek.

Summer 2022 Quarterly Event: Twenty-four surface water samples were collected from 20 discrete locations. Nineteen samples at 15 locations were within the Project 1007 Corridor and adjacent waterbodies, including four samples at varying distances from the Eagle Point Lake shoreline. Five locations were sampled from the expanded portion of the Site. As a result of low-flow conditions, samples were not collected from three locations: the western-most portion of Pre-Confluence Raleigh Creek, Pre-Confluence Raleigh Creek downstream of Ideal Avenue, or the wetland complex in the beltline interceptor area.

Fall 2022 Quarterly Event: Twenty-six surface water samples were collected from 22 discrete locations. Twenty samples at 16 locations were within the Project 1007 Corridor and adjacent waterbodies, including four samples at varying distances from the Eagle Point Lake shoreline. Six locations were sampled from the expanded portion of the Site. Due to low-flow conditions, a sample was not collected from Pre-Confluence Raleigh Creek downstream of Ideal Avenue.

Winter 2023 Quarterly Event: Eight surface water samples were collected from eight discrete locations, all of which were previously sampled key water bodies. Access to sampling locations was limited by freezing conditions and lack of flow prior to snowmelt.

March 29–30, 2023 Snowmelt Event: Thirteen surface water samples were collected from 11 discrete locations following the spring snowmelt. Sampled locations included Lake Jane, Sunfish Lake, Raleigh Creek, Eagle Point Lake, the discharges from Eagle Point Lake and Lake Elmo, Horseshoe Lake, and the West Lakeland ponds. The primary goal of this event was to assess surface water to groundwater interaction with select surface water samples being paired with shallow groundwater samples.

Spring 2023 Quarterly Event: Twenty-one surface water samples were collected from 17 discrete locations. Sixteen samples at 12 locations were within the Project 1007 Corridor and adjacent waterbodies. As part of the effort to better understand the behavior of PFAS during a rain event, four of these locations were sampled the week prior to the main sampling event on April 19th and 21st during rain events. Two locations were along Raleigh Creek, one location was from Eagle Point Lake, and one location was from the discharge outlet of Horseshoe Lake. Five additional locations were sampled from the expanded portion of the Site.

Summer 2023 Quarterly Event: Twelve surface water samples were collected from 12 discrete locations. Eight locations were within the Project 1007 Corridor and adjacent waterbodies, and four locations were from the expanded portion of the Site.

Fall 2023 Quarterly Event: Seventeen surface water samples were collected from 14 discrete locations. Twelve samples were collected from within the Project 1007 Corridor and adjacent water bodies, and five samples were collected from the expanded portion of the Site.

Winter 2024 Quarterly Event: Six surface water samples were collected from three discrete locations. Three samples were collected from within the Project 1007 Corridor and adjacent water bodies, and three samples were collected from the expanded portion of the Site. Access to sample locations was limited by freezing conditions and lack of flow prior to snowmelt.

Spring 2024 Quarterly Event: Fourteen surface water samples were collected from 11 discrete locations. Eight samples were collected from within the Project 1007 Corridor and adjacent water bodies, including two new pond sample locations at WCL. Six samples were collected from the expanded portion of the Site.

Summer 2024 Quarterly Event: Twenty-two surface water samples were collected from 18 discrete locations. Sixteen samples were collected from within the Project 1007 Corridor and adjacent water bodies, including five sample locations at WCL. Six samples were collected from the expanded portion of the Site.

Fall 2024 Quarterly Event: Twenty-two surface water samples were collected from 18 discrete locations. Seventeen samples were collected from within the Project 1007 Corridor and adjacent water bodies, including five sample locations at WCL. Five samples were collected from the expanded portion of the Site.

3.3 Foam and Surface Microlayer Investigations

Foam forms on surface water in nature regardless of the presence of PFAS; however, when PFAS is present in surface water and foam forms, foam concentrates PFAS. For foam to form in water, there must be a substance (i.e., surfactant) dissolved in the water that reduces the surface tension and turbulent flow that introduces air bubbles into the water. Turbulence in water can be caused by wave action or water flowing over rocks, trees, or other debris found in water bodies. PFAS is a surfactant that tends to accumulate at the air-surface boundary, or SML, because of the competing nature of the compound's hydrophobic tail, which prefers air, and hydrophilic head group, which prefers water. Foam readily forms as water turbulence allows air bubbles to be injected into the SML. The bubbles aggregate together and into large foam piles given the proper conditions. Large foam piles only form if there is a solid substrate in calmer water upon which the foam can accumulate, such as a bank, debris in a channel, or cattails. If the flow rate in a stream is too fast and there is not a suitable accumulation location, foam will condense back into the water column. If foam does accumulate due to the presence of PFAS, foam can be further enriched in other organic hydrophobic chemicals, as these chemicals will also preferentially diffuse into the foam from the SML. As a result, PFAS-containing foam can have significantly higher concentrations of PFAS compounds than the corresponding water column, making foam a unique exposure pathway of PFAS to human receptors.

Naturally occurring compounds found in shoreline plants and organic matter from sediment can also act as surfactants, facilitating the formation of foam in the same manner as previously described. Foam observed in the Project 1007 Corridor, including in the water bodies not associated with the direct Project 1007 flow path, were analyzed for PFAS.

Foam and SML samples were collected at 27 and six locations, respectively, between August 2019 and March 2022, as detailed in the following sections. These locations included the Pre- and Post-Confluence Raleigh Creek, Horseshoe Lake, Tri-Lakes Discharge, Valley Branch Creek, Lake Elmo, Sunfish Lake, West Lakeland, Farney Creek, Goose Lake, Eagle Point Lake (at discharge from Goose Lake), Friedrich's Pond, and the combined discharge of Lake Elmo and Eagle Point Lake, depicted on **Figure 25**.

3.3.1 Foam and Surface Microlayer Sampling Rationale

Foam samples were collected to confirm the presence of PFAS impacts in observed foam on surface water throughout the Project 1007 Corridor and to assess what relationship, if any, exists between PFAS concentrations in foam and the foam or water body type. In most cases, AECOM collected corresponding surface water samples with foam samples to assess the enrichment of PFAS compounds in foam. Additionally, select SML samples were collected in conjunction with foam samples when conditions allowed. The SML was sampled from different water bodies across the Site to assess the role, if any, it plays in hosting and transporting significant concentrations of PFAS in the water column.

Foam samples were collected to indicate potential sources and pathways (via preferential partitioning to the air-water interface) and to screen exposure potential. Foam data were not used for regulatory compliance comparisons because no numeric regulatory criteria exist for PFAS in foam.

3.3.2 Foam and Surface Microlayer Sampling Methods

3.3.2.1 Foam Sampling Methods

Foam sampling methods followed the SOP for Surface Water, Sediment, and Foam Sampling for PFAS developed by AECOM (AECOM, 2020), which is included as **Attachment A-1**. This SOP follows the MDEQ and EGLE sampling guidance for surface water, sediment, and foam (MDEQ, 2018a; MDEQ, 2018b; MDEQ, 2018c; EGLE, 2019).

Foam was sampled either by using a newly gloved hand to scoop the foam into a sealable plastic bag or with a modified pool skimmer to remove the foam from the water surface. The modified pool skimmer method was only used if it was not feasible to safely collect a foam sample using a gloved hand, given that the modified pool skimmer method is more likely to inadvertently collect the surface water directly below the foam. The skimmer was constructed by replacing the net of a pool skimmer with a single layer of cheesecloth, which was affixed to the pool skimmer with new zip ties. The cheesecloth net was then used to skim the foam off the surface of the water. The cheesecloth and zip ties were replaced for each new sample collected.

In both collection methods as much foam as possible was removed from the water surface without also collecting the water directly below the foam to ensure surface water did not dilute the foam sample. The foam was then placed in a one- or two-gallon sealable plastic bag depending on the quantity of accumulated foam. To account for variation of PFAS concentrations within a pile of foam, the entire foam pile was collected and allowed to condense as a single sample. The properties of foam collected, including the height of accumulated foam pile, color, and behavior in response to the collection (e.g., rate of re-accumulation), were documented on the field forms. The location of the foam relative to the waterbody, any indicators of how the foam was generated, and any other media contained within the foam were also documented on the field forms, which are provided in **Attachment B-1.**

After the foam was collected and bagged, the plastic bag was placed on ice for at least 24 hours to allow the foam to completely liquefy before being transferred to a laboratory-provided sample bottle. Gloves were disposed of properly after foam was bagged. New gloves were donned prior to each sample collection in the field and prior to transferring from plastic bag to sample bottle.

3.3.2.2 Surface Microlayer Sampling Methods

SML samples were collected using the glass plate method as described by Battelle (Battelle, 2018). The glass plate method entails dipping a glass plate affixed securely to a handle into the targeted surface water body. The physical properties of glass allow the SML to adhere to the surface of the plate. To ensure a representative sample, the glass plate was submerged by AECOM field personnel to the same pre-determined depth with each dip, withdrawn from the water at the same approximate rate, and held above the water vertically to allow water not adhered to the plate to drain. Once dripping from the plate stopped, a rubber squeegee blade tool was used to wipe the plate on either side to remove the SML sample from the plate while a second AECOM field personnel member collected the removed SML into a laboratory-provided sample bottle. This was repeated until sufficient volume was collected.

3.3.3 Foam and Surface Microlayer Sampling Events

This section summarizes the foam and SML sampling events completed between August 2019 through March 2022 that occurred in line with the quarterly sampling and trigger-event sampling for surface water (described in Section 3.2.3). SML sampling locations were selected from across the Project 1007 Corridor based on previous observations of foam. Foam and SML sampling events concluded in March 2022 under direction of MPCA as sufficient data had been collected. **Table 3.3.3** summarizes the dates, areas of investigation, and number of samples collected for each sampling event. Scanned field forms documenting site and hydrologic conditions at the time of each foam and SML sample collection are included on the surface water sampling field forms (**Attachment B-1)**. After March 2022, foam samples collection ceased because MPCA determined sufficient foam samples had been collected to assess the potential human health hazards and determine the potential range of PFAS concentrations.

2019 Baseline Surface Sampling and High-Rain Events: Five foam samples were collected from four unique locations. Prior to the rain event, foam was observed and collected along Pre-Confluence Raleigh Creek. Following the rain event, this location was resampled for foam due to an increase in observed foam accumulation. Foam samples were also collected from three additional locations along Pre- and Post- Confluence Raleigh Creek.

Winter 2020 Quarterly Event: Four foam and two SML samples were collected from six unique locations. Foam was collected from three locations along Pre- and Post-Confluence Raleigh Creek. A fourth foam sample was collected at the discharge outlet of Horseshoe Lake. Additionally, the SML was sampled at two locations: Post-Confluence Raleigh Creek and the channel downstream of North Pond.

Spring 2020 Foam Event: On April 7, 2020, two foam samples were collected from the Valley Branch Creek System, and one foam sample was collected from the Tri-Lakes discharge. The three locations were sampled for foam for the first time.

2020 Baseline Sediment Data-Gap Event: As part of the baseline data-gap sediment event, which is discussed in further detail in Section 3.4, two foam samples and one SML sample were collected. Foam was observed for the first time along the western shore of Lake Elmo adjacent to the canoe launch. Foam and SML samples were collected alongside corresponding surface water and sediment samples. A repeat foam sample was also collected from Post-Confluence Raleigh Creek for comparison against the sample collected there during the Winter 2020 Quarterly Event.

April 28–29, 2020, High-Rain Event: A repeat foam sample was collected from Pre-Confluence Raleigh Creek for comparison against samples collected during the 2019 high-rain event and 2020 baseline sediment data-gap event.

Spring 2020 Quarterly Event: Foam samples were collected for the first time from Sunfish Lake and from the channel downstream of Middle Pond. Additionally, foam samples were collected from Post-Confluence Raleigh Creek and Lake Elmo. The foam sample from Post-Confluence Raleigh Creek, which was co-located with a SML sample, was collected from a portion of the creek not previously sampled. The Lake Elmo foam sample was collected because of the foam's proximity to a boat launch, which is just north of the canoe launch.

A repeat SML sample was collected from the channel downstream of North Pond to compare against the previously collected SML sample in the winter 2020 quarterly event. Finally, two SML samples not associated with co-located foam samples were collected from Lake Elmo. The first location was immediately downstream of the secondary outlet structure from Eagle Point Lake, and the second location was at the northern shore of the lake.

June 29, 2020, High-Rain Event: Foam was observed and sampled for the first time from Goose Lake. As a result of the high water levels from this and previous high-rain events, Goose Lake began to flood along portions of 10th Street North. In response, the local municipality pumped water from Goose Lake into Eagle Point Lake during the first week of July 2020. The high rate of pumping from Goose Lake into Eagle Point Lake facilitated the generation and accumulation of a substantial amount of foam at the outlet of the discharge hose, which was collected and sampled.

Foam was also observed and sampled for the first time from Farney Creek. During the subsequent 2020 targeted wetland and focus area event completed in August of 2020, and discussed further in Section 3.4.3, a co-located sediment sample was collected where the foam was previously observed.

Summer 2020 Quarterly Event: Two foam samples were collected for the first time from Friedrich's Pond and the channel downstream of the combined discharge of Lake Elmo and Eagle Point Lake. Additionally, a repeat foam sample was collected from Post-Confluence Raleigh Creek because this was the first observation of foam when flow in Raleigh Creek was connected to the confluence.

Fall 2020 Quarterly Event: Repeat foam samples were collected from the following locations: along Pre-Confluence Raleigh Creek, at the discharge outlet of Horseshoe Lake, and along Valley Branch Creek. These three samples were collected for comparison against samples collected during the winter 2020 quarterly event or spring 2020 foam event.

September 2021 Ecological Vegetation Sampling Event: Three foam samples were collected from Pre-Confluence Raleigh Creek during the Ecological Vegetation Sampling Event. Foam samples were collected if foam was observed in the vicinity of the vegetation samples.

November 18, 2021, Eagle Point Lake Low Water-Level Event: During the surface water sampling event assessing low water-level conditions of Eagle Point Lake, foam was observed for the first time along the southeastern shoreline of the lake. As much of the foam was frozen due to low air temperatures, two separate foam samples were collected, one that was largely frozen and another that appeared to be freshly accumulated and not yet frozen.

March 28–29, 2022 Snowmelt Event: Foam was observed for the first time from Battle Creek. One foam sample was collected.

Other Foam Samples: Three foam samples were collected along Pre-Confluence Raleigh Creek as part of the 2021 BERA. The sampling plan and results of this investigation are summarized in the final report (AECOM, 2021a)**.**

Table 3.3.3: Foam and SML Sampling Events

Sampling Event	Area(s) of Investigation	No. of Foam Samples	No. of SML Samples	Co-Located Sampled Media
2019 Baseline Surface Sampling Event	Pre-Confluence Raleigh Creek	1	0	Surface Water
2019 Baseline High-Rain Event	Pre- and Post-Confluence Raleigh Creek	4	0	Surface Water
Winter 2020 Quarterly Event	Pre- and Post-Confluence Raleigh Creek, Horseshoe Lake	4	2	Surface Water
Spring 2020 Foam Event	Tri-Lakes Discharge, Valley Branch Creek	3	0	N/A
2020 Baseline Data-Gap Event	Post-Confluence Raleigh Creek, Lake Elmo	2	1	Surface Water and Sediment
April 28-29, 2020 High-Rain Event	Pre-Confluence Raleigh Creek	1	0	Surface Water

Sampling Event	Area(s) of Investigation	No. of Foam Samples	No. of SML Samples	Co-Located Sampled Media
Spring 2020 Quarterly Event	Sunfish Lake, Post-Confluence Raleigh Creek, Lake Elmo, West Lakeland	4	4	Surface Water
June 29, 2020 High-Rain Event	Farney Creek, Goose Lake, Eagle Point Lake (at discharge from Goose Lake)	3	0	Surface Water and Sediment
Summer 2020 Quarterly Event	Friedrich's Pond, Post-Confluence Raleigh Creek, Combined Discharge of Lake Elmo and Eagle Point Lake	3	0	Surface Water
Fall 2020 Quarterly Event	Pre-Confluence Raleigh Creek, Horseshoe Lake, Valley Branch Creek	3	0	Surface Water
September 2021 BERA Addendum	Raleigh Creek Wetland Confluences	3	0	Surface Water, Sediment, Vegetation
November 18, 2021 Eagle Point Lake Low Water-Level Event	Eagle Point Lake	2	0	Surface Water
March 28-29, 2022 Snowmelt Event	Battle Creek	1	0	Surface Water

Notes:
Sample count does not include QA/QC samples.
The co-located sediment sample from the June 29, 2020, high-rain event was collected in August 2020.

3.4 Sediment Investigations

Sediment sampling and investigations were completed to assess the magnitude and extent of PFAS-impacted sediments throughout the Project 1007 Corridor and at targeted water bodies located within the expanded Site between August 2019 and March 2023. During this time, 507 sediment samples were collected from 105 unique surface sediment locations. Sample locations along the Project 1007 Corridor are shown on **Figures 26 through 31,** and sample locations within the expanded Site domain are shown on **Figures 32 and 33**. The following sections detail the sediment investigations.

3.4.1 Sediment Sampling Rationale

The presence of PFAS impacts in near-surface sediments is influenced by many factors, including exposure to PFAS-impacted waters, proximity to primary source areas, surface water flow conditions, hydrogeologic properties and infiltration conditions, and the physical and geochemical properties of the sediment. The extent of PFAS sorption and leaching between sediments, surface water, and groundwater is not fully understood. PFAS accumulation in sediment impacts the fate and transport of PFAS in surface water and groundwater and can present risk to human health exposure from accessible sediments via incidental ingestion and ecological exposure through direct contact and food web bioaccumulation.

Sediment sampling activities were completed to establish a representative dataset for sediment of the Project 1007 Site with consideration given to the following factors:

- Geographic coverage
- Distance from primary and secondary source areas
- Hydrologic setting, such as flow conditions and depositional environment
- Surface-to-groundwater interaction, such as infiltration and groundwater discharge

- Sediment type
- Potential risk to human exposure

3.4.2 Sediment Sampling Methods

Sediment sampling methods followed the SOP for Surface Water, Sediment, and Foam Sampling for PFAS developed by AECOM (AECOM, 2020), which is included as **Attachment A-1**. This SOP follows the MDEQ and EGLE sampling guidance for surface water, sediment, and foam (MDEQ, 2018a; MDEQ, 2018b; MDEQ, 2018c; EGLE, 2019). Equipment used for sediment sampling was determined based on the composition of the sediment and depth of the water body. Sampling was completed by using either a hand auger or track-mounted push probe rig. The hand auger method was used in all locations by AECOM personnel except for the sampling of sediment in the wetland areas. To allow for better coverage of the wetlands and more sample locations to be accessed during the winter, a track-mounted push probe rig was utilized in wetland areas. These methods are described further below. Scanned field forms documenting site conditions and general sediment description of each sample collected are provided in **Attachment B-2.**

3.4.2.1 Hand-Auger Surface Sampling

A hand auger was used as the preferred sediment sampling tool to ensure the appropriate depth was accurately and evenly collected over the targeted depth interval. An appropriate number of rods were screwed together and attached to the handle and appropriate auger bucket. A standard closed-wall auger bucket was used for loose, sandy, or gravelly sediment. A clay auger bucket was used for more compact sediment as the open-walled construction of the bucket allows for easier removal of the sample. Alternatively, a shovel or hand trowel was used. Depending on the water depth and targeted sample location relative to the bank, the sample collector collected a sample from the bank or waded to the sampling location by entering downstream of the predetermined location. Once the sample was retrieved, a second person transferred the sediment with a newly gloved hand to a clean stainless-steel container. The sample was well homogenized by mixing the sediment with the gloved hand before being transferred to laboratory-supplied sample containers. If a greater sample volume was required for analysis, additional sediment was collected from a location adjacent to the original location and homogenized with the original sample in a clean container before distribution to the sample containers. The sediment was photographed and characterized based on the primary and secondary components. Sediment descriptors, such as color, moisture, plasticity, grain roundness, grain size, and grain distribution were noted on field forms. After sample collection, the auger bucket or shovel was rinsed in the surface water to dislodge any remaining sediment. Sediment sampling tools were decontaminated with Alconox and PFAS-free water prior to the collection of additional samples to maintain sample integrity at future sample locations.

In areas where multiple sediment depths were to be collected, a hand auger with the appropriate bucket for the sediment type was used to ensure that discrete depths were accurately sampled. Different bucket types may have been required for samples of different depths at the same location. Samples were collected from the same borehole whenever possible, taking care that slough was not included in the sample. Samples were homogenized in the same way as described previously before being placed in the laboratory-provided containers.

3.4.2.2 Direct-Push Sampling

Direct-push sediment sampling was accomplished using a track-mounted push probe rig (provided by a drilling subcontractor) with 2-foot macro core samplers. Sample locations were identified in the field using a handheld GPS unit. A subcontractor advanced the push probe 2 feet at a time to a maximum depth of 4 feet at each location. If applicable, overlying ice encountered during winter sampling was not counted towards the footage advanced. After each 2-foot run, the probe sleeve was recovered and provided to the AECOM staff geologist to log and sample. To ensure consistency between staff, each 2-foot run was divided in half (regardless of recovery volume) and each half was labeled as a relative single 1-foot interval. The full 1-foot interval (i.e., 50% of each probe recovery) was put in a clean stainless-steel container for homogenization and jarring. Staff directly handling samples for homogenization and jarring changed gloves between each sample. For each sediment sample, staff documented the surface conditions and general soil description, including color, moisture, plasticity, grain roundness, grain size, and grain distribution in field forms. Following boring advancement, staff recorded the GPS location on either a hand-held GPS or mobile device to account for any possible offset made from the predetermined location.

3.4.3 Sediment Sampling Events

Details regarding each sediment sampling event from the 2019 baseline sampling event through May 2022 are summarized below and in **Table 3.4.3.** Sediment sampling concluded in May 2022 because sufficient information had been collected to characterize PFAS sediment concentrations with the exception of the wetland area immediately east of ODS, located west of I-694. This wetland area could not be sampled further because an access agreement could not be reached with the landowner.

2019 Baseline Sampling Event: Similarly to the surface water investigation, the sediment investigation began with the collection of baseline sediment data within surface water bodies along and adjacent to the Project 1007 conveyance system. During the 2019 baseline sampling event, sediment samples were collected along channel bottoms and water body edges from the 0- to 3-inch depth interval. Sediment samples were paired with co-located surface water samples.

2020 Baseline Data-Gap Sediment Event and *2020 Targeted Wetland and Focus-Area Event*: Following review of the initial analytical results, two additional sediment sampling events were conducted: the 2020 baseline data-gap sediment event in April and May 2020 and the 2020 targeted wetland and focus-area event in August 2020. Sediment sampling locations were expanded to target depositional areas with constricted or reduced flow where increased sorption of PFAS was expected to occur. During these events, repeat sediment samples were also collected from locations previously sampled in the 2019 baseline sampling event to assess differing hydrologic conditions and geochemical sediment properties that may influence PFAS sorption and retention. Samples were collected along channel banks, from the edges and channelized areas within wetlands, and from littoral zones and beach sediments. In particular, wetland areas were targeted to assess the role organic content may play in the sorption of PFAS in sediments. Finally, sediment samples at select locations were collected from multiple depth intervals up to 48 inches bgs to estimate the vertical distribution of PFAS.

2020 BERA and September 2021 BERA Addendum: The surface water and sediment results of the 2019 baseline sampling event, 2020 baseline data-gap event, and 2020 targeted wetland and focus-area event were used to better evaluate the potential for ecological risks associated with exposure to PFAS in sediment from areas where aquatic and semi-aquatic receptors may be present. In September 2020, additional sediment sampling was paired with tissue sampling of various aquatic species as part of the BERA (AECOM, 2021a). For an addendum to the BERA, an additional round of sediment sampling was paired with targeted vegetative sampling from the Raleigh Creek wetlands and Eagle Point Lake in September 2021 (AECOM, 2022a). Data associated with these studies are included in this report. The conclusions and recommendations pertaining to ecological risk are provided in the final ecological reports (AECOM, 2021a and AECOM, 2022a).

2021 IAWC Investigation and 2021 Upper Raleigh Creek Wetland Investigation: In response to the observed elevated PFAS concentrations in sediments from two of the Upper Raleigh Creek Wetland Complexes and from AGWC (formerly known as IAWC), a series of focused sediment investigations were completed at the three wetland complexes between February and April 2021. The primary goal of these focused investigations, referred to as the 2021 IAWC Investigation and the 2021 Upper Raleigh Creek

Wetland Investigations, was to provide additional delineation of PFAS in sediments throughout the wetland complexes in support of human health exposure risk and future decision-making. The sampling design was developed using a systematic grid based on statistical sampling theory to ensure the characterization of PFAS variability and the identification of PFAS hot spots within each wetland complex. Additionally, the vertical distribution of PFAS was assessed. Sediment locations were sampled from two to four discrete depth intervals to a terminal depth of 48 inches bgs. At AGWC, sediment samples from four depth intervals were submitted for analysis of PFAS. At the two Upper Raleigh Creek Wetland Complexes, four depth intervals were collected. Samples from the second, third, and fourth depth intervals were put on hold at the laboratory until PFAS analytical results for the surface depth interval were reviewed. The following rationale was used for the analysis of samples beneath the surface depth:

- Analysis of the second depth interval was completed where the PFOS concentration in the corresponding surface depth interval sediment sample exceeded 100 micrograms per kilogram (ug/kg).
- Analysis of the third depth interval was completed where the PFOS concentration in the corresponding surface depth interval sediment sample exceeded 330 ug/kg.
- Analysis of the fourth depth profile was completed for one sample location from each of the two wetlands that had the highest observed PFOS concentration in the surface depth interval.

2022 IAWC Resample Investigation: In June 2021, the MPCA's Environmental Analysis and Outcomes Division completed a review of the analytical results of the AGWC sediment investigation and provided recommendations for further action including additional sampling. MPCA requested that confirmation sampling be performed at least 1 year later than the initial 2021 IAWC Investigation to determine whether PFAS concentrations in the sediment were increasing or decreasing over time. Additional sampling was requested at the inlet of AGWC considering its accessibility to potential receptors. This second sediment investigation, referred to as the 2022 IAWC resample investigation, was completed in May 2022.

2021 Summer Quarterly Event: In July 2021, the original Site was expanded to address data gaps identified in the development of the surface water–groundwater model, specifically to better evaluate the southward movement of PFAS compounds in groundwater from the ODS and Eagle Point Lake areas. Given the importance of understanding interactions between surface water and groundwater throughout the Site, the sampling plan for the summer 2021 quarterly event was modified to include sediment sampling of water bodies in these new areas. The targeted waterways included the disconnected wetlands and ponds south and southwest of ODS, Beaver Lake, the Greenway Corridor Area, Tanners Lake, Battle Creek Lake, Carver Lake, and Fish Creek. The sediment sample locations are depicted on **Figure 26 through 31**. **Figures 32 and 33** depict the locations of the sediment sample locations added as part of the expansion of the Site.

Table 3.4.3 summarizes all sediment sampling events carried out as of the date of this report.

Table 3.4.3: Sediment Sampling Events

Sampling Event	Date(s)	Area(s) of Investigation	Rationale for Samples Collected	No. of Samples
2019 Baseline Surface Sampling Event	8/12–15/2019; 8/27/2019; 11/21/2019	Tri-Lakes, Tri-Lakes Discharge, Pre- and Post-Confluence Raleigh Creek, Eagle Point Lake, Lake Elmo, Horseshoe Lake, West Lakeland	Initial Project 1007 Corridor Characterization	45

Sampling Event	Date(s)	Area(s) of Investigation	Rationale for Samples Collected	No. of Samples
2020 Baseline Data-Gap Event	4/23–30/2020 and 5/05–14/2020	Sunfish Lake, Tri-Lakes Discharge, Pre- and Post-Confluence Raleigh Creek, Eagle Point Lake, Lake Elmo, Farney Creek, Brown's Pond, Goose Lake, Valley Branch Creek	Areas Not Previously Sampled; Targeted Wetland Characterization; Depth Profile Characterization; Sediment Co-Located Foam	52
2020 Targeted Wetland and Focus Area Event	8/12–19/2020	Pre- and Post-Confluence Raleigh Creek, Raleigh Creek Wetland Complexes, Eagle Point Lake, West Lakeland Ponds, Valley Branch Creek	Further Characterization of Targeted Wetlands and Focus Areas; Areas Not Previously Sampled; Previously Observed Foam Accumulation Location	42
2020 BERA	9/15–28/2020	Tri-Lakes Discharge, Pre- and Post-Confluence Raleigh Creek, Eagle Point Lake, Brown's Pond, Lake Elmo, Horseshoe Lake, West Lakeland	Co-Located Surface Media Sampling in Conjunction with BERA Sampling	34
2021 AGWC Investigation	2/16–17/2021	AGWC	Wetland Complex Depth Profile Characterization	163
2021 Upper Raleigh Creek Wetland Investigation	3/15/2021; 3/31/2021; 4/6/2021; 4/14–16/2021	Upper Raleigh Creek Wetland Complexes	Wetland Complex Depth Profile Characterization	59
Summer 2021 Quarterly Event	7/19–22/2021	Disconnected Small Water Bodies and Wetlands South-Southwest of ODS, Beaver Lake, Tanners Lake, Greenway Corridor Area, Battle Creek Lake, Carver Lake	Baseline Characterization of New Surface Water Bodies as Part of Expanded Project Domain Sampling	28
September 2021 BERA Addendum	9/21–28/2022	Raleigh Creek Wetland Complexes, Eagle Point Lake	Co-Located Surface Media (foam, surface water, vegetation) Sampling in Conjunction with BERA Addendum for Vegetation Sampling	60
2022 AGWC Resample Investigation	5/18–19/2022	AGWC	Wetland Complex: Resampling of Select Locations	24

3.5 Subsurface Investigations

Many surface water to groundwater migration pathways across the Site contribute directly to the extent of PFAS impacts in deeper bedrock aquifers that are used for drinking water supply. To identify and characterize PFAS migration pathways from surface water to groundwater, and across surficial aquifers into deeper aquifers, AECOM installed 105 monitoring wells across the Site. During drilling activities, downhole soil and groundwater samples were collected from specific depth intervals to compare vertical stratification and PFAS concentrations at each well nest location and to develop a delineation strategy for future wells at similar sampled depth intervals.

Prior to installation, wells were categorized as beta site, single aquifer location, or piezometer pair. Targeted groundwater areas of study were established as beta sites. Each beta site included a multi-aquifer well nest or single aquifer location well. Several factors were considered in the selection of a beta site, including:

- Location within an existing, inferred PFAS plume,
- Proximity to a prominent surface water body with known PFAS surface water and/or sediment impacts,
- Downgradient location where vertical and horizontal PFAS migration may be observed in a well nest,
- Hydrogeological data gap,
- Analytical data gap, and
- Property access to beta site location.

Single aquifer location wells, which include both Quaternary and bedrock aquifer wells, were installed to address specific analytical data gaps identified following nearby beta site review. Piezometer pairs were installed in the Quaternary Aquifer around Eagle Point Lake to assess the surface water–groundwater interaction. **Figures 34 through 39** show groundwater sampling locations by aquifer. **Figure 40** presents the locations of each beta site, piezometer pair, and single aquifer location.

3.5.1 Well Types

Beta sites, single aquifer locations, and piezometer pairs comprise various well types. The installed well network of 105 wells includes 54 multi-aquifer wells installed as nests, 11 single aquifer wells, 20 paired piezometers, four pumping wells, and 16 observation wells. This section details the types of wells installed at the Site. Well construction details are included in **Table 3.5.1**. Well construction logs are included in **Attachment C-1**.

3.5.1.1 Multi-aquifer Well Nests

Nineteen multiple-aquifer well nests are associated with beta sites. They include between two and six monitoring wells screened at various depths and installed within 30 feet of each other. Each monitoring well is designated with MW followed by the corresponding beta site number and a letter to distinguish the depth interval (i.e., beta site 9 includes wells MW9A and MW9B). For most multi-aquifer well nests the greatest depth interval is associated with letter A on the well ID. Subsequent letters (i.e., B, C, D, etc.) correspond to shallower depth intervals. One exception to this is for the nest at BS2 where an additional well MW2E was installed at a later date at a depth of 100 feet bgs, which is between MW2A (depth of 263 feet bgs) and MW2B (depth of 62 feet bgs) (**Table 3.5.1**). Well nests were installed with either 2- or 4-inch-diameter stainless steel or polyvinyl chloride (PVC) screens or a 7-inch-diameter open borehole. Wells were initially installed as open boreholes at the request of MDH. As a result of equipment catching on the casing, AECOM and MPCA requested that subsequent wells be installed with screens. This request was granted in Fall 2020.

3.5.1.2 Piezometers

Twenty piezometers were installed as 10 shallow and deep pairs within the Quaternary Aquifer around Eagle Point Lake, as the lake was suspected to be a key point of surface water infiltration. Each piezometer is designated with PZ followed by a letter (A through J) designating location and either S for shallow or D for deep (i.e., Location E includes piezometers PZES and PZED). Piezometers were installed with 2-inch-diameter stainless steel screens.

3.5.1.3 Single Aquifer Wells

Eight single aquifer location wells, which include both Quaternary and bedrock aquifer wells, were installed to address specific analytical data gaps identified following nearby beta site review. Three wells

(MW4A, MW12A, and MW21A) are associated with beta sites 4, 12, and 21, respectively. These beta site wells have 7-inch diameter open borehole or 4-inch diameter stainless steel screens.

Other single aquifer well locations include wells MW14D, MW20A, and MW20B and piezometers PZH-1, PZH-2, and PZH-3. The piezometers are installed at various depths near the PZH piezometer pair from 30 to 100 feet bgs with 2-inch-diameter stainless steel well screens. MW14D has a 2-inch-diameter stainless steel well screen. MW20A and MW20B have 4-inch-diameter stainless steel well screens.

3.5.1.4 Pumping Test and Observation Wells

For the purposes of completing four aquifer pumping tests within the Shakopee and Jordan Aquifers, four pumping test wells and 16 associated observation wells were installed at three beta site locations: beta site 5, beta site 7, and beta site 20, as shown on **Figure 41**. Beta site 5 has one pumping test well installed in the Jordan Aquifer. Beta site 7 has one pumping test well installed in the Shakopee Aquifer. Beta site 20 has two pumping test wells, one installed in the Shakopee Aquifer and one installed in the Jordan Aquifer. Each pumping test well is designated with PW followed by the corresponding beta site number, a letter to distinguish which aquifer the well is screened in (J for Jordan and S for Shakopee), and an incremental increasing number to distinguish between multiple wells at the same beta site and aquifer (i.e., pumping well PW5J-1 is located at beta site 5 and screened in the Jordan Aquifer). There is one pumping test well per beta site and aquifer. Pumping test wells were installed with 6-inch-diameter stainless steel screens.

Observation wells are designated similarly to the pumping test wells using OW; however, observation wells were also installed in the Quaternary Aquifer (designated by Q), Oneota Aquitard (designated by O), and St. Peter Sandstone (designated by P for Pigs Eye Member or T for Tonti Member). Four observation wells were installed around each pumping test well at beta sites 5 and 7, and eight observation wells were installed around the two pumping test wells at beta site 20. Observation wells installed at the same beta site and in the same aquifer are identified by incremental increasing numbers (i.e., beta site 5 includes three observation wells in the Jordan Aquifer: OW5J-1, OW5J-2, and OW5J-3). Observation wells were installed with 4-inch-diameter stainless steel screens. Though these wells were installed primarily for completion of the aquifer pumping tests, they also serve as key sources of analytical and hydrogeological data in the development of the CSM.

Table 3.5.1 summarizes well construction information for AECOM-installed wells.

Table 3.5.1: AECOM Well Construction Information

Well Category	Well Name	Well ID	Installed Date	Total Well Depth (ft bgs)	Screen Length (ft)	Screened Aquifer	Screen Diameter (in)	Casing Diameter (in)
BS1	MW1A	850554	11/23/2020	370	10	Jordan	4	4
	MW1B	854442	04/20/2021	120	20	St Peter	4	4
	MW1C	854439	04/22/2021	45	5	Platteville	4	4
BS2	MW2A	848623	06/29/2020	263	23 (open hole)	Jordan	7	4
	MW2B	833405	10/13/2020	62	5	Quaternary	2	2
	MW2C	833406	10/13/2020	40	5	Quaternary	2	2
	MW2D	833407	10/14/2020	17	10	Quaternary	2	2
	MW2E	854440	07/15/2021	100	10	St Peter	7	4
BS3	MW3A	847052	01/10/2020	250	20 (open hole)	Jordan	7	4
	MW3B	847053	01/16/2020	130	20 (open hole)	Shakopee	7	4
SAL	MW4A	847054	12/18/2019	160	20 (open hole)	Oneota	7	4
BS5	MW5A	847056	12/06/2019	220	10 (open hole)	Jordan	7	4
	MW5B	847057	12/12/2019	120	10 (open hole)	Shakopee	7	4
	PW5J-1	854555	07/22/2021	280	50	Jordan	6	6
	OW5J-1	854556	07/24/2021	238	10	Jordan	4	4
	OW5O-1	854557	08/05/2021	210	10	Oneota	4	4
	OW5J-2	854558	08/03/2021	225	10	Jordan	4	4
	OW5J-3	854559	08/05/2021	225	10	Jordan	4	4
BS6	MW6A	847058	11/25/2019	210	7	Jordan	7	4
	MW6B	847059	11/21/2019	150	10	Oneota	4	4
	MW6C	833403	11/17/2020	40	5	Quaternary	2	2
	MW6D	833404	11/16/2020	18	10	Quaternary	2	2
BS7	MW7A	848622	06/01/2020	210	10	Jordan	4	4
	PW7S-1	877386	07/13/2022	150	50	Shakopee	6	6
	OW7S-1	877387	08/22/2022	100	10	Shakopee	4	4

Well Category	Well Name	Well ID	Installed Date	Total Well Depth (ft bgs)	Screen Length (ft)	Screened Aquifer	Screen Diameter (in)	Casing Diameter (in)
	OW7Q-1	877390	08/23/2022	74	10	Quaternary	4	4
	OW7S-2	877388	08/23/2022	110	10	Shakopee	4	4
	OW7S-3	877389	08/24/2022	110	10	Shakopee	4	4
BS8	MW8A	867654	08/18/2022	212	10	Jordan	4	4
	MW8B	867655	08/18/2022	60	10	Shakopee	4	4
BS9	MW9A	848624	06/03/2020	150	10	Oneota	4	4
	MW9B	854441	04/23/2021	100	10	Quaternary	4	4
BS10	MW10A	860296	11/19/2021	283	10	Jordan	4	4
	MW10B	860297	11/24/2021	140	10	Shakopee	4	4
	MW10C	855328	03/14/2023	20	10	Quaternary	2	2
SAL	MW12A	850553	10/20/2020	360	10	Tunnel City	4	4
BS13	MW13A	848626	06/12/2020	370	20 (open hole)	Tunnel City	7	4
	MW13B	848625	06/19/2020	305	10	Jordan	4	4
	MW13C	854546	11/03/2020	236	10	Quaternary	2	2
	MW13D	833402	10/15/2020	25	10	Quaternary	2	2
BS14	MW14A	850557	12/14/2020	326	10	Jordan	4	4
	MW14B	850558	12/17/2020	70	10	St Peter	4	4
	MW14C	854438	04/20/2021	36	20	Quaternary	2	2
	MW14D	855330	04/27/2021	21	15	Quaternary	2	2
BS15	MW15A	850551	10/29/2020	340	10	Wonewoc	4	4
	MW15B	850552	11/05/2020	225	10	Tunnel City	4	4
BS17	MW17A	850556	02/18/2021	245	10	Jordan	4	4
	MW17B	854409	02/22/2021	100	10	St Peter	4	4
	MW17C	855329	04/29/2021	48.5	10	Quaternary	2	2
BS18	MW18A	854525	12/17/2021	362	10	Jordan	4	4
	MW18B	860259	01/14/2022	235	10	Shakopee	4	4

Well Category	Well Name	Well ID	Installed Date	Total Well Depth (ft bgs)	Screen Length (ft)	Screened Aquifer	Screen Diameter (in)	Casing Diameter (in)
BS20	MW20A	867664	09/28/2022	140	10	Shakopee	4	4
	MW20B	867665	09/26/2022	100	10	St Peter	4	4
	PW20J-1	860281	09/30/2021	358	50	Jordan	6	6
	PW20S-1	867656	09/14/2022	250	50	Shakopee	6	6
	OW20T-1	867660	09/16/2022	108	10	St Peter (Tonti)	4	4
	OW20P-1	867657	09/15/2022	160	10	St Peter (Pigs Eye)	4	4
	OW20S-1	860282	10/13/2021	200	10	Shakopee	4	4
	OW20S-2	867658	09/22/2022	210	10	Shakopee	4	4
	OW20S-3	867659	09/21/2022	175	10	Shakopee	4	4
	OW20J-1	860283	10/08/2021	320	10	Jordan	4	4
	OW20J-2	860284	09/17/2021	320	10	Jordan	4	4
	OW20J-3	860285	09/23/2021	290	10	Jordan	4	4
SAL	MW21A	877381	06/22/2022	417	10	Jordan	4	4
BS22	MW22A	876344	06/03/2022	439	10	Jordan	4	4
	MW22B	876345	06/09/2022	300	10	Shakopee	4	4
	MW22C	877378	06/13/2022	170	10	St Peter	4	4
BS23	MW23A	870299	05/20/2023	432	10	Jordan	4	4
	MW23B	870300	05/24/2023	309	10	Shakopee	4	4
	MW23C	870301	05/26/2023	160	10	St Peter	4	4
BS25	MW25A	870303	06/26/2023	400	10	Jordan	4	4
	MW25B	870302	06/29/2023	270	10	Shakopee	4	4
BS26	MW26A	877391	07/21/2022	390	10	Jordan	4	4
	MW26B	877392	07/26/2022	259	10	Shakopee	4	4
	MW26C	877393	7/27/2022	140	10	St Peter	4	4
BS27	MW27A	877383	06/28/2022	231	10	Shakopee	4	4
	MW27B	877384	06/30/2022	130	10	St Peter	4	4

Well Category	Well Name	Well ID	Installed Date	Total Well Depth (ft bgs)	Screen Length (ft)	Screened Aquifer	Screen Diameter (in)	Casing Diameter (in)
BS28	MW28A	883751	08/05/2024	245	10	Jordan	4	4
	MW28B	883752	08/07/2024	129	10	Shakopee	4	4
	MW28C	883753	08/08/2024	80	10	Quaternary	2	2
SAL	WC5A	883749	07/30/2024	278	10	Jordan	4	4
SAL	WC6A	883750	07/25/2024	288	10	Jordan	4	4
PZA	PZAS	854536	10/27/2020	16	5	Quaternary	2	2
	PZAD	854537	10/27/2020	26	5	Quaternary	2	2
PZB	PZBS	854538	10/26/2020	11	5	Quaternary	2	2
	PZBD	854539	10/26/2020	21	5	Quaternary	2	2
PZC	PZCS	854540	10/27/2020	11	5	Quaternary	2	2
	PZCD	854541	10/30/2020	21	5	Quaternary	2	2
PZD	PZDS	854544	10/28/2020	30	10	Quaternary	2	2
	PZDD	854545	10/28/2020	40	5	Quaternary	2	2
PZE	PZES	854526	10/21/2020	11	5	Quaternary	2	2
	PZED	854527	10/26/2020	21	5	Quaternary	2	2
PZF	PZFS	854528	10/20/2020	28	10	Quaternary	2	2
	PZFD	854529	10/20/2020	38	5	Quaternary	2	2
PZG	PZGS	854530	10/23/2020	30	10	Quaternary	2	2
	PZGD	854531	10/23/2020	40	5	Quaternary	2	2
PZH	PZHS	854532	10/21/2020	16	10	Quaternary	2	2
	PZHD	854533	10/21/2020	26	5	Quaternary	2	2
	PZH-1	867661	09/22/2022	100	10	St Peter	2	2
	PZH-2	867662	09/21/2022	50	10	St Peter	2	2
	PZH-3	867663	09/20/2022	40	5	St Peter	2	2
PZI	PZIS	854534	10/27/2020	17	10	Quaternary	2	2
	PZID	854535	10/27/2020	27	5	Quaternary	2	2

Well Category	Well Name	Well ID	Installed Date	Total Well Depth (ft bgs)	Screen Length (ft)	Screened Aquifer	Screen Diameter (in)	Casing Diameter (in)
PZJ	PZJS	854542	10/29/2020	25	10	Quaternary	2	2
	PZJD	854543	10/29/2020	35	5	Quaternary	2	2

Notes: BS = Beta Site, PZ= Piezometer Pair, SAL = Single Aquifer Location, OW = Observation Well, PW = Pumping Well, MW = Monitoring Well, WC = Washington County (well installed at WCL)

3.5.2 Drilling Events

The installation of the Project 1007 well network was completed in several phases between November 2019 and August 2024. Additional wells may be installed in the future to address data gaps. The drilling events, which at times occurred concurrently, included eight beta site phases and four pumping test drilling events. The beta site phases included the installation of all beta site wells, single aquifer location wells, and piezometer pairs. Field forms documenting groundwater and soil sampling activities are provided in **Attachment B-4**. Daily drilling logs are included in **Attachment C-2**.

Beta Phase I: From November 11, 2019, to January 20, 2020, seven bedrock monitoring wells were installed at four beta sites: BS3, BS4, BS5, and BS6. Each beta site was newly identified and included the collection of groundwater and soil samples. Downhole video logging and geophysical data collection were completed at the deepest borehole at each beta site.

Beta Phase II: From May 26, 2020, to June 25, 2020, five bedrock monitoring wells were installed at four beta sites: BS2, BS7, BS9, and BS13. Each beta site was newly identified and included the collection of groundwater and soil samples. Downhole video logging and geophysical data collection were completed at the deepest borehole at each beta site.

Beta Phase III: From October 12, 2020, to February 22, 2021, 15 monitoring wells were installed at eight beta sites, and 10 piezometer pairs (20 piezometers total) were installed around Eagle Point Lake. Of the 15 beta site wells, eight were installed in bedrock aquifers at five newly identified beta site locations: BS1, BS12, BS14, BS15, and BS17. Each newly identified beta site location included the collection of groundwater and soil samples as well as downhole video logging and geophysical data collection from the deepest borehole. The remaining seven beta site wells were installed in the Quaternary Aquifer at three existing beta site locations: BS2, BS6, and BS13. Finally, at seven of the 10 piezometer pair locations around Eagle Point Lake, soil and groundwater samples were collected at soil type transitions within the overburden and from the top of first encountered bedrock.

Beta Phase IV: From April 19, 2021, to April 30, 2021, five monitoring wells were installed at five beta sites, and one Quaternary Aquifer well was installed at a single aquifer location. One beta site well was installed in the Quaternary Aquifer at the newly identified beta site location, BS10. The remaining four beta site wells were installed at existing beta site locations; one monitoring well was installed in the St. Peter Aquifer (BS2), and three monitoring wells were installed in the Quaternary Aquifer (BS9, BS14, and BS17). At the single aquifer location, a Quaternary Aquifer well MW14D was installed for the purposes of addressing an analytical data gap identified through data evaluation collected from the beta phase III drilling activities associated with BS14. Groundwater and soil sampling, geophysical data collection, and video logging were not completed because five wells were installed in the Quaternary Aquifer (BS10, BS9, BS14, BS17, and MW14D) and one well was installed at the top of first encountered bedrock (BS2).

Beta Phase V: From November 15, 2021, to January 13, 2022, four bedrock monitoring wells were installed at one newly identified beta site (BS18) and one existing beta site (BS10). Groundwater and soil sampling, geophysical data collection, and video logging were completed at both beta site locations.

Beta Phase VI: From May 24, 2022, to September 30, 2022, 17 monitoring wells were installed at five newly identified beta site locations, one existing beta site location, and three single aquifer locations. Of the five newly identified beta site locations, two locations (BS21 and BS22) were identified as part of the expansion of the Site and included the installation of four bedrock monitoring wells. As discussed in previous sections, the original Site encompassed the VBWD watershed boundaries, within which flow paths associated with the Project 1007 Corridor were contained. In 2021, the Site was expanded to address data gaps identified through previous investigative work, allowing for a better understanding of the aquifer-specific potentiometric surfaces and groundwater flow direction.

The remaining three newly identified beta site locations (BS8, BS26, and BS27) were within the original Site and included installation of seven bedrock monitoring wells. At the existing beta site location (BS2), one bedrock monitoring well was installed for the purposes of addressing an analytical and hydrogeological data gap within the Shakopee Aquifer. The three single aquifer locations (MW20A, MW20B, and PZH) were selected to address analytical data gaps associated with the characterization of PFAS impacts in bedrock aquifers contributing to Eagle Point Lake via groundwater discharge and contributing to groundwater by Eagle Point Lake via surface water infiltration. These locations were located within the original Site and included the installation of five bedrock monitoring wells: MW20A and MW20B and three piezometers at PZH (PZH-1, PZH-2, and PZH-3). Groundwater and soil sampling, geophysical data collection, and video logging were completed at the newly identified beta site locations.

Beta Phase VII: From May 15, 2023, to June 23, 2023, five bedrock monitoring wells were installed at two newly identified beta site locations (BS23 and BS25), which were located within the expanded portion of the Site. Groundwater and soil sampling, geophysical data collection, and video logging were completed at each location.

Jordan Aquifer Pumping Test Area 1 Drilling Event: From July 14, 2021, to September 10, 2021, one bedrock aquifer pumping well and four bedrock aquifer observation wells were installed at beta site location BS5. The pumping well was screened in the Jordan Aquifer, and the observation wells were screened in the Jordan Aquifer, Oneota Aquitard, and Shakopee Aquifer. Three previously installed monitoring wells (MW4A, MW5A, and MW5B) were included in the well network of the aquifer pumping test.

Jordan Aquifer Pumping Test Area 2 Drilling Event: From September 14, 2021, to October 13, 2021, one bedrock aquifer pumping well and four bedrock aquifer observation wells were installed at newly identified beta site location BS20. The pumping well was screened in the Jordan Aquifer, and the observation wells were screened in either the Jordan or Shakopee Aquifers. Monitoring wells were not previously installed at this beta site.

Shakopee Aquifer Pumping Test Area 2 Drilling Event: From September 12, 2022, to September 21, 2022, one bedrock aquifer pumping well and six bedrock aquifer observation wells were installed at beta site location BS20. The pumping well was screened in the Shakopee Aquifer, and the observation wells were screened in the Oneota Aquitard, Shakopee Aquifer, St. Peter Aquitard, and St. Peter Aquifer. The pumping and observation wells previously installed during the Jordan Aquifer Pumping Test Area 2 Drilling Event were included as part of the well network for this aquifer pumping test.

Shakopee Aquifer Pumping Test Area 3 Drilling Event: From August 22, 2022, to September 2, 2022, one bedrock aquifer pumping well, three bedrock aquifer observation wells, and one Quaternary Aquifer observation well were installed at beta site location BS7. The pumping well was screened in the Shakopee Aquifer, and the observation wells were screened in the Shakopee and Quaternary Aquifers. One existing Jordan Aquifer monitoring well (MW7A) was included as part of the well network for the aquifer pumping test.

Washington County Landfill Drilling Event: From July 22, 2024, to July 29, 2024, two bedrock aquifer observation wells were installed in the Jordan Aquifer at WCL. Groundwater and soil samples were collected at these locations.

Beta Phase VIII: From July 29, 2024, to August 8, 2024, three observation wells were installed in the unconsolidated Quaternary, the Shakopee, and the Jordan Aquifers.

Table 3.5.2 summarizes the details regarding each drilling event.

Table 3.5.2: Drilling Events

Drilling Event	Dates	Work Completed	Newly Identified Beta Sites	Existing Beta Sites	Installed Wells	No. of Installed Wells
Beta Phase I	11/11–25/2019, 12/2–19/2019, 1/6–16/2020	Newly Identified Beta Sites	BS3, BS4, BS5, BS6	N/A	MW3A, MW3B, MW4A, MW5A, MW5B, MW6A, MW6B	7
Beta Phase II	5/26–6/26/2020	Newly Identified Beta Sites	BS2, BS7, BS9, BS13	N/A	MW2A, MW7A, MW9A, MW13A, MW13B	5
Beta Phase III	10/29–11/4/2020, 11/17–12/17/2020, 2/3–22/2021	Newly Identified Beta Sites Existing Beta Sites Piezometer Pairs	BS1, BS12, BS14, BS15, BS17	BS2, BS6, BS13	MW1A, MW1B, MW12A, MW14A, MW14B, MW15A, MW15B, MW17A, MW17B MW2B, MW2C, MW2D, MW6C, MW6D, MW13C, MW13D All 20 Piezometers (PZA through PZJ)	26
Beta Phase IV	4/19–23/2021, 4/27–5/3/2021	Newly Identified Beta Sites Existing Beta Sites Single Aquifer Well	BS10	BS2, BS9, BS14, BS17	MW10C MW2E, MW9B, MW14C, MW17C MW14D	6
Beta Phase V	11/15–22/2021, 12/13–17/2021, 1/12–14/2022	Newly Identified Beta Sites Existing Beta Sites	BS18	BS10	MW18A, MW18B, MW10A, MW10B	4
Beta Phase VI	5/24–7/28/2022, 8/15–19/2022, 9/19–30/2022	Newly Identified Beta Sites – Original Project Domain Newly Identified Beta Sites – Expanded Project Domain Existing Beta Sites Single Aquifer Location Wells	BS8, BS26, BS27 BS21, BS22	BS2	MW8A, MW8B, MW26A, MW26B, MW26C, MW27A, MW27B MW21A, MW22A, MW22B, MW22C, MW2F MW20A, MW20B, PZH-1, PZH-2, PZH-3	17
Beta Phase VII	5/15–6/7/2023	Newly Identified Beta Sites – Expanded Project Domain	BS23, BS25	N/A	MW23A, MW23B, MW23C, MW25A, MW25B	5
Jordan Aquifer Pumping Test Area 1 Drilling Event	7/14–8/5/2021, 9/10/2021	Pumping Test Well Observation Wells	N/A	BS5	PW5J-1 OW5J-1, OW5O-1, OW5J-2, OW5J-3	15
Jordan Aquifer Pumping Test Area 2 Drilling Event	9/14–10/13/2021	Pumping Test Well Observation Wells	BS20	N/A	PW20J-1 OW20J-1, OW20S-1, OW20J-2, OW20J-3	30

Drilling Event	Dates	Work Completed	Newly Identified Beta Sites	Existing Beta Sites	Installed Wells	No. of Installed Wells
Shakopee Aquifer Pumping Test Area 2 Drilling Event	9/12–16/2022	Pumping Test Well Observation Wells	N/A	BS20	PW20S-1 OW20J-1, OW20S-1, OW20S-2, OW20S-3, OW20T-1, OW20P-1	12
Shakopee Aquifer Pumping Test Area 3 Drilling Event	8/22–24/2022, 9/2/2022	Pumping Test Well Observation Wells	N/A	BS7	PW7S-1 OW7Q-1, OW7S-1, OW7S-2, OW7S-3	13
Washington County Landfill Drilling Event	7/22–29/2024	Single Aquifer Location Wells	N/A	N/A	WC5A, WC6A	2
Beta Phase VIII	7/29–8/8/2024	Newly Identified Beta Site	N/A	N/A	MW28A, MW28B, MW28C	3

Table 3.5.1 summarizes all monitoring wells completed to date.

3.5.3 Drilling Methods

Wells at the Site were installed in accordance with Minnesota Statutes Chapter 103I.205 by well contractors licensed in Minnesota. Rotosonic Drilling Rig operated by Traut Companies (Traut) was used to complete drilling activities associated with the installation of bedrock monitoring wells. For monitoring wells or piezometers completed in the unconsolidated overburden, a Hollow Stem Auger (HSA) operated by Stevens Drilling & Environmental Services Inc., a Geoprobe® Direct Push Drill Rig (Geoprobe) operated by Traut, or a Geoprobe operated by Dakota Technologies, Inc. was used. A select number of monitoring wells screened at deeper intervals of the unconsolidated overburden were completed using the Rotosonic Drilling Rig operated by Traut. Bedrock wells were cased down to the targeted interval and were completed either as an open hole or with a stainless-steel screen. Wells screened in unconsolidated overburden were cased down to the targeted interval and completed with either a stainless steel or PVC screen. No PTFE/FEP components were used. Wells were finished with bentonite/cement grout, and well development met criteria to achieve low turbidity.

3.5.4 Borehole Sampling Methods

3.5.4.1 Vertical Aquifer Profile Samples

During borehole advancement, downhole soil and groundwater samples were collected from predetermined depth intervals at each beta site. Groundwater samples, referred to as vertical aquifer profile (VAP) samples, were collected from the shallower aquifer units during the drilling process to assess conditions of vertical stratification in PFAS concentrations at each well nest location and to determine if additional wells should be installed at the sampled depth intervals. Targeted intervals typically included bedrock units not planned for well placement, the bottom of the unconsolidated Quaternary overburden, the top of the water table, and between the water table and the bottom of the overburden. At times, adverse downhole conditions such as insufficient groundwater flow or borehole collapse prevented the collection of VAP samples from bedrock units.

These groundwater samples were collected using the VAP method, which is detailed in **Attachment A-3**, and allows for a groundwater sample to be collected from a targeted discrete depth interval during drilling. With Rotosonic drilling activities, once the borehole was advanced to the bottom of the targeted interval for sampling, a temporary 4-foot screen was set by the driller at the bottom of the cased borehole, and the casing was then pulled up by 4 feet. This screen and casing placement allows formation water to enter the borehole at the discrete 4-foot interval of the screen. The pump used for VAP sample collection was selected based on the depth of the targeted interval and head space above the water table. The peristaltic tubing or intake point of the submersible pump was then positioned at the approximate mid-point of the screen and water purged until water stabilization parameters were met or until the volume purged was greater than the volume of water used in drilling to advance to the VAP interval. Typically, the water used in drilling was recirculated or lost to shallower formations, so purging the volume used in drilling was often not required to reach formation water. Water stabilization parameters included pH, oxidation-reduction potential (ORP), dissolved oxygen (DO), temperature, conductivity, turbidity, and water level. As the water being purged was the water used in drilling, stabilization of temperature, turbidity, and water level were key indicators of reaching formation water. VAP sample collection with a Geoprobe rig was the same as collection with a Rotosonic rig, except a 2-foot temporary screen was used.

3.5.4.2 Soil Samples

Soil samples from the unconsolidated Quaternary overburden were collected where VAP samples were collected, at the water table interface, and from soil intervals with an abundance of clays because of the PFAS adsorption potential. Additionally, at seven piezometer pair locations around Eagle Point Lake, soil and VAP samples were collected at each transition of soil type within the overburden and from the top of first encountered bedrock. At beta sites with installed well pairs or nests, observations of soil cuttings and subsurface lithology from the first borehole were used to identify targeted intervals for soil and groundwater sampling in the second borehole. At beta site locations with one monitoring well and from intervals deeper than subsequent monitoring wells in a nest, groundwater and soil sampling intervals were determined during borehole advancement following geologic interpretation of soil and bedrock cores.

Cores were retrieved in 10-foot-long acetate bags for Rotosonic drilling activities and in 4-foot-long high-density polyethylene (HDPE) liners for Geoprobe drilling. For HSA drilling activities, a Geoprobe was used for soil sampling. Each well had a corresponding soil boring that was logged in the field by an AECOM geologist. The following parameters were recorded during soil field screening: primary and secondary soil classification according to the Unified Soil Classification System (USCS), moisture level, trace constituents, evidence of oxidation, and Munsell soil color. The grain type (i.e., coarse or fine), grain size and shape, grading, and plasticity were also recorded. Soil samples were collected directly from the acetate bags and homogenized prior to placement in laboratory supplied sample containers. Complete well logs including well construction details and lithologic information are provided in **Attachment C-1.**

As discussed further in Section 4.1.5, PFAS concentrations in soil samples were typically non-detect or low concentrations below the MPCA Residential/Recreational Soil Reference Values (SRVs), except for locations near Pre-Confluence Raleigh Creek and Eagle Point Lake. Due to the frequency of non-detects, AECOM determined that soil sampling at well installations farther from areas of surface water infiltration was not significant to CSM development.

3.5.5 Geophysical Investigation

To address geological data gaps and to verify bedrock lithologic contacts identified during logging, geophysical data were generally collected in the deepest borehole at each beta site location. Geophysical logging tools, which were provided by staff from the MGS, included gamma, caliper, multi-parameter e-log (i.e., fluid resistivity and temperature), flowmeter, and borehole video. In addition, MGS collaborated with AECOM to provide a summary report of each geophysical assessment, discuss hydrogeologic conditions, provide relevant research, and discuss site-specific geologic interpretations. Locations where monitoring well depths did not exceed the first encountered bedrock formations did not include geophysical analysis. A detailed discussion of geophysical data collected is provided in **Attachment C-3**.

3.5.6 Investigative Derived Waste

Investigation-derived waste (IDW) generated during the beta round I drilling event from November 2019 through January 2020 included solid media such as soil cuttings and bedrock cores and aqueous waste such as drilling fluids and purge water. IDW solids were placed inside steel drums and stored in a secured portable storage unit until they could be transported by Clean Harbors Environmental Services (Clean Harbors) to the Deer Trail Landfill. Aqueous IDW was pumped and transported offsite daily by Clean Harbors and stored inside a frac tank at a secured facility in Afton, Minnesota, for future transportation to the Spruce Ridge Landfill by Clean Harbors.

From June 2020 until November 2022, aqueous IDW associated with drilling activities was discharged to ground, and solid IDW was thin spread at each beta site, except for beta site 26 (Meadows Park). Discharge to ground was deemed an acceptable method of disposal considering the connection to stormwater conveyance and the lack of PFAS impacts in nearby surface waters and shallow groundwater. At beta site 26, two frac tanks were stored onsite to containerize drilling mud and purge water generated during the drilling process. The frac tanks were transported by Clean Harbors and Harold Marcus Ltd. to Clean Harbors' disposal site in Bothwell, Ontario, for incineration. The soil cuttings were containerized in 55-gallon steel drums at the Site and then transported to Clean Harbors' Deer Trail Landfill.

At beta sites 23 and 25, which were both located in areas with unimpacted surface waters and shallow groundwater, aqueous IDW was pumped through a centrifuge to remove solids and then through a GAC filter to remove any PFAS impacts in the fluids. The treated water was then discharged to an adjacent creek connected to the storm water conveyance system at BS23 and to the sanitary sewer via a manhole at BS25. Soil cuttings at both sites were containerized in 55-gallon steel drums and then transported to Clean Harbors' Sawyer Disposal Services facility in North Dakota.

3.5.7 Well Surveying Activities

A licensed land surveyor from the Minnesota MDNR surveyed newly installed monitoring wells during this investigation. **Table 3.5.7** provides the ground surface elevation, casing elevation, northing, easting, and the state-issued unique ID for each well installed to date.

Table 3.5.7: Surveyed Well Data

Well Name	Unique Well ID	Easting	Northing	Ground Elevation (ft amsl)	Casing Elevation (ft amsl)
MW1A	850554	503582.85	4982424.18	992.701	994.24
MW1B	854442	503580.9	4982422.75	992.677	994.701
MW1C	854439	503584.55	4982426.26	992.647	994.916
MW2A	848623	505707.3	4982063.72	913.092	915.018
MW2B	833405	505709.63	4982065.47	912.859	915.188
MW2C	833406	505707.19	4982066.53	912.951	915.339
MW2D	833407	505705.08	4982063.21	913.259	915.28
MW2E	854440	505705.19	4982065.60	913.202	915.202
MW2F	867666	4982068.126	505703.748	913.397	914.993
MW3A	847052	507372.86	4979696.86	910.508	912.368

Well Name	Unique Well ID	Easting	Northing	Ground Elevation (ft amsl)	Casing Elevation (ft amsl)
MW3B	847053	507372.01	4979693.32	910.379	912.008
MW4A	847054	508614.01	4980608.11	890.06	892.009
MW5A	847056	508682.95	4980840.19	908.045	909.731
MW5B	847057	508681.37	4980837.84	907.861	909.785
PW5J-1	854555	508645.68	4980878.49	927.972	929.982
OW5J-1	854556	508619.47	4980902.65	923.477	925.688
OW5J-2	854558	508573.75	4980942.68	912.596	914.718
OW5J-3	854559	508461.03	4981031.52	911.48	913.442
OW5O-1	854557	508616.87	4980903.92	923.537	925.776
MW6A	847058	509410.8	4980133.29	890.464	892.45
MW6B	847059	509412.93	4980132.12	890.534	891.99
MW6C	833403	509409.65	4980131.76	890.71	892.741
MW6D	833404	509411.72	4980130.46	890.73	892.859
MW7A	848622	511211.38	4979425.32	885.023	887.625
PW7S-1	877386	511237.71	4979424.30	885.073	886.771
OW7S-1	877387	511214.47	4979426.79	885.048	886.874
OW7S-2	877388	511208.29	4979388.70	884.682	886.539
OW7S-3	877389	511154.2	4979343.26	881.854	883.465
OW7Q-1	877390	511212.11	4979422.19	884.958	886.499
MW8A	867654	512336.94	4979062.43	879.007	880.642
MW8B	867655	512339.52	4979063.19	879.406	881.567
MW9A	848624	512443.1	4978389.20	870.054	871.856
MW9B	854441	512445.97	4978389.14	870.268	871.924
MW10A	860296	507553.44	4983106.43	970.135	971.743
MW10B	860297	507553.28	4983103.72	970.286	971.851
MW10C	855328	507625.69	4983416.71	913.493	915.993
MW12A	850553	513957.88	4977584.33	894.86	896.76
MW13A	848626	508221.33	4979807.85	911.211	913.39
MW13B	848625	508216.15	4979807.13	910.219	912.208
MW13C	854546	508215.68	4979810.14	909.851	912.049
MW13D	833402	508220.62	4979811.17	910.851	913.108
MW14A	850557	504393.72	4982094.89	963.448	965.245
MW14B	850558	504393.79	4982089.69	963.28	965.011
MW14C	854438	504393.64	4982087.88	963.117	964.97
MW14D	855330	503989.62	4982340.52	975.16	977.55
MW15A	850551	516759.79	4978461.84	860.431	862.731
MW15B	850552	516760.99	4978458.53	860.589	862.269

Well Name	Unique Well ID	Easting	Northing	Ground Elevation (ft amsl)	Casing Elevation (ft amsl)
MW17A	850556	506085.99	4982534.98	915.346	917.455
MW17B	854409	506083.64	4982533.17	915.386	917.424
MW17C	855329	506086.31	4982531.99	915.475	917.961
MW18A	854525	504205.83	4983117.57	1003.926	1005.408
MW18B	860259	504208.38	4983116.92	1003.468	1005.31
MW20A	867664	506415.628	4980554.796	925.809	927.441
MW20B	867665	506004.841	4981320.155	965.570	967.365
MW21A	877381	501609.38	4982280.23	995.152	996.864
MW22A	876344	502792.5	4980345.15	1027.825	1029.463
MW22B	876345	502789.02	4980344.47	1027.302	1028.852
MW22C	877378	502785.28	4980343.75	1026.733	1028.145
MW23A	870299	502162.015	4981282.314	1020.817	1022.121
MW23B	870300	502165.575	4981283.498	1019.830	1021.259
MW23C	870301	502169.069	4981285.014	1018.998	1020.714
MW25A	870303	502813.167	4977104.628	988.106	990.241
MW25B	870302	502812.988	4977101.454	987.947	989.767
MW26A	877391	503948.45	4981304.07	1008.185	1010.054
MW26B	877392	503948.67	4981308.79	1007.798	1009.939
MW26C	877393	503948.85	4981313.38	1007.328	1009.337
MW27A	877383	504832.22	4981547.25	996.78	998.289
MW27B	877384	504833.14	4981542.25	997.386	999.252
PW20J-1	860281	505379.29	4980727.74	963.657	965.553
OW20J-1	860283	505387.51	4980776.55	966.653	968.042
OW20J-2	860284	505458.01	4980790.15	970.732	972.837
OW20J-3	860285	505626.03	4980867.85	943.344	945.12
PW20S-1	867656	505374.65	4980728.46	964.953	966.386
OW20S-1	860282	505388.76	4980779.62	967.558	969.09
OW20S-2	867658	505457.28	4980794.09	971.804	973.432
OW20S-3	867659	505625.64	4980863.75	943.039	944.597
OW20P-1	867657	505390.38	4980782.72	968.293	969.766
OW20T-1	867660	505391.16	4980785.01	968.882	970.158
PZH-1	867661	506613.055	4979767.579	967.051	968.886
PZH-2	867662	506974.157	4979636.642	925.048	927.417
PZH-3	867663	507102.772	4979549.715	922.213	925.306
PZAD	854537	506429.42	4980894.42	904.45	906.872
PZAS	854536	506431.29	4980897.01	904.801	906.94
PZBD	854539	506654.84	4981032.68	897.83	900.73

Well Name	Unique Well ID	Easting	Northing	Ground Elevation (ft amsl)	Casing Elevation (ft amsl)
PZBS	854538	506653.96	4981030.10	897.79	900.671
PZCD	854541	506897.39	4980856.89	895.95	898.751
PZCS	854540	506900.32	4980856.01	896.301	898.919
PZDD	854545	507422.29	4980638.66	919.611	920.631
PZDS	854544	507423.86	4980636.26	919.89	921.399
PZED	854527	507434.94	4980267.63	895.95	898.738
PZES	854526	507433.94	4980264.91	895.832	898.361
PZFD	854529	507313.92	4980074.84	916.691	919.49
PZFS	854528	507313.72	4980072.22	917.17	919.549
PZGD	854531	507375.84	4979696.97	910.9	913.23
PZGS	854530	507376.26	4979693.62	910.5	912.77
PZHD	854533	506993.18	4979725.73	901.849	903.952
PZHS	854532	506996.07	4979724.44	901.101	903.601
PZID	854535	506747.38	4980150.52	905.979	907.721
PZIS	854534	506747.54	4980147.64	906.13	908.069
PZJD	854543	507218.63	4980609.10	912.301	913.952
PZJS	854542	507215.5	4980610.97	912.501	914.099
MW28A	883751	Wells have not been surveyed at the time of this report			
MW28B	883752				
MW28C	883753				
WC5A	883749				
WC6A	883750				

3.6 Groundwater Investigations

Groundwater sampling events were completed in newly installed or preexisting wells generally quarterly at the Site from October 2020 through October 2024. More than 1,200 samples were collected and submitted for laboratory analysis. The following sections detail the groundwater investigation.

3.6.1 Groundwater Sampling Rationale

The surface water to groundwater connection is a significant factor in the movement of PFAS impacts from the surface water regime of the Project 1007 Corridor into the subsurface where PFAS-impacted groundwater migrates horizontally and vertically from surficial aquifers into and within deeper bedrock aquifers. PFAS impacts in groundwater extend across an area of nearly 120 square miles, spanning across multiple groundwater divides and at least three drinking water aquifers. The Project 1007 groundwater investigation initially identified locations that were thought to provide information about potential surface water–to-groundwater pathways for PFAS migration. The beta sites, single aquifer locations, and piezometer pairs locations were established based on this review. As the investigation continued, locations were also added based on reviews of private well sampling and in areas where private wells were not located in specific aquifers to provide additional information for plume delineation and plume mapping. Groundwater sampling commenced as wells were installed to assess changes in PFAS concentrations over time, PFAS plume migration, and seasonal variations in PFAS concentrations, and to gain a more detailed understanding of surface water-groundwater interactions.

3.6.2 Groundwater Sampling Events

Monitoring wells were sampled as they were installed until the fall 2020 quarterly event. After the fall 2020 quarterly event, the well network was sampled on a quarterly basis for 1 year. Following four quarters of sampling, the analytical results of each well were evaluated to determine the need for continued quarterly sampling. Beginning in 2022, the frequency of sampling was reduced to either semi-annually or annually at locations where seasonal fluctuation was determined insignificant, where the locations were deemed redundant, or when relatively low PFAS concentrations confirmed a lack of hydrogeologic connection to existing plumes or plume migration pathways. In 2021 and 2022, a select number of monitoring wells were sampled during high-rain and snowmelt trigger events to confirm suspected surface-to-groundwater connection at those locations.

Table 3.6.2 summarizes groundwater sampling events through October 2024. Scanned field forms documenting water stabilization parameters, water level, and sample conditions are provided in **Attachment B-3.**

Table 3.6.2: Well Sampling Events

Sampling Event	Date(s)	Area(s) of Investigation	No. of Sampled Wells
Summer 2020 (well sampling following installation)	6/2/2020–8/26/2020	BS2, BS3, BS4, BS5, BS6, BS7, BS9, BS13	12
Fall 2020 Quarterly Event	10/21–27/2020	BS2, BS3, BS4, BS5, BS6, BS7, BS9, BS12, BS13, BS15	18
Spring 2021 Quarterly Event	4/13/2021–5/3/2021	BS1, BS2, BS3, BS4, BS5, BS6, BS7, BS9, BS10, BS12, BS13, BS14, BS15, BS17, PZA, PZB, PZC, PZD, PZE, PZF, PZG, PZH, PZI, PZJ	55
Summer 2021 Quarterly Event	7/13–22/2021	BS1, BS2, BS3, BS4, BS5, BS6, BS7, BS9, BS10, BS12, BS13, BS14, BS15, BS17, PZA, PZB, PZC, PZD, PZE, PZF, PZG, PZH, PZI, PZJ	54
August 30, 2021 Rain Event	8/30/2021	BS2, BS9, BS14, BS17	9
September 1–4, 2021 Rain Event	9/1/2021	BS14 (MW14C)	1
Fall 2021 Quarterly Event	10/21/2021–11/1/2021	BS1, BS2, BS3, BS4, BS5, BS6, BS7, BS9, BS10, BS12, BS13, BS14, BS15, BS17, BS20, PZA, PZB, PZC, PZD, PZE, PZF, PZG, PZH, PZI, PZJ, WCL/3M Wells	61
Winter 2022 Quarterly Event	1/26/2022–2/3/2022	BS1, BS2, BS3, BS5, BS6, BS9, BS10, BS13, BS14, BS17, BS18, BS20, PZA, PZB, PZC, PZD, PZE, PZF, PZG, PZH, PZI, PZJ	51
March 28–29, 2022 Snowmelt Event	3/29/2022	BS2, BS14	5
Spring 2022 Quarterly Event	4/18–27/2022	BS1, BS2, BS3, BS4, BS5, BS6, BS7, BS9, BS10, BS12, BS13, BS14, BS15, BS17, BS18, BS20, PZA, PZB, PZC, PZD, PZE, PZF, PZG, PZH, PZI, PZJ, WCL/3M Wells	73

Sampling Event	Date(s)	Area(s) of Investigation	No. of Sampled Wells
Summer 2022 Quarterly Event	7/11–18/2022	BS2, BS3, BS5, BS10, BS14, BS18, BS20, BS21, BS22, BS27, PZB, PZE, PZF, PZG, PZH, PZI, WCL/3M Wells	36
Fall 2022 Quarterly Event	10/25/2022–11/4/2022; 11/17–23/2022	BS2, BS3, BS4, BS5, BS6, BS7, BS8, BS9, BS10, BS12, BS13, BS14, BS15, BS17, BS20, BS21, BS22, BS26, BS27, PZA, PZB, PZC, PZE, PZF, PZG, PZH, PZI, WCL/3M Wells, EPL	86
Winter 2023 Quarterly Event	1/23/2023–2/2/2023	BS2, BS3, BS7, BS8, BS10, BS14, BS18, BS20, BS21, BS22, BS26, BS27, PZB, PZE, PZF, PZG, PZH, PZI, WCL/3M Wells	51
March 29–30, 2023 Snowmelt Event	3/29–30/2023	BS2, BS9, BS10, BS14, BS22, PZE, PZH, R1, W33	10
Spring 2023 Quarterly Event	4/17–24/2023	BS1, BS2, BS3, BS4, BS5, BS6, BS7, BS8, BS9, BS10, BS13, BS14, BS17, BS18, BS20, BS22, BS26, BS27, PZA, PZB, PZC, PZE, PZF, PZG, PZH, PZI, WCL/3M Wells	73
Summer 2023 Quarterly Event	7/18–28/2023	BS2, BS5, BS6, BS7 BS8, BS10, BS14, BS17, BS20, BS21, BS22, BS23, BS25, BS26, PZE, PZG, PZH 3M Wells	42
Fall 2023 Quarterly Event	10/23–30/2023; 11/06/2023	BS2, BS6, BS7, BS8, BS10, BS14, BS17, BS20, BS21, BS22, BS23, BS25, BS26, PZE, PZG, PZHD, 3M Wells	43
Winter 2024 Quarterly Event	01/22–25/2024	BS2, BS6, BS7, BS8, BS10, BS14, BS17, BS20, BS25, BS26, PZE, PZG, PZH, 3M Wells	27
Spring 2024 Washington County Landfill Event	04/22–30/2024	All possible WCL Wells	16
Spring 2024 Quarterly Event	05/06–17/2024	BS1, BS2, BS3, BS6, BS8, BS10, BS13, BS14, BS15, BS17, BS23, BS25, BS26, PZB, PZE, PZH, PZI, 3M Wells	34
Summer 2024 Quarterly Event	07/15/2024–07/24/2024	BS7, BS8, BS10, BS14, BS20, BS22, BS23, BS26, PZE, PZG, PZH, 3M Wells	26
2024 New Well Sampling	08/13/2024 and 08/15/2024	BS28, WC5A, WC6A	4
Fall 2024 Quarterly Event	10/14/2024–10/23/2024	BS2, BS6, BS7, BS8, BS10, BS14, BS20, BS22, BS23, BS25, BS26, BS28, PZE, PZG, PZH, WC5A, WC6A, 3M Wells, select WCL Wells	56

3.6.3 Groundwater Sampling Methods

Three groundwater sampling methods were used at the Site, including low-flow sampling with a peristaltic pump, standard purge sampling with a submersible pump, and passive sampling with HYDRASLEEVE^{TM} bags. Groundwater sampling procedures are provided in the Groundwater Sampling SOP (**Attachment A-2**).

3.6.3.1 Peristaltic Pump Low-Flow Sampling

For shallow groundwater wells less than 50 feet deep and with less than 30 feet of head space, a peristaltic pump was used as the method for groundwater sample collection. Prior to sampling, the water level and total well depth were measured to determine the placement of the peristaltic tubing and to calculate the volume of water in the well. The tubing was placed approximately at the middle of the screened interval of the well. To ensure a representative sample was collected from the groundwater, the well was purged until three well volumes were removed and water quality parameters stabilized. To collect water quality parameters, the water was pumped through a flow-through chamber of a YSI or similar device to record periodic measurements of pH, ORP, DO, temperature, and conductivity. Water quality parameters were considered stabilized when three consecutive measurements, which were collected every 5 minutes, met the following criteria relative to each other: pH within 0.1 units, temperature within 0.1 degrees Celsius, and specific conductance within 5%. The water level was documented at the same periodic intervals as the other water stabilization parameters as another indicator of stabilization. If the water level decreased, the pumping rate was reduced.

Groundwater samples were collected in laboratory-provided bottles when the water quality parameters stabilized and when three well volumes were purged. Notes were made in field forms for any odor, color, or turbidity observed in the sample.

3.6.3.2 Submersible Pump Sampling

For wells screened up to 100 feet bgs or those less than 50 feet but with greater than 30 feet of head space, a submersible pump was used for sample collection. The intake point of the submersible pump was positioned at approximately the middle of the screened interval of the well. As water is typically pumped at 5 to 8 gallons per minute with a submersible pump, this method is not classified as low-flow sampling, though water quality parameters were also collected when purging the well. Three well volumes were removed prior to sample collection.

3.6.3.3 Passive Sampling

For wells screened between 100 and 500 feet bgs, passive sampling was conducted using HYDRASleeve^{TM} bags. Passive sample bags were deployed and hung at the middle of the well screen using nylon rope and retrieved 48 hours later to collect the sample. Sample volume with the sample bag typically yielded between 1 and 3 liters. A bag would be deployed a second time if the initial deployment was unsuccessful either due to tearing or insufficient sample volume. Color, odor, turbidity, and recovery were noted during sample collection.

In select instances for wells screened between 100 and 500 feet bgs, a bladder pump was used when the well casing was known to have protrusions that prevented the successful deployment of the passive sampling bag or when additional sample volume was needed for analysis. Similar to peristaltic sampling, bladder pump sampling is a low-flow sampling method. Purging was completed until water quality parameters stabilized following the criteria described above.

3.6.4 Investigative Derived Waste

IDW collection for groundwater sampling activities began in 2023. Previously, all purge water generated during well sampling activities was discarded on the ground nearest to the wells sampled. Beginning in 2023, all purge water generated during well sampling activities was placed into open-top steel 55-gallon drums for storage and disposal. The sampling teams utilized 5-gallon buckets to collect purge water from each sampling location and transported the contents to a central location. The buckets were emptied into securely stored 55-gallon drums. After each sampling event, arrangements were made with Clean Harbors to pick up and transport drums of purge water for disposal (via incineration) at the Clean Harbors Environmental Services, Inc. facility located at 2247 South Highway 71, Kimball, NE.

3.7 Hydrologic and Hydrogeologic Investigations

As part of the effort to assess PFAS migration pathways from source areas through surface water and groundwater, AECOM developed a steady-state groundwater flow model (MODFLOW-USG) and a transient integrated surface water-groundwater model (MIKE SHE/MIKE HYDRO Basin) for the Site. MODFLOW-USG was developed by U.S. Geological Survey (USGS) (Panday et al., 2017). MIKE SHE/MIKE HYDRO Basin were developed by DHI Water & Environment, Inc. (DHI) (DHI, 2025a; DHI, 2025b). The original model domain encompassed the VBWD watershed boundaries, within which flow paths associated with the Project 1007 Corridor were contained. In 2021, the model domain was expanded to address data gaps identified through AECOM investigative work, allowing for a better understanding of the aquifer-specific potentiometric surfaces and groundwater flow direction. The resulting approximately 120-square-mile model domain is defined by hydrologic, hydrogeologic, and geologic boundaries that make up the areas connected via surface water and groundwater migration pathways from ODS and WCL. Investigation activities first entailed the compilation of available information, including, but not limited to, ground-surface topography, meteorological data, land-use classification distribution, surface water flow regimes and associated infrastructure, surface water elevation data, groundwater head measurements, mapped extents of unconsolidated and bedrock formations, and site-wide surface water and groundwater analytical data. Following the assessment of available data, a series of hydrologic and hydrogeologic investigations were conducted predominantly within the Project 1007 Corridor to gain further insight into areas lacking sufficient data. Data collected from these investigations in conjunction with existing data were utilized to refine the groundwater and integrated surface water-groundwater models as part of the larger effort to assess the future fate and transport of PFAS.

Field activities associated with hydrologic investigations involved the regular measurement of water levels and flow velocity through streams, channels, and storm culverts within the Project 1007 Corridor. Hydrogeologic field activities associated with the Project 1007 well network included the regular measurement of water levels from monitoring wells and piezometers and the characterization of hydraulic conductivity within targeted aquifers.

3.7.1 Water Level and Flow Measurement Activities

The VBWD has installed numerous staff gauges at major water bodies within the watershed district to measure water elevations throughout the year, nine of which were regularly recorded as part of the routine Project 1007 Corridor hydrologic investigation. In September 2020, AECOM installed an additional 25 staff gauges along streams and channels and smaller water bodies within the Project 1007 Corridor to supplement the existing VBWD staff gauges. **Figures 23 and 24** depict the staff gauge and flow measurement locations. Over time, six AECOM-installed staff gauges were removed from the gauging network following a review of analytical data and a determination they were not of value to the development of the CSM. At select locations, pressure transducers were installed adjacent to staff gauges to collect continuous water level measurements to ensure rapid changes from precipitation events were captured. The transducers were removed each winter and reinstalled and reprogrammed the following spring to protect transducers from damage due to low temperatures. At each AECOM-installed staff gauge and transducer location, annual surveys for horizontal position and elevation were conducted to account for any gauge housing displacement that may have occurred during the winter months. VBWD-installed staff gauges were removed at the start of each winter and then reinstalled and surveyed the following spring. Survey information was provided to AECOM.

Flow and stream bed measurements were collected to calculate stream and channel discharge at designated stream and channel staff gauge locations. To measure flow, field personnel entered the creek or channel immediately upstream of the corresponding staff gauge and transducer to measure the total width of the stream bed and to determine the minimum number of evenly spaced flow and depth measurements required for a representative transect oriented perpendicular to flow. The following number of measurements were collected based on the stream width: 0–3 feet, 3 measurements; 3–9 feet, 5 measurements; 9–15 feet, 8 measurements; 15–30 feet, 10 measurements; >30 feet, 20 measurements. At each evenly spaced point along this transect, field personnel measured both the stream depth and flow velocity by submerging a small portable flow probe approximately two-thirds into the water column. The average flow velocity spanning 1 minute was then recorded. For storm culverts, only one depth measurement and one flow measurement from the center of the culvert were collected as the dimensions of the storm culvert were available through VBWD documents. Water level measurements were collected from the Tri-Lakes, Sunfish Lake, the small ponds within AGWC, Eagle Point Lake, Goose Lake, Lake Elmo, Horseshoe Lake, and the West Lakeland Ponds. Paired water level and flow measurements were collected along Raleigh Creek, from the discharge pipes of Eagle Point Lake and Lake Elmo, along the channel between Horseshoe Lake and the West Lakeland Ponds, and along the channels connecting the West Lakeland Ponds. Field forms associated with the water level and flow velocity measurements are provided in **Attachment D-1**. Surface water levels, flow velocity measurements, and transducer data are shown in **Attachment D-2**.

Rating curves were established by matching water level measurements from stream gauges to measured discharge rates based on flow measurements from field events, allowing for calculation of discharge rates with transducer data and creating a continuous data set for stream and channel discharge. In spring and summer 2021, AECOM collected flow measurements approximately every 2 weeks to represent a range of expected flow conditions for the development of rating curves for each location. These measurements were repeated during the spring and summer of 2022, but the frequency was decreased to monthly and at the beginning of each sampling event. An exception to this approach occurred when precipitation events triggered higher stream depths in a stream that did not have corresponding flow measurements from previous field efforts. Field measurements were not collected during the winter when water bodies were frozen. These measurements allowed for the monitoring of water levels and flow conditions across seasons and meteorological events. The rating curves developed from these activities are provided in **Attachment D-2**. The measurements were also evaluated against PFAS analytical results to determine the relationship, if any, between hydrologic conditions and PFAS fate and transport.

Additionally, to aid in the calibration of the integrated surface water/groundwater model, AECOM data were supplemented with VBWD and MDNR water level records (MDNR, 2022).

Table 3.7.1 summarizes the locations of gauging stations, locations with transducers were installed, the flow measurements collected, and the source of the information.

Table 3.7.1: Staff Gauge Locations

Station Name	Location Details	Data Collected	Station Type	Source	Notes
RC Wetlands 1	Pre-Confluence Raleigh Creek	Water Level and Flow	Staff Gauge and Transducer	AECOM Installed and Collected	Rating curve developed
RC Wetlands 2	Pre-Confluence Raleigh Creek	Water Level and Flow	Staff Gauge and Transducer	AECOM Installed and Collected	Rating curve developed
RC Post RR 1	Pre-Confluence Raleigh Creek	Water Level and Flow	Staff Gauge and Transducer	AECOM Installed and Collected	Rating curve developed
RC Pond Sys 1	Pre-Confluence Raleigh Creek	Water Level and Flow	Staff Gauge and Transducer	AECOM Installed and Collected	Rating curve developed
RC Pond 1	North Pond at AGWC	Water Level	Staff Gauge Station	AECOM Installed and Collected	Removed due to dry conditions of pond
RC Pond 2	South Pond at AGWC	Water Level	Staff Gauge Station	AECOM Installed and Collected	-
RC Pond Sys 2	Pre-Confluence Raleigh Creek	Water Level and Flow	Staff Gauge and Transducer	AECOM Installed and Collected	Rating curve developed
RC Intermittent 1	Pre-Confluence Raleigh Creek	Water Level and Flow	Staff Gauge and Transducer	AECOM Installed and Collected	Rating curve developed
RC Intermittent 2	Pre-Confluence Raleigh Creek	Water Level and Flow	Staff Gauge and Transducer	AECOM Installed and Collected	Removed after determination of redundancy
RC Intermittent 3	Pre-Confluence Raleigh Creek	Water Level and Flow	Staff Gauge and Transducer	AECOM Installed and Collected	Rating curve developed

Station Name	Location Details	Data Collected	Station Type	Source	Notes
RC Confluence 1	Post-Confluence Raleigh Creek	Water Level and Flow	Staff Gauge and Transducer	AECOM Installed and Collected	Rating curve developed
RC Confluence 2	Post-Confluence Raleigh Creek	Water Level and Flow	Staff Gauge and Transducer	AECOM Installed and Collected	Rating curve developed
Eagle Point Lake	-	Water Level	Staff Gauge	MDNR Data and AECOM Collected	-
DG Eagle 1	Channel downstream of Eagle Point Lake	Water Level	Staff Gauge	AECOM Installed and Collected	Channel too deep to safely collect flow measurements
DG Eagle 3	Channel downstream of Eagle Point Lake	Water Level	Staff Gauge and Transducer	AECOM Installed and Collected	Channel too deep to safely collect flow measurements
Margaret Lake	-	Water Level	Staff Gauge	AECOM Installed and Collected	Removed due to lack of hydrologic connection to Project 1007 Corridor
Unnamed Pond	Formerly Park Pond in Eagle Point Lake	Water Level	Staff Gauge	AECOM Installed and Collected	Removed due to lack of hydrologic connection to Project 1007 Corridor
Browns Pond	-	Water Level	Staff Gauge	AECOM Installed and Collected	Removed due to lack of hydrologic connection to Project 1007 Corridor
Lake Elmo	-	Water Level	Staff Gauge	MDNR Data and AECOM Collected	-
DG Elmo 1	Channel downstream of Lake Elmo	Water Level and Flow	Staff Gauge	AECOM Installed and Collected	Rating curve developed
DG Elmo 2	Channel downstream of Lake Elmo	Water Level and Flow	Staff Gauge	AECOM Installed and Collected	Removed due to clogged infrastructure resulting in inaccurate representation of hydrologic conditions
DG Horseshoe 1	Channel downstream of Horseshoe Lake	Water Level and Flow	Staff Gauge	AECOM Installed and Collected	Rating curve developed
DG Horseshoe 2	Channel downstream of Horseshoe Lake	Water Level and Flow	Staff Gauge	AECOM Installed and Collected	Rating curve developed
North Pond	-	Water Level	Staff Gauge	MDNR Data and AECOM Collected	-
North Channel 1	Channel downstream of North Pond	Water Level and Flow	Staff Gauge and Transducer	AECOM Installed and Collected	Rating curve developed
North Channel 2	Channel downstream of North Pond	Water Level and Flow	Staff Gauge and Transducer	AECOM Installed and Collected	Rating curve developed
Middle Pond	-	Water Level	Staff Gauge	AECOM Installed and Collected	-
South Pond	-	Water Level	Staff Gauge	MDNR Data and AECOM Collected	-

Station Name	Location Details	Data Collected	Station Type	Source	Notes
Battle Creek Lake	Expanded Domain Water Body	Water Level	Staff Gauge	MDNR Data	-
Beaver Lake	-	Water Level	Staff Gauge	MDNR Data	-
Carver Lake	-	Water Level	Staff Gauge	MDNR Data	-
Colby Lake	-	Water Level	Staff Gauge	MDNR Data	-
Beutels Pond	-	Water Level	Staff Gauge	MDNR Data	-
Echo Lake	-	Water Level	Staff Gauge	MDNR Data	-
Goose Lake	-	Water Level	Staff Gauge	MDNR Data and AECOM Collected	-
Horseshoe Lake	-	Water Level	Staff Gauge	MDNR Data and AECOM Collected	-
Lake Edith	-	Water Level	Staff Gauge	MDNR Data and AECOM Collected	-
Lake Jane	-	Water Level	Staff Gauge	MDNR Data and AECOM Collected	-
Lake Olson	-	Water Level	Staff Gauge	MDNR Data and AECOM Collected	-
Long Lake	-	Water Level	Staff Gauge	MDNR Data	-
Markgraf Lake	-	Water Level	Staff Gauge	MDNR Data	-
Powers Lake	-	Water Level	Staff Gauge	MDNR Data	-
Silver Lake	-	Water Level	Staff Gauge	MDNR Data	-
Sunfish Lake	-	Water Level	Staff Gauge	MDNR Data and AECOM Collected	-
Tanners Lake	-	Water Level	Staff Gauge	MDNR Data	-
Tartan Pond	-	Water Level	Staff Gauge	AECOM Installed and Collected	-
Wilmes Lake	-	Water Level	Staff Gauge	MDNR Data	-

3.7.2 Well Gauging Activities

Following the installation of the first 12 monitoring wells at eight beta site locations, regular measurements of groundwater levels from each monitoring well began in June 2020. As with surface water gauging activities, monitoring wells were gauged monthly and at the start of each sampling event to assess seasonal fluctuation, response to meteorological events, and connection to surface water bodies. In April 2023, gauging of the monitoring well network was reduced to a quarterly frequency interval that corresponded with the start of each sampling event. To gauge the static water level within a well, a water level meter probe attached to high-tensile stainless-steel tape jacketed in polyethylene was lowered into the well until contact with the static water level triggered the meter’s alarm. The depth to this water level was recorded from the top of the well casing. The water level meter probe was decontaminated between wells using a solution of PFAS-free water and Alconox. The well gauging network included each AECOM-installed well at the time of each gauging event, expanding to the current well network of 105 monitoring wells as new wells were installed. **Figures 34 to 39** show the wells where groundwater gauging was completed. Water-level transducers were installed at select monitoring wells to capture the response, if any, to precipitation events and to evaluate suspected surface water–to-groundwater connection at those locations. These locations were adjusted based on the observed response and after discussions with MPCA. Transducers were initially placed in wells in all aquifers with distribution throughout the Site. Multiple transducers were also deployed in single well nests to assess the vertical gradient. However, as some wells were not observed to fluctuate in water level, transducers were moved to wells with larger and more frequent changes in water levels. Wells without transducers were gauged monthly.

The field forms associated with the well gauging activities are provided in **Attachment E-1**. Stacked hydrographs were developed for AECOM-installed wells and are included in **Attachment E-2.** A complete tabulation of well gauging measurements is included in **Attachment E-3**.

3.7.3 Slug Testing

AECOM personnel performed a series of slug tests following the construction of each of the 66 bedrock wells. The intent of slug testing was to induce an instantaneous change in the static water level in the formation screened by a well and to measure the resultant water level response (i.e., rising or falling head) of the groundwater in the well. The well response data were evaluated to determine the horizontal hydraulic conductivity of the monitored unit.

Prior to each slug test, details regarding the well geometry and the static water level within or above the screened interval were reviewed using well construction logs and field measurements. After determining the height of the water column in the well and whether the water column intersected the screened interval, field personnel slowly lowered a corded transducer and secured it at a sufficient depth in the water column such that the introduced slug would not impact the transducer. Once the transducer was fully submerged and the groundwater elevation was allowed to equilibrate, a corded solid slug was dropped down the well to induce sufficient groundwater displacement. This displacement commenced the "rising head" displacement test. Once the water level returned to static conditions, a new data log was started, and the slug was quickly pulled out of the water to induce the "falling head" displacement test. The slug was hung carefully just above the water table by wrapping the slug cord around the well riser several times. When the water level recovered to at least 90% of the original static water level prior to the test, the test was stopped, and the response data was stored as a separate data log. A detailed discussion regarding slug testing procedures can be found in the Slug Testing SOP (**Attachment A-4**). Initial slug test results were submitted to MPCA in 2020 along with the analysis methods details (AECOM, 2020a).

Two to three separate tests comprising both rising head and falling head displacement tests were conducted at each well to confirm that the response data was reproducible and to ensure that multiple datasets were available if one dataset was unusable.

3.7.4 Aquifer Pumping Tests

In addition to individual well slug testing, three beta site locations (BS5, BS7, and BS20) were selected for aquifer pumping tests to better assess the hydraulic properties of the Shakopee and Jordan Aquifers, both of which are sources of drinking water in the East Metropolitan Area. BS5 was selected to assess the impact of Lake Elmo and the underlying buried bedrock valley on aquifer characteristics in the Jordan Aquifer. BS20 was selected as representative of Shakopee and Jordan Aquifer hydrogeologic characteristics in western Lake Elmo. BS7 was selected as representative of Shakopee Aquifer hydrogeologic characteristics in eastern Lake Elmo with proximity to a shallow branch of the buried bedrock valley. Hydraulic properties assessed include horizontal hydraulic conductivity, transmissivity, and storativity (specific storage). The Shakopee Aquifer, Jordan Aquifers, and the Oneota Formation, which is the vertical aquitard stratigraphically positioned between the two aquifers, vary in competence, thickness, and extent throughout the Site. This hydrogeologic variation is due to the presence of overlying aquifers and aquitards with varying competence, depth from first encountered bedrock, proximity to buried bedrock valleys, and position relative to regional bedrock groundwater divides. Given this variability, a detailed assessment of the hydraulic properties of the three formations was warranted to understand groundwater flow within and between the Shakopee and Jordan Aquifers.

As depicted on **Figure 41**, aquifer pumping tests were performed in the Jordan Aquifer at BS5 and BS20 and in the Shakopee Aquifer at BS7 and BS20. All four of these tests required the installation of additional pumping and observation wells screened in the pumped, overlying, and underlying aquifers and aquitards. For comparison purposes, slug testing was also performed on each of the pumping and observation wells. **Table 3.7.4** provides details of the aquifer pumping tests.

Table 3.7.4: Aquifer Pumping Test Details

Pumping Test Area	Tested Aquifer	Monitored Units for Response	Pumping Test Dates	Pumping Well	Observation Well Network
Area 1 (BS5)	Jordan	Jordan Aquifer, Oneota Aquitard, Shakopee Aquifer	September – October 2021	PW5J-1	MW4A, MW5A, OW5J-1, OW5O-1, OW5J-2, and OW5J-3
Area 2 (BS20)	Jordan	Jordan Aquifer, Shakopee Aquifer	November 2021	PW20J-1	OW20J-1, OW20S-1, OW20J-2, and OW20J-3
Area 2 (BS20)	Shakopee	Jordan Aquifer, Oneota Aquitard, Shakopee Aquifer, St. Peter Aquitard, St. Peter Aquifer	October – November 2022	PW20S-1	OW20J-1, OW20S-1, OW20S-2, OW20S-3, OW20T-1, and OW20P-1
Area 3 (BS7)	Shakopee	Jordan Aquifer, Shakopee Aquifer, Quaternary Aquifer	September – October 2022	PW7S-1	OW7Q-1, OW7S-1, OW7S-2, OW7S-3, and MW7A

Details regarding the methods, results, and conclusions of the four aquifer pumping tests are provided in the corresponding final reports (AECOM, 2021c; AECOM, 2022b; AECOM 2023a; AECOM 2023b).

4 Summary of Investigation Results

This section summarizes the results of the source assessment investigations conducted by AECOM for the various source media types as well as historical data for wells in the vicinity of the Site and the hydrologic and hydrogeologic investigations. Analytical results for PFAS compounds are discussed in relation to applicable screening criteria to identify impacted media across the site. Hydrologic and hydrogeologic investigation results shed light on the conveyance of PFAS across the Site through surface water and groundwater flow.

4.1 Per- and Polyfluoroalkyl Substances Analytical Results

Section 4.1 details the PFAS and PFOS laboratory analytical results for samples collected by AECOM in surface water, foam, sediment, groundwater, and soil at the Site. Select PFAS compounds are discussed within these Sections based on applicable screening criteria for each studied media. Tables and laboratory analytical reports referenced below include the full datasets.

4.1.1 Surface Water

The MPCA established site-specific Water Quality Criteria (WQC) for various surface water bodies, referred to as Classes, associated with fish consumption, recreation, and domestic consumption. Because of the potential for infiltration of surface water into drinking water aquifers, this set of criteria for the Class 1 (domestic consumption), Class 2A (cold water habitat), and Class 2Bd (warm water habitat that is also protected as a source for drinking waters) was selected for review against the Project 1007 surface water bodies. The WQCs were defined for PFOS (0.05 nanogram per liter [ng/L]), perfluorooctanoic acid (PFOA) (25 ng/L), perfluorobutanoic acid (PFBA) (5700 ng/L), perfluorobutane sulfonic acid (PFBS) (140 ng/L), perfluorohexane sulfonic acid (PFHxS) (20 ng/L), and perfluorohexanoic acid (PFHxA) (220 ng/L). Additionally, Swimming Screening Values (SSVs) for PFOS and PFOA were established at 330 ng/L and 1900 ng/L, respectively, both of which are higher than their respective WQC.

The following sections summarize PFAS impacts within the surface water bodies across the Site as divided into eight distinct areas of the surface water regime. As described in Section 2.4, these areas include: the Tri-Lakes (**Figure 2**), Sunfish Lake (**Figure 5**), Raleigh Creek (**Figures 6 and 7**), Eagle Point Lake (**Figure 8**), Lake Elmo (**Figures 5 and 8**), Horseshoe Lake (**Figure 9**), the West Lakeland Ponds (**Figure 9**), and Other Disconnected Water Bodies **(Figure 11**). Specifically, these sections present exceedances of the WQCs, exceedances of the SSV in recreational water bodies, and identify where site-wide maximum concentrations were observed. When applicable, trends associated with seasonal or meteorological variation are also discussed. Where appropriate, these sections further discuss the hydrologic properties of the areas as they relate to the distribution and movement of PFAS impacts within these surface water bodies.

Figures 42 through 47 present the maximum reported concentrations of the six discussed PFAS compounds from sampled surface water locations for the Site. The results along the Project 1007 Corridor are shown on **Figures 48 through 53**. A complete tabulation of surface water PFAS analytical results is provided for the six discussed PFAS compounds and other PFAS compounds in **Appendices F-1 and F-2**, respectively.

4.1.1.1 Site-Wide Overview

Each surface water sample analyzed either exceeded the WQC for PFOS or was below a laboratory detection limit that was higher than the WQC. Of 165 sample locations sampled, 101 exceeded the PFOA WQC and 28 of 165 sample locations exceeded the PFHxS WQC. Thirty-nine of 165 sample locations exceeded the PFOS SSV of 330 ng/L, and four of 165 sample locations exceeded the PFOA SSV of 1900 ng/L. All sample locations with PFOS and PFOA SSV exceedances were within Pre-Confluence Raleigh Creek. Of approximately 800 surface water samples, three samples exceeded the PFBA WQC, two collected from WCL and one collected from Sunfish Lake. Exceedances of the PFHxA WQC were observed at two locations, one location at WCL and one location along Pre-Confluence Raleigh Creek immediately downstream of ODS. Concentrations of PFBS did not exceed the WQC for any surface water sample collected.

PFOS concentrations in the Site's surface water bodies ranged from below the laboratory detection limit to 8810 ng/L, which was collected from Pre-Confluence Raleigh Creek location RC3 in May 2020. Generally, concentrations of PFOS were highest along Pre-Confluence Raleigh Creek immediately downstream of ODS and decreased steadily with distance from the source area, as shown on **Figure 48**. Maxima that contradict this trend further downstream occurred at the eastern lobes of Eagle Point Lake.

PFOA concentrations in surface water ranged from below the laboratory detection limit to 2690 ng/L, which was collected from Pre-Confluence Raleigh Creek location RC3A in May 2024. PFOA concentrations generally mirrored PFOS concentrations with the highest concentrations immediately downstream of ODS in Pre-Confluence Raleigh Creek, as shown on **Figure 49**. Relatively high PFOA concentrations were observed in Sunfish Lake Park, which is hydrogeologically downgradient of WCL.

PFBA concentrations in surface water ranged from below the laboratory detection limit to 15700 ng/L, which was collected from WCL location WC5 in October 2024, as shown on **Figure 50**. PFBA concentrations were highest in Sunfish Park Lake, which is hydrogeologically downgradient of WCL. PFBA concentrations generally decreased with distance from both ODS and WCL, such that there were relatively low PFBA concentrations in the Project 1007 surface water flow path between the Raleigh Creek confluence and Lake Elmo.

PFBS concentrations in surface water ranged from below the laboratory detection limit to 88.3 ng/L, which was collected from Battle Creek location BL5 in July 2022, as shown on **Figure 51**. The highest concentrations of PFBS were observed immediately downstream of ODS in Pre-Confluence Raleigh Creek and in Battle Creek.

PFHxS concentrations in surface water ranged from below the laboratory detection limit to 242 ng/L. PFHxA concentrations in surface water ranged from below the laboratory detection limit to 272 ng/L. Maximum detected concentrations for PFHxA and PFHxS were both from the surface water sample collected from Pre-Confluence Raleigh Creek location RC3 in April 2020, as shown on **Figures 52 and 53**, respectively. Overall, PFHxS and PFHxA concentrations mirrored those of PFOS and PFOA, peaking in Pre-Confluence Raleigh Creek immediately downstream of ODS and decreasing with distance from the source area.

4.1.1.2 Tri-Lakes

The distribution and concentration of PFAS compounds in surface water from the Tri-Lakes downstream to the confluence with Raleigh Creek were consistent over time, with little to no seasonal or meteorological variation. While concentrations of PFBA were above laboratory detection limits, they were lower overall than those in other areas of the Site. Similarly, PFOS and PFOA concentrations in this area were above laboratory detection limits but were lower than in the overall corridor by at least an order of magnitude. PFOS impacts in Lake Olson were over three orders of magnitude lower than those in Raleigh Creek. For PFOA and PFBA, the highest concentrations were generally observed at the Tri-Lakes, while for all other compounds, the highest concentrations were generally observed farthest downstream of the Tri-Lakes. One sample collected in July 2024 from the north shore of Lake De Montreville (WC6) had unusually high PFAS concentrations: PFOS (405 ng/L), PFOA (135 ng/L), PFBA (513 ng/L), PFBS (5.99 ng/L), PFHxS (12.9 ng/L), and PFHxA (18.4 ng/L); a subsequent sample from the same location in October 2024 was more consistent with the PFAS concentrations typically observed in the Tri-Lakes area.

Table 4.1.1.1 summarizes the Tri-Lakes surface water PFAS concentrations. Concentrations are bolded if in exceedance of the WQC. There were no exceedances of the SSVs.

Table 4.1.1.1: Summary of Tri- Lakes Surface Water Results

Analyte	Mean Concentration* (ng/L)	Minimum Concentration (ng/L)	Minimum Sample Location Name	Maximum Concentration* (ng/L)	Maximum Sample Location Name
PFOS	**2.8**	**1.32**	RC1	**11.1**	RC14
PFOA	7.9	5.73	RC14	10.7	RC2
PFBA	90	29.6	RC2	182	RC2
PFBS	2.4	0.737	RC2	3.31	RC14
PFHxS	3.1	2.17	RC2	4.3	RC14
PFHxA	4.4	<9.2	RC14	6.3	RC14

* Mean and Maximum concentrations exclude the outlier Lake De Montreville sample (WC6) from 7/16/24.

4.1.1.3 Washington County Landfill and Sunfish Lake

PFOS and PFOA concentrations were generally similar in Sunfish Lake to other Project 1007 Corridor surface water bodies. PFBA was one order of magnitude greater in Sunfish Lake compared to the Project 1007 conveyance. When compared to Raleigh Creek and other major water bodies in the Project 1007 Corridor, PFOS concentrations in Sunfish Lake were among the lowest. As compared to Raleigh Creek specifically, PFOS concentrations were over three orders of magnitude lower. Compared to the Tri-Lakes, concentrations of PFBA in Sunfish Lake were up to two orders of magnitude greater.

Table 4.1.1.2 summarizes the WCL and Sunfish Lake surface water PFAS concentrations. Concentrations are bolded if in exceedance of the WQC. There were no exceedances of the SSVs.

Table 4.1.1.2: Summary of Washington County Landfill and Sunfish Lake Surface Water Results

Analyte	Mean Concentration (ng/L)	Minimum Concentration (ng/L)	Minimum Sample Location Name	Maximum Concentration (ng/L)	Maximum Sample Location Name
PFOS	**8.4**	**<3.35**	EP24	**53.7**	WC2
PFOA	**150**	2.76	WC3	**754**	WC5
PFBA	370	19.2	WC1	**15700**	WC5
PFBS	4.1	<1.53	WC3	14.1	WC5
PFHxS	4.3	<1.75	WC3	14.4	WC5
PFHxA	50	0.866	WC3	**227**	WC5

4.1.1.4 Raleigh Creek

PFOS concentrations exceeded the WQC in all surface water samples collected from Raleigh Creek. Thirty-one of 38 sampling locations along Raleigh Creek exceeded the PFOA WQC and 24 of 38 locations exceeded the PFHxS WQC. One of 38 sampling locations exceeded the PFHxA WQC. RC3, immediately downgradient of ODS in Pre-Confluence Raleigh Creek, exceeded the PFHxA WQC in five samples: one was collected in the February 2020 quarterly sampling event, two were collected during the April 2020 high-rain event, one was collected during the May 2020 quarterly sampling event, and one was collected during the March 2023 quarterly sampling event.

Along Pre-Confluence Raleigh Creek, concentrations of sampled compounds were the highest immediately downstream of ODS and steadily decreased with distance from that source area. Concentrations of PFAS compounds along Post-Confluence Raleigh Creek generally remained consistent down to the inlet with Eagle Point Lake. Stormwater inputs and tributaries to Raleigh Creek that are not hydrologically connected to ODS had lower PFAS concentrations and a relatively high proportion of PFBA, which was distinct from the relatively high proportion of PFOS observed in Raleigh Creek. Detections at these locations likely reflect ambient anthropogenic background PFAS levels rather than impacts from a known source area.

Precipitation events may trigger the release of PFAS trapped in surficial sediments at ODS and provide connections to otherwise disconnected PFAS-impacted waters such as isolated wetlands, small ponds, and shallow groundwater. Concentrations of PFOS, PFOA, and PFHxS fluctuated significantly along Pre- and Post-Confluence Raleigh Creek with higher concentrations typically observed during high-flow conditions, as shown on the RC3/RC Wetlands 1 and RC23/RC23 Pond graphs in **Attachment G-1**. During high-flow conditions, due to precipitation or snowmelt, the volume of PFAS-impacted water that exits ODS via Pre-Confluence Raleigh Creek increases and surface water flows uninterrupted through the intermittent portion of Raleigh Creek to the confluence with the Tri-Lakes Discharge. The increase in Post-Confluence Raleigh Creek surface water PFAS concentrations associated with flow across the intermittent portion of Raleigh Creek is best observed in the February, April, May, and June 2020 sampling event data as shown on the RC21/RC Confluence 1 graph in **Attachment G-1**. Analytical data collected prior to staff gauge installation are included because, as discussed in Section 3.2.3, this period had particularly high precipitation and snowmelt such that there were multiple instances of Raleigh Creek flowing continuously. For events when Raleigh Creek is flowing continuously and Post-Confluence Raleigh Creek surface water does not reflect the same increase in PFAS concentrations, Tri-Lakes discharge flow could potentially have diluted the Post-Confluence Raleigh Creek surface water. The variability and proportionality of flow from Pre-Confluence Raleigh Creek and the Tri-Lakes discharge to Post-Confluence Raleigh Creek are not fully understood.

Table 4.1.1.3 summarizes the Raleigh Creek surface water PFAS concentrations. Concentrations are bolded and/or italicized if in exceedance of the WQC and/or SSV, respectively.

Table 4.1.1.3: Summary of Raleigh Creek Surface Water Results

Analyte	Mean Concentration (ng/L)	Minimum Concentration (ng/L)	Minimum Sample Location Name	Maximum Concentration (ng/L)	Maximum Sample Location Name
PFOS	***1800***	**1.64**	RC17	***8810***	RC3
PFOA	**600**	2.53	RC3	***2690***	RC3
PFBA	390	13.2	RC3	1290	RC5
PFBS	22	<5.72	RC8	81.4	RC3
PFHxS	77	<0.372	RC3	**242**	RC3
PFHxA	74	<9.2	RC17	**272**	RC3

4.1.1.5 Eagle Point Lake

PFOS concentrations exceeded the WQC in all samples collected from Eagle Point Lake. Nearly every location sampled (28 out of 32) exceeded the PFOA WQC. Only two of 32 sample locations exceeded the PFHxS WQC. Elevated concentrations of PFOS, PFOA, and PFBA were consistently observed in samples collected from Eagle Point Lake, with a PFOS-dominant signature similar to that of Pre-Confluence Raleigh Creek. Although Post-Confluence Raleigh Creek, which had fluctuating concentrations and distributions of PFAS compounds, is the primary surface water input into Eagle Point Lake, PFOS, PFOA, and PFBA concentrations in the lake were relatively stable under upstream flow conditions, as shown in the EP26A/EP26D/Eagle Point Lake graphs in **Attachment G-1**. Multiple factors may influence elevated concentrations of PFAS in Eagle Point Lake, including shallow groundwater discharge, sorption and leaching from PFAS-impacted sediments, and dispersion and mixing effects associated with large water bodies. Within Eagle Point Lake, the highest PFOS, PFOA, and PFHxA concentrations were observed in the eastern and southeastern lobes.

Table 4.1.1.4 summarizes the Eagle Point Lake surface water PFAS concentrations. Concentrations are bolded and/or italicized if in exceedance of the WQC and/or SSV, respectively.

Table 4.1.1.4: Summary of Eagle Point Lake Surface Water Results

Analyte	Mean Concentration (ng/L)	Minimum Concentration (ng/L)	Minimum Sample Location Name	Maximum Concentration (ng/L)	Maximum Sample Location Name
PFOS	***500***	**2.44**	RC18	***5340***	EP26
PFOA	**115**	6.85	RC18	**627**	EP17
PFBA	150	52.5	FP1	895	EP10
PFBS	6.2	<5.64	EP2	19.8	EP17
PFHxS	12	1.39	FC2	**41.3**	EP17
PFHxA	16	<9.2	RC18	58.9	EP17

4.1.1.6 Lake Elmo

Each sample location in Lake Elmo exceeded the WQC for PFOS and PFOA, and one location exceeded the PFOS SSV. None of the sample locations had WQC exceedances for PFBA, PFBS, PFHxA, or PFHxS. Lake Elmo and nearby Sunfish Lake both had PFBA-dominant, high PFAS concentration signatures. PFBA concentrations in Lake Elmo are elevated compared to concentrations in Eagle Point Lake and in Raleigh Creek immediately upstream of Eagle Point Lake. Surface water PFOS concentrations are several times lower in Lake Elmo and downgradient areas than they are in upgradient Eagle Point Lake. Surface water PFOA concentrations are slightly lower in Lake Elmo and downgradient areas than in upgradient Eagle Point Lake.

The similar distribution of PFAS impacts in Lake Elmo and Sunfish Lake suggests a possible groundwater–surface water connection between the two lakes. The combination of a PFBA-dominant signature with elevated PFBA concentrations when compared to Site-wide PFBA concentrations suggests WCL contributes to PFAS impacts in Lake Elmo. PFOA and PFBA concentrations do not appear to be influenced by flow conditions, suggesting their primary migration pathway into Lake Elmo may be groundwater. PFOS concentrations are more variable and slightly elevated in Lake Elmo compared to Sunfish Lake, potentially due to variations in shallow groundwater flow and occasional surface water inputs from Eagle Point Lake via the secondary discharge pipe at the Eagle Point Lake Dam. PFOS variability in Lake Elmo suggests there are connections to upstream ODS impacts. Downgradient of Lake Elmo at the combined Eagle Point Lake and Lake Elmo discharge, variability in flow volume from the two lakes likely contributes to differences in PFOS and PFOA concentration ranges as shown in the EP16/DG Elmo 2 graphs in Attachment G-1. The area surrounding EP16 and DG Elmo 2 is susceptible to flooding and is impacted by flow through a downgradient culvert, which was observed to occasionally become blocked by debris. Based on these factors, surface water elevation at DG Elmo 2 is not representative of flow conditions and cannot be correlated to PFAS concentrations.

Table 4.1.1.5 summarizes the Lake Elmo surface water PFAS concentrations. Concentrations are bolded and/or italicized if in exceedance of the WQC and/or SSV, respectively.

Table 4.1.1.5: Summary of Lake Elmo Surface Water Results

Analyte	Mean Concentration (ng/L)	Minimum Concentration (ng/L)	Minimum Sample Location Name	Maximum Concentration (ng/L)	Maximum Sample Location Name
PFOS	**130**	**45.1**	EP21	***482***	EP20
PFOA	**73**	**51.3**	EP20	**105**	EP20
PFBA	680	90.8	EP20	1170	EP21
PFBS	3.5	1.25	EP9	5.6	EP20
PFHxS	7.6	4.93	EP21	13	EP20
PFHxA	16	7.66	EP20	22	EP21

4.1.1.7 Horseshoe Lake

PFOS concentrations in Horseshoe Lake were lower than the western portion of the Project 1007 Corridor by an order of magnitude. The western areas with lower overall impacts, including the Tri-Lakes, Tri-Lakes Discharge, and Post-Confluence Raleigh Creek, have either intermittent or no surface water connection with Raleigh Creek, which flows directly from ODS. PFOS concentrations appear to have a direct relationship with flow conditions, while PFOA and PFBA concentrations remain relatively consistent regardless of flow. PFOS variability may be due to changes in surface water flow from Eagle Point Lake.

Table 4.1.1.6 summarizes the Horseshoe Lake surface water PFAS concentrations. Concentrations are bolded and/or italicized if in exceedance of the WQC and/or SSV, respectively.

Table 4.1.1.6: Summary of Horseshoe Lake Surface Water Results

Analyte	Mean Concentration (ng/L)	Minimum Concentration (ng/L)	Minimum Sample Location Name	Maximum Concentration (ng/L)	Maximum Sample Location Name
PFOS	**160**	**48.2**	EP16	***748***	EP16
PFOA	**79**	**49**	EP13	**253**	EP16
PFBA	570	214	EP13	1210	EP16
PFBS	4.0	<5.53	WL3	9.51	EP16
PFHxS	8.7	5.04	EP16	17.3	EP16
PFHxA	15	7.93	WL6	28.9	EP16

4.1.1.8 West Lakeland Ponds

The West Lakeland Ponds mirror the results of Horseshoe Lake: PFOS concentrations were an order of magnitude lower than the western portion of the Project 1007 Corridor. The areas with lower overall impacts, including the Tri-Lakes Area and Post-Confluence Raleigh Creek, have either intermittent or no surface water connection with Raleigh Creek, which flows directly from ODS. Seasonal variation and precipitation events appear to have minimal effect on PFAS impacts in the West Lakeland Ponds area, except under very high (Spring 2020) or very low (Summer/Fall 2021) flow conditions. PFOS concentrations appear to have a direct relationship with flow conditions, potentially due to changes in surface water flow from Eagle Point Lake, while PFOA and PFBA concentrations remain consistent regardless of flow.

Table 4.1.1.7 summarizes the West Lakeland Ponds surface water PFAS concentrations. Concentrations are bolded and/or italicized if in exceedance of the WQC and/or SSV, respectively.

Table 4.1.1.7: Summary of West Lakeland Ponds Surface Water Results

Analyte	Mean Concentration (ng/L)	Minimum Concentration (ng/L)	Minimum Sample Location Name	Maximum Concentration (ng/L)	Maximum Sample Location Name
PFOS	**170**	**2.59**	WL18	***736***	WL15
PFOA	**73**	6.42	WL18	**193**	WL15
PFBA	410	92.1	WL18	961	WL11
PFBS	4.2	<5.54	WL15	7.16	WL15
PFHxS	9.3	1.35	WL18	14.5	WL15
PFHxA	14	3.38	WL18	22.7	WL15

4.1.1.9 Other Water Bodies

Several water bodies disconnected from the main Project 1007 Corridor were evaluated as part of the Site investigation. As discussed in Section 2.4.8, these water bodies fall into three general areas: isolated perched water bodies in Lake Elmo, the Valley Branch Creek System and Lake Edith, and the water bodies identified in the expanded portion of the Site. As with the Project 1007 Corridor water bodies, samples from these disconnected water bodies either exceeded the WQC for PFOS or were below a laboratory detection limit that was above the WQC. Exceedances of the PFOA WQC were observed in isolated ponds downstream of Eagle Point Lake and Lake Elmo. No exceedances of PFBA, PFHxA, PFHxS, or PFBS were observed. No apparent response to seasonal variation or meteorological events was observed in sample locations from these water bodies.

Down's Lake and Legion's Pond east of Lake Elmo and Margaret Lake, Brown's Pond, and Park Pond southeast of Eagle Point Lake are small, disconnected water bodies that were sampled to determine the extent of impacts outside of the Project 1007 Corridor surface water flow path and to assess surface water–groundwater connections to larger water bodies with known impacts (**Figure 11**). Like Lake Elmo and Sunfish Lake, PFBA was the dominant compound in all five smaller, disconnected water bodies. However, the concentrations of PFBA in the five water bodies were one and two orders of magnitude lower than Lake Elmo and Sunfish Lake, respectively.

All five water bodies were an order of magnitude lower in PFOS concentrations than Lake Elmo and more than two orders of magnitude lower than Eagle Point Lake. Site-wide, PFAS concentrations in these five water bodies are among the lowest in surface water bodies. The combination of overall low PFAS concentrations and a PFBA-dominant distribution of PFAS compounds suggests the PFAS impacts in these water bodies are the result of ambient anthropogenic background.

Table 4.1.1.8 through Table 4.1.1.10 summarize the surface water PFAS concentrations from the isolated perched water bodies in Lake Elmo, the Valley Branch Creek System and Lake Edith, and the water bodies identified in the expanded portion of the Site, respectively. Concentrations are bolded if in exceedance of the WQC. There were no exceedances of the SSVs.

Table 4.1.1.8: Summary of Lake Elmo Isolated Perched Water Bodies Surface Water Results

Analyte	Mean Concentration (ng/L)	Minimum Concentration (ng/L)	Minimum Sample Location Name	Maximum Concentration (ng/L)	Maximum Sample Location Name
PFOS	**18**	**1.24**	BP1	**157**	WL1
PFOA	21	3.43	DL1	**81**	ML1
PFBA	150	30.6	GL1	439	WL1
PFBS	2.6	<0.73	GL1	7.2	ML1
PFHxS	3.8	<0.363	DL1	6.82	WL1
PFHxA	8.7	<9.2	BP1	32	ML1

Table 4.1.1.9: Summary of Valley Branch Creek System and Lake Edith Surface Water Results

Analyte	Mean Concentration (ng/L)	Minimum Concentration (ng/L)	Minimum Sample Location Name	Maximum Concentration (ng/L)	Maximum Sample Location Name
PFOS	**9.2**	**<0.367**	VB6	**14.5**	VB3
PFOA	7.7	2.1	VB5	16.1	VB1
PFBA	240	136	VB1	325	VB4
PFBS	2.4	1.21	VB4	5.86	VB1
PFHxS	2.4	1.02	VB6	5.03	VB1
PFHxA	3.6	<9.2	VB3	11	VB1

Table 4.1.1.10: Summary of Expanded Site Surface Water Results

Analyte	Mean Concentration (ng/L)	Minimum Concentration (ng/L)	Minimum Sample Location Name	Maximum Concentration (ng/L)	Maximum Sample Location Name
PFOS	**35**	**<3.17**	BL3	**198**	OD3
PFOA	23	<3.17	BL3	**73**	OD3
PFBA	170	22	CL1	327	TL1
PFBS	9.2	<3.17	BL3	88.3	BL5
PFHxS	79	<2.84	TL3	105	BL5
PFHxA	11	<3.17	BL3	32.4	BL5

4.1.2 Foam and Surface Microlayer

Consistent with Section 3.3.1, foam and surface microlayer results were interpreted for indication and screening purposes only and were not compared to surface water WQC and SSV values. As of the date of this report, no regulatory agency has established limits for PFAS concentrations in foam. As such, this section of the report discusses concentrations of PFAS in foam in comparison to other foam samples collected from the Site.

Figures 54 through 60 present the concentrations of the six PFAS compounds and the HI in the collected foam samples. A complete tabulation of PFAS analytical results for collected foam and SML samples is provided in **Attachments F-3** (Key PFAS Compounds) **and F-4** (All Other Detected PFAS Compounds). PFOS was found to be present in the highest concentrations in foam across the Site with concentrations exceeding 1000 micrograms per liter (ug/L). These elevated concentrations were observed in Raleigh Creek immediately downstream of ODS and as far downstream of source areas as Horseshoe Lake. PFOA was present in the foam at lower concentrations compared to PFOS. The difference in the enrichment of these two PFAS into foam is likely a result of the differences in the chemistry associated with the head group (sulfonate versus carboxylate). Shorter chain PFAS (PFHxS, PFBS, and PFBA) were found at lower concentrations in the foam compared to PFOS and PFOA, likely because these PFAS are less hydrophobic and are present at lower concentrations in the surface water.

Foam with lower concentrations of PFOS (less than 0.5 ug/L) was observed within the Site, specifically within the Project 1007 conveyance upgradient of the confluence with Raleigh Creek, Goose Lake, Fredrich's Pond, Lake Elmo, and within the Project 1007 Corridor. Why there is so much variability in PFAS concentrations in foam is unclear. Factors potentially impacting the enrichment of PFAS into the foam could be the flow conditions, age of the foam (foam that appeared more deflated tended to have lower PFAS concentrations), and variability of naturally occurring organic matter. The enrichment of PFAS into the foam is outside the scope of this project and was not investigated further.

PFAS was not observed to enrich in the SML relative to the concentration observed in co-located surface water samples. This was likely a result of the locations selected for SML sampling and the timing of the samples. SML sampling was conducted in flowing waterways as opposed to lakes, except for Lake Elmo. However, Lake Elmo has relatively low concentrations of PFOS compared to other surface water bodies such as Eagle Point Lake. Based on observations of relatively lower PFOA concentration in foam samples, PFOA may similarly be less likely to enrich in the SML layer. The SML may also be less likely to form under turbulent flow. Based on these observations, Eagle Point Lake could potentially have elevated PFOS concentrations in the SML but was not sampled as part of this investigation.

In general, foam and SML were not found to be important factors in the fate and transport of PFAS within the surface water and migration to the groundwater. While PFAS does concentrate into foam and potentially the SML, it dissipates back into surface water when foam breaks up and when mixing occurs within the water column. Data indicate that the public should avoid foam in the Project 1007 Corridor given the high concentrations and potential for exposure.

4.1.3 Sediment

The MPCA established site-specific sediment screening values (SDSVs) for both 5-day/week and 2-day/week exposure scenarios associated with recreational activities in intertidal/littoral sediments within the Project 1007 Corridor, as outlined in **Table 4.1.3** below.

Table 4.1.3: 5-day and 2-day SDSVs

Analyte	5-day SDSV (ug/kg)	2-day SDSV (ug/kg)
PFOS	18	45
PFOA	0.40	0.99
PFBA	120000	250000
PFBS	1500	3700
PFHxS	170	430
PFHxA	2600	6600
HFPO-DA	160	390

The following sections provide a summary of sediment PFAS impacts, including exceedances of the 5-day and 2-day SDSVs, and observed site-wide maximum concentrations associated with the following surface water body groups across the Site:

- Pre-Confluence Raleigh Creek
- Tri-Lakes Discharge and Post-Confluence Raleigh Creek
- Eagle Point Lake
- Sunfish Lake and Lake Elmo
- West Lakeland Waterbodies, including Horseshoe Lake, West Lakeland Ponds, and connected channels
- Disconnected Waterbodies, including isolated perched water bodies within Lake Elmo, water bodies within the Valley Branch Creek System, and waterbodies identified in the expanded portion of the Site

Sediment PFAS concentrations generally follow surface water trends in that they decrease with distance from the source areas. As shown in **Attachment G-2**, sediment samples taken from depositional environments, such as wetlands and lakes, tended to have higher PFOS concentrations than samples taken from erosional environments, such as channels and creeks. In some cases, depositional environments such as Eagle Point Lake and the West Lakeland Ponds had low PFOS concentrations in sediment, likely due to sand-dominated composition. Most depositional sediments were dominated by organics or clayey sediments corresponding to a higher PFAS sorption potential, while erosional sediments were dominated by sand and gravel sediments corresponding to a relatively lower PFAS sorption potential. As discussed in the Project 1007 IAWC Investigation Summary Report, the highest PFAS concentrations in sediment at a given location were typically found in the shallowest sampling interval (AECOM, 2021b).

Over the 3-year sampling period, detection limits decreased for all seven PFAS compounds with established SDSVs because of improved laboratory analytical methods, resulting in various maximum concentrations observed below the detection limit.

Figures 61 through 66 present the maximum reported concentrations of six PFAS compounds from sampled surface sediment locations across the Site; there were no detections of hexafluoropropylene oxide dimer acid (HFPO-DA) in sediment. A complete tabulation of PFAS analytical results for all sediment samples is provided in **Attachments F-5** (Key PFAS Compounds) **and F-6** (All Other Detected PFAS Compounds).

4.1.3.1 Pre-Confluence Raleigh Creek

Of the six PFAS compounds detected at Pre-Confluence Raleigh Creek, the highest PFAS concentrations were observed in the 0- to 6-inch-depth interval and decreased with depth in sediment samples. Concentrations for each compound were generally greatest in the wetland complexes through which Raleigh Creek flows, including Upper Raleigh Creek Wetland Complexes and AGWC. These wetland complexes are immediately downstream from ODS. Of the 139 sampled locations, 117 exceeded the 5-day PFOS SDSV and 96 exceeded the 2-day PFOS SDSV. Of the 139 sediment sample locations, 132 exceeded the 5-day PFOA SDSV and 109 exceeded the 2-day PFOA SDSV. The lowest concentrations were observed in samples collected from the intermittent portion of the Pre-Confluence Raleigh Creek downstream of AGWC.

Figures 67 through 72 present the maximum reported concentrations for the six detected PFAS compounds with established SDSVs in the Upper Raleigh Creek Wetlands Complexes and AGWC. **Table 4.1.3.1** summarizes the sediment PFAS concentrations from Pre-Confluence Raleigh Creek.

Concentrations are bolded and/or italicized if in exceedance of the 5-day and/or 2-day SDSV, respectively.

Table 4.1.3.1: Summary of Pre-Confluence Raleigh Creek Sediment Results

Analyte	Mean Concentration (ug/kg)	Minimum Concentration (ug/kg)	Minimum Sample Location Name	Maximum Concentration (ug/kg)	Maximum Sample Location Name
PFOS	***110***	0.595	RC7	***2570***	RC3A
PFOA	***4.1***	<0.0362	RC7	***123***	RC3
PFBA	1.7	<0.142	RC27	39.2	RC3A
PFBS	0.12	<0.02	RC22	<1.6	RC6A
PFHxS	0.41	<0.0246	RC22	12.7	RC3A
PFHxA	0.39	<0.0355	RC27	6.29	RC3A
HFPO-DA	0.25	<0.0934	RC22	<1.6	RC22

4.1.3.2 Tri-Lakes Discharge and Post-Confluence Raleigh Creek

The lowest sediment PFAS concentrations in the Project 1007 conveyance were observed in the Tri-Lakes, Tri-Lakes Discharge, and Post-Confluence Raleigh Creek. Two of 15 sediment sample locations exceeded the 5-day SDSV for PFOA, both of which were in Post-Confluence Raleigh Creek. No other PFAS SDSV exceedances were observed in the Tri-Lakes, Tri-Lakes Discharge, or Post-Confluence Raleigh Creek.

Table 4.1.3.2 summarizes the sediment PFAS concentrations from Tri-Lakes Discharge and Post-Confluence Raleigh Creek. Concentrations are bolded and/or italicized if in exceedance of the 5-day and/or 2-day SDSV, respectively.

Table 4.1.3.2: Summary of Tri-Lakes Discharge and Post-Confluence Raleigh Creek Sediment Results

Analyte	Mean Concentration (ug/kg)	Minimum Concentration (ug/kg)	Minimum Sample Location Name	Maximum Concentration (ug/kg)	Maximum Sample Location Name
PFOS	3.5	<0.0739	RC1	14	RC18, RC18A
PFOA	0.30	<0.0739	RC1	**0.857**	RC17
PFBA	0.67	<0.153	RC18B	1.16	RC17
PFBS	All ND	<0.0382	RC18B	<1.5	RC18A, RC21A
PFHxS	0.86	<0.0382	RC18B	0.086	RC18
PFHxA	0.26	<0.0382	RC18B	<1.6	RC18A, RC21A
HFPO-DA	All ND	<0.145	RC18B	<1.6	RC18A, RC21A

4.1.3.3 Eagle Point Lake

Elevated concentrations of PFOS and PFOA were observed in sediment samples in and along Eagle Point Lake, with lower concentrations observed around isolated water bodies adjacent to the lake. Thirty-three of 58 sample locations exceeded the 5-day PFOS SDSV and 21 of 58 sample locations exceeded the 2-day PFOS SDSV. As for PFOA, 40 of 58 sample locations exceeded the 5-day SDSV and 23 of 58 sample locations exceeded the 2-day SDSV. There were no exceedances of 5-day or 2-day SDSVs for other compounds.

Figures 73 through 78 present the maximum reported concentrations for the six detected PFAS compounds with established SDSVs in Eagle Point Lake. **Table 4.1.3.3** summarizes the sediment PFAS concentrations from Eagle Point Lake. Concentrations are bolded and/or italicized if in exceedance of the 5-day and/or 2-day SDSV, respectively.

Table 4.1.3.3: Summary of Eagle Point Lake Sediment Results

Analyte	Mean Concentration (ug/kg)	Minimum Concentration (ug/kg)	Minimum Sample Location Name	Maximum Concentration (ug/kg)	Maximum Sample Location Name
PFOS	**42**	<0.038	FC2	***299***	EP26
PFOA	***2.0***	<0.038	FC2	***11***	EP27
PFBA	0.81	0.15	EP1	<4.2	EP27
PFBS	0.31	<0.04	EP1	<4.2	EP27
PFHxS	0.55	<0.0371	EP1	<2.7	EP1
PFHxA	0.30	<0.0368	EP28	<2.7	EP1
HFPO-DA	0.44	<0.134	EP17	<4.2	EP27

4.1.3.4 Sunfish Lake and Lake Elmo

PFOA was the only compound to exceed the 5-day SDSV or the 2-day SDSV in Lake Elmo sediment samples. The sediment sample location in Sunfish Lake (EP24) did not exceed the SDSVs for any of the seven PFAS compounds. The highest PFAS concentrations in sediment samples from Lake Elmo were observed at its northern extent just southeast of Sunfish Lake and at its southern extent east of Eagle Point Lake.

Table 4.1.3.4 summarizes the sediment PFAS concentrations from Sunfish Lake and Lake Elmo. Concentrations are bolded and/or italicized if in exceedance of the 5-day and/or 2-day SDSV, respectively.

Table 4.1.3.4: Summary of Sunfish Lake and Lake Elmo Sediment Results

Analyte	Mean Concentration (ug/kg)	Minimum Concentration (ug/kg)	Minimum Sample Location Name	Maximum Concentration (ug/kg)	Maximum Sample Location Name
PFOS	2.0	0.165	EP21A	5.46	EP19
PFOA	0.35	<0.0752	EP21A	**1.24**	EP9
PFBA	0.24	<0.301	EP21A	5.21	EP15
PFBS	All ND	<0.0752	EP21A	<0.171	EP9
PFHxS	All ND	<0.0752	EP21A	<0.171	EP9
PFHxA	0.033	<0.0752	EP21A	0.2	EP9
HFPO-DA	All ND	<0.286	EP21A	<0.684	EP9

4.1.3.5 West Lakeland Waterbodies

There were no exceedances of 5-day or 2-day PFAS SDSVs in sediment samples from the West Lakeland Waterbodies, except for one PFOA exceedance of the 5-day SDSV in the West Lakeland Ponds channel between North Pond and Middle Pond. **Table 4.1.3.5** summarizes the sediment PFAS concentrations from West Lakeland Waterbodies.

Table 4.1.3.5: Summary of West Lakeland Waterbodies Sediment Results

Analyte	Mean Concentration (ug/kg)	Minimum Concentration (ug/kg)	Minimum Sample Location Name	Maximum Concentration (ug/kg)	Maximum Sample Location Name
PFOS	2.0	0.287	EP13	8.59	WL21
PFOA	0.19	0.053	WL23	**0.47**	WL11
PFBA	0.58	0.171	WL23	<1.3	WL8
PFBS	0.42	<0.02	WL21	<1.3	WL8
PFHxS	0.42	<0.0254	WL23	<1.3	WL8
PFHxA	0.37	<0.0254	WL23	<1.3	WL8
HFPO-DA	0.55	<0.0947	WL21	<1.3	WL8

4.1.3.6 Disconnected Waterbodies

PFOS and PFOA were the only compounds in exceedance of either the 5-day SDSV or the 2-day SDSV in disconnected waterbody sediment samples. Of 31 sampled locations, one location exceeded the 5-day SDSV for PFOS and one location exceeded the 5-day and 2-day SDSVs for PFOA. Generally, sediment samples near these waterbodies exhibited lower concentrations than samples found in and around Pre-Confluence Raleigh Creek, Post-Confluence Raleigh Creek, and Eagle Point Lake and exhibited similar concentrations to samples collected in and around Sunfish Lake, Lake Elmo, and the West Lakeland Waterbodies. Higher concentrations for PFOS and PFOA were observed in samples adjacent to ODS, and above mean concentrations of PFOA were observed along Valley Branch Creek.

Table 4.1.3.6 summarizes sediment PFAS concentrations from the disconnected waterbodies. Concentrations are bolded and/or italicized if in exceedance of the 5-day and/or 2-day SDSV, respectively.

Table 4.1.3.6: Summary of Disconnected Waterbodies Sediment Results

Analyte	Mean Concentration (ug/kg)	Minimum Concentration (ug/kg)	Minimum Sample Location Name	Maximum Concentration (ug/kg)	Maximum Sample Location Name
PFOS	1.7	0.04	GC7	**38.1**	OD3
PFOA	0.17	<0.0318	CL1	***1.42***	OD3
PFBA	0.46	<0.139	OD4	2.1	GC1
PFBS	0.062	<0.03	CL1	0.26	OD3
PFHxS	0.068	<0.0318	CL1	0.305	OD3
PFHxA	0.076	<0.0347	OD4	0.418	OD3
HFPO-DA	0.22	<0.121	CL1	<0.903	TL3

4.1.4 Groundwater

Table 4.1.4 outlines the MDH-established HRLs and HBVs for the evaluation of potential risk to human health for exposure to PFAS in drinking water as well as the EPA MCLs. Regulatory values are subject to review and change; the subsequent sections of this report compare groundwater samples against regulatory criteria as established at the end of the data collection period reported in this document (October 2024).

Table 4.1.4: Established Groundwater Regulatory Values

Analyte	HRL (short-term, subchronic, and chronic exposure duration) (ng/L)	HBV (short-term, subchronic, chronic exposure duration) (ng/L)	HBV (cancer exposure duration) (ng/L)	MCL (ng/L)	Combination HI MCL (ng/L)*
PFOS	NS	2.3	7.6	4	-
PFOA	NS	0.24	0.0079	4	-
PFBA	7000	NS	NS	NS	-
PFBS	100	NS	NS	NS	1
PFHxS	47	NS	NS	10	1
PFHxA	200	NS	NS	NS	-
PFNA	NS	NS	NS	10	1
HFPO-DA	NS	NS	NS	10	1

* The HI MCL of 1 for the combination of PFNA, PFHxS, PFBS, and HFPO-DA is used to quantify additive impacts.

The following sections provide a summary of groundwater PFAS impacts within the two source areas and six groups of hydrogeologic units:

- ODS
- WCL
- Quaternary Aquifer
- Platteville Aquifer
- St. Peter Aquifer and Aquitard
- Shakopee Aquifer and Oneota Aquitard
- Jordan Aquifer
- Units stratigraphically below the Jordan Aquifer: St. Lawrence Aquitard, Tunnel City Group, and Wonewoc Aquifer

Specifically, these sections present exceedances of the HRLs and HBVs, where site-wide maximum concentrations are observed, and when applicable, any trends in impacts associated with seasonal or meteorological variation for the six currently regulated PFAS compounds.

Figures 79 through 120 present the aquifer-specific maximum reported concentrations of the six discussed PFAS compounds from groundwater samples collected from the monitoring well network. A complete tabulation of surface water PFAS analytical results for the six discussed PFAS compounds and other PFAS compounds is provided in **Attachments F-7 and F-8**, respectively. Additionally, branched-linear isomer analysis of PFOS was run on select surface water locations and select groundwater samples collected from wells and during drilling activities to develop a better understanding of points of surface water infiltration. While branched and linear PFOS compounds are similarly mobile in surface water, branched PFOS compounds are more mobile in groundwater than their linear counterparts. As such, groundwater that has a similar proportion of linear PFOS to nearby surface water is likely close to a point of infiltration. As PFOS in groundwater migrates farther from the point of infiltration, the relative branched fraction will increase. **Figures 121 through 128** depict the branched-linear analysis results for PFOS. A complete tabulation of results from the branched-linear analysis is provided in **Attachment F-9.**

Over the 5-year sampling period, detection limits decreased for the six PFAS compounds with regulatory criteria because of improved analytical methods, resulting in various maximum observed concentrations observed as below the detection limit.

Historical and current PFAS analytical data for wells located within the complete Site were provided by MDH and MPCA via digital correspondence on May 6, 2021, April 27, 2023, and August 8, 2024. These datasets were composed of PFAS analytical data as stored in the Minnesota EQuIS database and included results from November 2004 until July 2024. This dataset was supplemented with reported sampling results of the monitoring well network located at ODS as provided by 3M.

Where sufficient data were available, aquifer-specific interpolated plume maps were developed in Leapfrog Works modeling software using the MDH-provided analytical data in conjunction with groundwater analytical data collected during drilling activities and monitoring well sampling events. **Figures 129 through 158** present the plume maps for the six regulated PFAS compounds for the Quaternary Aquifer, St. Peter Aquifer, Prairie du Chien (Shakopee Aquifer and Oneota Aquitard), and Jordan Aquifer.

4.1.4.1 Site-wide Overview

Nearly 1300 groundwater samples were collected from monitoring wells in the eight hydrogeologic unit groups listed above.

- Each sample exceeded or had a detection limit that was above the HBVs for the short-term, subchronic, and chronic exposure durations and the cancer exposure duration for PFOA.
- Of 139 total wells sampled, 124 wells exceeded the short-term, subchronic, and chronic exposure duration PFOS HBV and 107 wells exceeded the cancer exposure duration PFOS HBV.
- Of 139 total wells sampled, 99 wells exceeded the PFOA HRL and 31 wells exceeded the PFOS HRL.
- Of 139 wells sampled, 15 exceeded the PFBA HRL, 28 exceeded the PFHxS HRL, 18 exceeded the PFHxA HRL, and seven exceeded the PFBS HRL.

The highest concentrations for sampled PFAS compounds were observed immediately downgradient of ODS except for concentrations of PFBA and PFOA, which were highest immediately downgradient of WCL. In general, fluctuations of PFAS concentrations associated with seasonal variation or meteorological events were observed primarily in groundwater samples collected from the Quaternary and St. Peter Aquifers immediately downgradient of Raleigh Creek and Eagle Point Lake (**Attachment G-5**). Samples collected from wells near Sunfish Lake Park and the St. Croix River generally exhibited lower concentrations for all compounds.

Several locations across the site were investigated for impacted surface water infiltration to shallow groundwater, including Pre-Confluence Raleigh Creek and AGWC, the confluence of Raleigh Creek with Project 1007, Eagle Point Lake, Lake Elmo, Horseshoe Lake, and the West Lakeland Ponds. At these locations, multiple lines of evidence support a surface water–to– shallow groundwater connection. Comparable PFAS distributions, similar proportions of branched-linear PFOS, and water levels indicating a downward vertical hydraulic gradient were observed at these locations. These data are shown in **Attachment G-4**.

PFAS concentrations and compound distribution (shown in **Attachment G-3**) variability with depth at beta sites and with distance horizontally indicates migration through bedrock aquifers. At BS2 (located next to the confluence of Raleigh Creek with the Project 1007 conveyance) the composition of groundwater PFAS impacts varies with depth. PFOS impacts associated with surface water infiltration from Raleigh Creek generally decrease with depth and there is a large drop in concentration from the Shakopee Aquifer to the Jordan Aquifer. PFOA concentrations generally decrease with depth. PFBA concentrations generally decrease with depth until the Shakopee Aquifer, where the concentrations increase comparable to water table impacts. The highest PFBA concentration observed at the beta site is in the Jordan Aquifer where there is also a higher proportion of PFOA to PFOS relative to what is observed in shallower bedrock aquifers. The changes in PFAS distribution with depth at BS2 suggest vertical migration of surface water PFAS impacts from Raleigh Creek associated with ODS (observed from the Quaternary to the Shakopee) and horizontal migration of groundwater PFAS impacts in bedrock associated with WCL (observed in the Shakopee and the Jordan).

PFOS concentrations in Site groundwater ranged from below the laboratory detection limit to 4,850 ng/L. PFOS concentrations were typically highest in wells immediately downgradient of AGWC while the lowest concentrations were observed in wells located along Sunfish Lake Park and Eagle Point Lake.

PFOA concentrations in Site groundwater ranged from below the detection limit to 1,300 ng/L. The highest PFOA concentrations were observed in wells immediately downgradient of AGWC, and the lowest concentrations were observed in wells located along Sunfish Lake Park and Eagle Point Lake. Lower concentrations were also observed closer to the St. Croix River in the St. Lawrence Aquitard, Tunnel City Group, and Wonewoc Aquifer.

PFBA concentrations in Site groundwater ranged from below the detection limit to 9,560 ng/L. The highest PFBA concentrations were observed in wells immediately downgradient of WCL while the lowest concentrations were observed in wells east of Lake Elmo toward the St. Croix River.

PFBS concentrations in Site groundwater ranged from below the detection limit to 136 ng/L. The highest PFBS concentrations were observed in wells immediately downgradient of ODS, AGWC, and the southern lobe of Eagle Point Lake. The lowest PFBS concentrations were observed in wells east of Lake Elmo toward the St. Croix River.

PFHxS concentrations in Site groundwater ranged from below the detection limit to 128 ng/L. The highest PFHxS concentrations were observed in wells immediately downgradient of ODS, AGWC, and the southern lobe of Eagle Point Lake. The lowest concentrations of PFHxS were observed in wells situated east of Lake Elmo toward the St. Croix River and along the northern edge of Eagle Point Lake.

PFHxA concentrations in Site groundwater ranged from below the detection limit to 1,460 ng/L. Generally, the highest concentrations of PFHxA were observed in wells immediately downgradient of ODS, AGWC, and WCL. The lowest concentrations were observed in wells closer the St. Croix River and along Eagle Point Lake.

4.1.4.2 Oakdale Disposal Site

Two wells in the ODS source area were routinely sampled, PL41 (screened in the Platteville Aquifer) and SP42 (screened in the St. Peter Aquifer). **Table 4.1.4.1** summarizes the groundwater PFAS concentrations in these wells. The HI exposure limit of 1 was exceeded in 27 groundwater samples collected from these wells.

Table 4.1.4.1: Summary of Oakdale Disposal Site Results

Analyte	Mean Concentration (ng/L)	Minimum Concentration (ng/L)	Minimum Sample Location Name	Maximum Concentration (ng/L)	Maximum Sample Location Name
PFOS	43	12.2	PL41	232	SP42
PFOA	77	1.58	SP42	149	PL41
PFBA	1200	<46.6	SP42	3200	PL41
PFBS	5.0	<1.54	SP42	9.46	PL41
PFHxS	4.5	<1.63	SP42	9.01	PL41
PFHxA	5.0	<1.54	SP42	261	PL41

4.1.4.3 Washington County Landfill

Groundwater sampling at wells in the WCL source area began in 2024. Wells within the source area are screened in the Quaternary, PDC, and Jordan Aquifers. Observed PFAS concentrations were highest on the southern side of the landfill property in the Quaternary Aquifer. The highest PFOA and PFBA concentrations observed within the Site were found at WCL with comparatively lower PFOS concentrations. PFAS concentrations were lowest in monitoring wells screened within deeper bedrock aquifers located directly west and east of the landfill property.

Table 4.1.4.2 summarizes the groundwater PFAS concentrations from wells located in the WCL source area. The HI exposure limit of 1 was exceeded in 20 groundwater samples collected from these wells.

Table 4.1.4.2: Summary of Washington County Landfill Results

Analyte	Mean Concentration (ng/L)	Min Concentration (ng/L)	Minimum Sample Location Name	Maximum Concentration (ng/L)	Maximum Sample Location Name
PFOS	94	<1.63	N/A	493	R2
PFOA	3100	0.781	WC5A	14300	R2
PFBA	54000	4.27	WC5A	412000	R2
PFBS	35	<160	N/A	272	R2
PFHxS	52	<1.77	WC5A	250	R2
PFHxA	700	<1.54	WC5A	3850	R2

4.1.4.4 Quaternary Aquifer

Quaternary Aquifer samples were collected from 50 locations, including groundwater wells, piezometers, and VAP sampling locations. Of the 50 locations sampled, 37 had exceedances of the short-term, subchronic, and chronic exposure duration PFOS HBV. Additionally, 30 of 50 locations had exceedances of the cancer exposure duration PFOS HBV. The PFOS HRL was exceeded in samples at 15 of 50 locations.

All 50 sample locations had exceedances of the short-term, subchronic, and chronic exposure duration HBV and the cancer exposure duration HBV for PFOA. The PFOA HRL was exceeded in 28 of 50 locations. Additionally, six locations had exceedances of the PFHxS HRL, one sample from PZCS exceeded the PFHxA HRL, and no samples exceeded the HRLs for PFBA or PFBS. The HI was on average 1.5 times greater than the threshold for adverse acute non-cancer health impacts, which is set at 1.

PFOS and PFOA concentrations were elevated directly downgradient of ODS and WCL and near the Raleigh Creek Confluence, with lower concentrations in downgradient locations adjacent to Eagle Point Lake and Sunfish Lake Park. Observed fluctuations of PFAS concentrations immediately downgradient of Raleigh Creek and Eagle Point Lake can be attributed to seasonal variability or meteorological events.

Plume maps of PFOS, PFOA, PFBA, PFBS, PFHxA, and PFHxS in the Quaternary Aquifer are shown in **Figures 129, 134, 139, 144, 149, and 154**, respectively.

Table 4.1.4.3 summarizes the groundwater PFAS concentrations from wells screened in the Quaternary Aquifer. The HI exposure limit of 1 was exceeded in 207 groundwater samples collected from these wells.

Table 4.1.4.3: Summary of Quaternary Aquifer Results

Analyte	Mean Concentration (ng/L)	Minimum Concentration (ng/L)	Minimum Sample Location Name	Maximum Concentration (ng/L)	Maximum Sample Location Name
PFOS	360	<0.359	PZGS	4410	MW14D
PFOA	120	<0.366	PZJD	1160	MW14D
PFBA	380	<1.71	MW2D	6080	MW28C
PFBS	7.3	<0.375	PZIS	36.9	MW14D
PFHxS	13	<0.363	PZAS	92	MW14D
PFHxA	21	<0.363	PZAS	1460	PZCS

4.1.4.5 Platteville Aquifer

Platteville Aquifer samples were collected from 7 locations, including groundwater wells and VAP samples. Of the 7 locations in the Platteville Aquifer, three had exceedances of the short-term, subchronic, and chronic exposure duration HBV and the cancer exposure duration PFOS HBVs. No samples exceeded the PFOS HRL. Additionally, all locations had exceedances of the short-term, subchronic, and chronic exposure duration HBV and the cancer exposure duration HBV for PFOA. Of the 7 locations, three exceeded the HRL for PFOA. No samples exceeded the HRLS for PFBA, PFBS, PFHxS, or PFHxA. The HI was on average 2.5 times greater than the threshold.

The only AECOM-installed Platteville Aquifer well is MW1C, which is situated directly downgradient of ODS, near a wetland through which Raleigh Creek flows. Groundwater from 3M well W6102, located downgradient of ODS to the southwest, was also sampled. Based on the available data, it is unclear whether variation in results is caused by seasonal fluctuations, meteorological events, or another factor.

Table 4.1.4.4 summarizes the groundwater PFAS concentrations from wells screened in the Platteville Aquifer. The HI exposure limit of 1 was exceeded in 13 samples collected from these wells.

Table 4.1.4.4: Summary of Platteville Aquifer Results

Analyte	Mean Concentration (ng/L)	Minimum Concentration (ng/L)	Minimum Sample Location Name	Maximum Concentration (ng/L)	Maximum Sample Location Name
PFOS	160	2.24	W6102	285	MW1C
PFOA	210	88.7	W6102	344	MW1C
PFBA	1200	618	MW1C	1730	W6102
PFBS	19	11.8	W6102	27.3	MW1C
PFHxS	24	6.41	W6102	45.4	MW1C
PFHxA	120	81.9	MW1C	144	W6102

4.1.4.6 St. Peter Aquifer and St. Peter Aquitard

St. Peter Aquifer samples were collected from 26 locations, including monitoring wells and VAP samples. Of the 26 locations sampled in the St. Peter Aquifer and St. Peter Aquitard, 20 exceeded the short-term, subchronic, and chronic exposure duration PFOS HBV and 14 of 26 locations exceeded the cancer exposure duration PFOS HBV. The PFOS HRL was exceeded at eight of the St. Peter Aquifer sample locations.

Of the 26 locations in the St. Peter Aquifer and St. Peter Aquitard, 21 exceeded the short-term, subchronic, and chronic exposure duration HBV and the cancer exposure duration HBV for PFOA. The PFOS HRL was exceeded in 14 of 26 locations. Additionally, one well (W6102) exceeded the PFBS HRL, five locations exceeded the PFHxS HRL, and two locations exceeded the PFHxA HRL. No samples exceeded the HRL for PFBA. The HI was on average two times greater than the threshold.

In general, higher concentrations of PFOA, PFOS, PFBS, and PFHxA were observed at locations downgradient of ODS, directly downgradient of the AGWC, and at the Raleigh Creek Confluence. Concentrations of PFBS and PFHxS were the highest downgradient of WCL. For all compounds, the lowest concentrations were observed at locations south of Raleigh Creek and along the southern lobe of Eagle Point Lake. Observed fluctuations of PFAS concentrations immediately downgradient of Raleigh Creek and Eagle Point Lake can be attributed to seasonal or meteorological events.

Plume maps of PFOS, PFOA, PFBA, PFBS, PFHxA, and PFHxS in the St. Peter Aquifer are shown in **Figures 130, 135, 140, 145, 150, and 155**, respectively.

Table 4.1.4.5 summarizes the groundwater PFAS concentrations from wells screened in the St. Peter Aquifer and St. Peter Aquitard. The HI exposure limit of 1 was exceeded in 57 samples collected from these wells.

Table 4.1.4.5: Summary of St. Peter Aquifer and St. Peter Aquitard Results

Analyte	Mean Concentration (ng/L)	Minimum Concentration (ng/L)	Minimum Sample Location Name	Maximum Concentration (ng/L)	Maximum Sample Location Name
PFOS	530	<1.44	PZH-3	4850	MW14B
PFOA	190	<1.44	PZH-3	1100	MW14B
PFBA	920	4.78	MW23C	6260	W6201
PFBS	24	<1.6	MW23C	191	W6201
PFHxS	21	<1.44	OW20P-1	128	MW1B
PFHxA	140	1.44	PZH-3	1890	W6201

4.1.4.7 Shakopee Aquifer and Oneota Aquitard

Shakopee Aquifer and Oneota Aquitard samples were collected from 37 locations, including groundwater monitoring wells and VAP samples. Of the 37 locations in the Shakopee Aquifer and Oneota Aquitard, 36 had exceedances of the short-term, subchronic, and chronic exposure duration PFOS HBV and 31 of 37 locations had exceedances of the cancer exposure duration PFOS HBV. The PFOS HRL was exceeded at eight of 37 locations.

All locations in the Shakopee Aquifer and Oneota Aquitard had exceedances of the short-term, subchronic, and chronic exposure duration PFOA HBV and the cancer exposure duration HBV. The PFOS HRL was exceeded at 29 of 36 locations. Additionally, three locations had exceedances of the PFHxS HRL, two locations had exceedances of the PFBA HRL, and one location had exceedances of the PFHxA HRL. No samples exceeded the HRLs for PFBS. The HI was, on average, 1.6 times greater than the threshold.

Concentrations for PFAS compounds were highest at MW3B, located along the southeastern lobe of Eagle Point Lake. Higher concentrations were also observed downgradient of ODS and along Pre-Confluence Raleigh Creek. Generally, groundwater samples gathered from wells near Sunfish Lake Park and adjacent to the Eagle Point Lake inlet exhibited lower concentrations for sampled compounds. While there was concentration variability between the wells, fluctuation could not be attributed to seasonal or metrological events.

Plume maps of PFOS, PFOA, PFBA, PFBS, PFHxA, and PFHxS in the Prairie du Chien (Shakopee Aquifer and Oneota Aquitard) are shown in **Figures 131, 136, 141, 146, 151, and 156**.

Table 4.1.4.6 summarizes the groundwater PFAS concentrations from wells screened in the Shakopee Aquifer and Oneota Aquitard. The HI exposure limit of 1 was exceeded in 98 samples collected from these wells.

Table 4.1.4.6: Summary of Shakopee Aquifer and Oneota Aquitard Results

Analyte	Mean Concentration (ng/L)	Minimum Concentration (ng/L)	Minimum Sample Location Name	Maximum Concentration (ng/L)	Maximum Sample Location Name
PFOS	120	<0.397	MW10B	1130	MW3B
PFOA	130	<11.2	OW20S-3	960	MW3B
PFBA	590	8.52	OW20S-1	5050	LEPR-1
PFBS	8.8	<0.381	MW6B	59.4	MW3B
PFHxS	16	<0.381	MW6B	110	MW3B
PFHxA	28	<9.2	MW6B	200	MW3B

4.1.4.8 Jordan Aquifer

Jordan Aquifer samples were collected from 30 locations, including groundwater wells and VAP samples. All 30 well locations in the Jordan Aquifer had exceedances of the short-term, subchronic, and chronic exposure duration PFOS HBV and 21 of 30 locations exceeded the cancer exposure duration PFOS HBV. The PFOS HRL was exceeded at three locations. Each location sampled in the Jordan Aquifer had exceedances of the short-term, subchronic, and chronic exposure duration PFOA HBV and the cancer exposure duration PFOA HBV. Of the 30 locations, 17 had exceedances of the PFOA HRL and one location had exceedances of the HRL for PFBA. No samples exceeded the HRLs for PFBS, PFHxS, or PFHxA.

Higher concentrations of PFOS, PFOA, PFBS, and PFHxS were observed downgradient of ODS and relatively higher concentrations of PFBA and PFHxA were observed downgradient of WCL. In general, lower concentrations for all compounds were observed in locations upgradient of ODS, adjacent to Sunfish Lake Park, and east of Lake Elmo toward the St. Croix River. Below average concentrations for PFAS compounds were observed in wells adjacent to Horseshoe Lake. Although there was variability in concentrations, these changes could not be attributed to seasonal or meteorological events.

Plume maps of PFOS, PFOA, PFBA, PFBS, PFHxA, and PFHxS in the Jordan Aquifer are shown in **Figures 132, 137, 142, 147, 152, and 157**, respectively.

Table 4.1.4.7 summarizes the groundwater PFAS concentrations from wells screened in the Shakopee Aquifer and Oneota Aquitard. The HI exposure limit of 1 was exceeded in 81 samples collected from these wells.

Table 4.1.4.7: Summary of Jordan Aquifer Results

Analyte	Mean Concentration (ng/L)	Minimum Concentration (ng/L)	Minimum Sample Location Name	Maximum Concentration (ng/L)	Maximum Sample Location Name
PFOS	110	<1.44	OW5J-1	2460	MW22A
PFOA	100	2.32	MW18A	467	MW17A
PFBA	970	19	OW5J-1	9440	MW17A
PFBS	5.5	<0.729	MW2A	20.4	MW22A
PFHxS	10	0.379	OW5J-1	43	MW22A
PFHxA	26	1.05	OW5J-3	144	MW17A

4.1.4.9 Units Deeper Than Jordan Aquifer

MW13A in the Tunnel City Group and MW15A in the Wonewoc Sandstone each had one sample in exceedance of the short-term, subchronic, and chronic exposure duration PFOS HBV. No samples exceeded the cancer exposure duration PFOS HBV or the PFOS HRL. The St. Lawrence VAP sample at MW15B, Tunnel City Group wells (MW12A, MW13A, MW15B), and the Wonewoc Sandstone well (MW15A) had exceedances of the short-term, subchronic, and chronic exposure duration PFOA HBV and the cancer exposure duration PFOA HBV. No samples exceeded the HRLs for PFOA, PFBA, PFBS, PFHxS, or PFHxA. The HI was 0 for each sample collected for adverse acute non-cancer health impacts.

In general, groundwater concentrations for each compound decreased farther downgradient with higher concentrations directly east of Eagle Point Lake and lower concentrations in wells closer to the St. Croix River.

Table 4.1.4.8 summarizes the groundwater concentrations from wells screened in the St. Lawrence Aquitard, Tunnel City Group, and Wonewoc Aquifer.

Table 4.1.4.8: Summary of Units Deeper Than Jordan Aquifer Results

Analyte	Mean Concentration (ng/L)	Minimum Concentration (ng/L)	Minimum Sample Location Name	Maximum Concentration (ng/L)	Maximum Sample Location Name
PFOS	0.55	<0.395	MW15A	2.37	MW15A
PFOA	0.062	<0.365	MW15A	0.56	MW13A
PFBA	1.6	0.63	MW13A	13.1	MW15B
PFBS	All ND	<0.365	MW15A	<11.6	MW12A
PFHxS	All ND	<0.365	MW15A	<11.6	MW12A
PFHxA	All ND	<0.365	MW15A	<11.6	MW12A

4.1.5 Soil

As discussed in Section 3.5.4, soil samples from the Quaternary Aquifer were collected during monitoring well installation where VAP samples were collected, at the water table interface, and from intervals with an abundance of clay because of the potential for PFAS adsorption. The MPCA has established Residential/Recreational Soil Reference Values (SRVs) for PFOS (13 ug/kg), PFOA (0.36 ug/kg), PFBA (250,000 ug/kg), PFBS (110 ug/kg), PFHxS (130 ug/kg), PFHxA (1,900 ug/kg), and HFPO-DA (66 ug/kg). Soil samples were collected from 22 monitoring well locations at multiple intervals. Of 104 total soil samples collected, one sample exceeded the PFOS SRV at PZED. PZED is located on the northeast side of Eagle Point Lake where surface water and sediment PFOS concentrations were elevated relative to the west side of the lake. There were no SRV exceedances for PFOA, PFBA, PFBS, PFHxS, and HFPO-DA. PFAS detections in soils were observed at locations near areas of suspected surface water infiltration where sitewide PFAS concentration in surface water was highest, such as Pre-Confluence Raleigh Creek and Eagle Point Lake.

A complete tabulation of PFAS analytical results for all soil samples is provided in **Appendices F-10 and F-11. Table 4.1.5** summarizes the results of soil analytical results. Concentrations are bolded if in exceedance of the Residential/Recreational SRVs.

Table 4.1.5: Summary of Soil Results

Analyte	Mean Concentration (ug/kg)	Minimum Concentration (ug/kg)	Minimum Sample Location Name	Maximum Concentration (ug/kg)	Maximum Sample Location Name
PFOS	1.3	<0.0367	MW17B	**14**	VAPE (PZED)
PFOA	0.22	<0.0367	MW17B	0.57	VAPE (PZED)
PFBA	0.42	<0.147	MW17B	0.597	MW9A
PFBS	All ND	<0.0367	MW17B	<1.2	VAPE (PZED)
PFHxS	All ND	<0.0367	MW17B	<1.2	VAPE (PZED)
PFHxA	0.05	<0.0367	MW17B	0.053	MW14C
HFPO-DA	0.6	<0.14	MW17B	0.061	MW12A

4.2 Hydrologic and Hydrogeologic Investigation Results

Section 4.2 details the investigation results for the elevation, flow conditions, and variability of surface water and groundwater throughout the Project 1007 Corridor as well as the geologic conditions that may impact the conveyance of PFAS mass across the Site.

4.2.1 Hydrologic Investigation Results

Surface water flow conditions throughout the Project 1007 conveyance system are discussed in Section 2.4, and the variability of surface water PFAS concentration as it relates to flow conditions is discussed in Section 4.1.1. Surface water elevations, flow, and rating curves as collected and calculated over the course of the monitoring period are reported in **Attachment D-2**. Variability in the rating curves was observed, as indicated by the R^2 value on graphs in **Attachment D-2**. Areas with well-defined stream channels (RC Intermittent 1 and 3) tended to have a better fit compared to those in wetland areas. Additionally, locations in West Lakeland (North Channel 1 and 2) tended to have fewer high-flow occurrences, making it difficult to develop accurate rating curves across the entire range of observed water elevations. Overall, flow in these areas is less variable.

Across the Site, surface water elevations and flow were generally highest during spring months, corresponding with increases in snowmelt and precipitation. Flow volume showed relative increases at each monitoring location over the course of Pre-Confluence Raleigh Creek, with the highest flow measurements observed in the intermittent portion of the creek. Based on rating curves and the range of observed surface water elevations, the intermittent portion of Raleigh Creek and the confluence have the highest flow capacity of monitored locations across the Site, indicating occasional high flow into Eagle Point Lake from Raleigh Creek and Project 1007. Subsequent monitoring locations downgradient of Horseshoe Lake had high-flow measurements and less surface water elevation variability, likely because of consistent groundwater discharge from Lake Elmo.

Surface water elevation variability was more significant in wetlands, ponds, and channels (greater than 2 feet over the course of the monitoring period in gauging stations RC Wetlands 2, RC Post RR 1, RC Pond System 1 and 2, RC Intermittent 1 and 3, DG Elmo 1 and 2, North Pond, Middle Pond, and South Pond) than in Lake Elmo and Horseshoe Lake (0.57 and 0.86 feet, respectively). In comparison, Sunfish Lake and Eagle Point Lake were more variable than the other two lakes (5.55 and 5.88 feet, respectively). The high fluctuations in the wetlands along Raleigh Creek prior to the confluence with Project 1007 illustrate the storage capacity of these wetlands and indicate that these wetlands may be points of seasonal infiltrations.

Transducer data provided additional information about flow conditions in Pre-Confluence Raleigh Creek, beginning in 2021 when transducers were first deployed. Short duration increased water elevations were observed after periods of rainfall at all locations along Raleigh Creek. In RC Wetlands 1 and 2, surface water elevations took longer to return to the baseline elevation following rainfall compared to RC Intermittent locations. After a period of higher water elevations in the spring, likely the result of snowmelt and precipitation, the presence of water was observed to start and end abruptly throughout the summer and fall. This was confirmed with visual observations. This starting and stopping indicates there may be short periods (less than 24 hours) when flow is occurring in Raleigh Creek, allowing for the migration of PFAS from ODS to Eagle Point Lake. The duration of this flow is partially dependent on upgradient conditions in Upper Raleigh Creek Wetlands Complexes and AGWC. Small rainfall events when the wetlands already have high water levels can result in flow through the intermittent portion of Raleigh Creek. When water levels are low in the wetlands, they have higher storage capacity for rainfall and the occurrence of flow in the intermittent portion of Raleigh Creek is less likely.

Evaluation of flow and surface water PFAS concentrations throughout the Project 1007 Corridor is important to understand areas where high PFAS mass is likely conveyed downgradient. Given the relatively high flow and surface water PFAS concentrations in Pre-Confluence Raleigh Creek, the largest PFAS mass in surface water is likely transported into Eagle Point Lake and the Project 1007 conveyance when the intermittent portion is flowing. Surface water gauging and flow data also supported development of the MODFLOW and MIKE SHE/MIKE HYDRO Basin models, as discussed in their respective model reports (AECOM 2024a and 2024b).

4.2.2 Hydrogeologic Investigation Results

4.2.2.1 Hydrographs

Hydrographs were developed using manually collected groundwater elevation data for each beta site (except for beta site 28) and each piezometer pair. Hydrographs and a tabulation of manual water levels are included in **Attachment E-2 and E-3**, respectively.

Groundwater elevations from wells gauged during the reporting period ranged from 695 feet in MW15A (beta site 15; March 2023) to 995 feet in MW1C (beta site 1; February 2022). The lowest observed groundwater elevations at MW15A, which is screened in the Wonewoc Sandstone Aquifer east of the Cottage Grove Fault, were over 50 feet lower than groundwater elevations at MW15, which is screened in the Tunnel City Group. MW1C (beta site 1) is the only Platteville Aquifer well and it exhibited a median groundwater elevation approximately 80 feet higher than the other two wells within its nest.

The highest elevations were consistently recorded in the northwest portion of the Site, particularly at beta sites 1, 2, 10, 14, and 18, as shown on the hydrographs in **Attachment E-2** and potentiometric surface elevation maps, **Figures 14** through **16**. Groundwater elevations generally decreased toward the southeast, approaching the St. Croix River, with beta sites 8, 9, and 15 exhibiting the lowest elevations, as shown on the hydrographs in **Attachment E-2** and the potentiometric surface elevation map for the Jordan Aquifer (**Figure 17**). **Figure 17** (and other potentiometric surface elevation maps) shows that groundwater elevation also decreases to the southwest; hydrographs are not available as no wells were installed in this area during the reporting period. The potentiometric surface elevation figures were developed using the groundwater flow model dataset (AECOM, 2024a).

Monitoring wells and piezometers screened in Quaternary deposits across the Site exhibited the most seasonally variable water levels. Groundwater elevations typically reached annual highs in the spring and summer months with annual lows in winter months (beta sites 2, 14, 6, 17, and 7). Seasonal fluctuations ranged from approximately 2 to 10 feet. This pattern is particularly strong in Eagle Point Lake piezometers (PZA, PZB, PZC, PZE, PZH, and PZI), where seasonal fluctuations consistently ranged from approximately 2 to 4 feet over the monitoring period.

Groundwater elevations for monitoring wells screened in first encountered bedrock aquifers without overlying bedrock aquitards (St. Peter, Shakopee, weathered Oneota in select locations) were similarly variable, with annual highs in the spring and summer that generally mirrored Quaternary patterns at the same beta site. Seasonal fluctuations typically ranged from less than 1 to 3 feet in St. Peter monitoring wells (PZH and beta sites 2, 14, 17, and 20) and from less than 1 to 2 feet in Shakopee and Oneota monitoring wells (beta sites 5, 6, 7, 8, and 9).

Seasonal variability of groundwater elevation was limited or not observed at monitoring wells screened in bedrock aquifers with overlying bedrock aquitards (St. Peter, Shakopee, and Jordan). For locations with discernible patterns, minor fluctuations of less than 1 foot mirrored the seasonable variability of overlying units with groundwater elevation increases in the spring and summer (beta sites 3, 6, and 8). At several beta sites across the Site, groundwater elevations in bedrock aquifers decreased by as much as 5 feet generally from spring 2020 until spring 2024 (beta sites 2, 3, 5, 6, 7, 8, and 10). Groundwater elevations in subsequent summer and fall 2024 events increased at these beta sites.

In general, the magnitude of seasonal variability decreased with depth. Where variability occurred, annual highs were typically observed in the spring and summer months when infiltration from snowmelt and precipitation were highest.

4.2.2.2 Hydrogeologic Observations

The geologic information gathered during subsurface investigations was largely consistent with the hydrostratigraphy and geologic descriptions found in the Washington County Atlas. Borehole lithologic logs are reported in **Attachment C-1** and geophysical data captured by MGS are documented in **Attachment C-3**. Horizontal hydraulic conductivity (Kh) was evaluated through slug tests and aquifer pumping tests in multiple hydrostratigraphic units, with a focus on drinking water aquifers. The acquired slug test response data were analyzed in AQTESOLV using the methods of Bouwer & Rice (1976) (unconfined/overdamped), Hvorslev (1951) (confined), and Hyder et al. (1994; Kansas Geological Survey). The chosen method for each test matched observed response and well/aquifer conditions. **Table 4.2.2.1** summarizes the resulting horizontal conductivity values, which were calculated as the geometric mean of the three analyses performed.

Table 4.2.2.1: Calculated Horizontal Hydraulic Conductivities from Slug Tests

Beta Site	Well	Hydrostratigraphic Unit	Calculated Kh (ft/d)
BS15	MW15A	Wonewoc Aquifer	4.76
BS12	MW12A	Tunnel City Aquifer	0.890
BS13	MW13A	Tunnel City Aquifer	2.25
BS15	MW15B	Tunnel City Aquifer	0.970
BS1	MW1A	Jordan Aquifer	13.5
BS2	MW2A	Jordan Aquifer	13.6
BS3	MW3A	Jordan Aquifer	11.0

Beta Site	Well	Hydrostratigraphic Unit	Calculated Kh (ft/d)
BS5	MW5A	Jordan Aquifer	10.7
	PW5J-1	Jordan Aquifer	8.40
	OW5J-1	Jordan Aquifer	21.2
	OW5J-2	Jordan Aquifer	22.2
	OW5J-3	Jordan Aquifer	28.3
BS6	MW6A	Jordan Aquifer	128
BS7	MW7A	Jordan Aquifer	12.0
BS8	MW8A	Jordan Aquifer	18.9
BS10	MW10A	Jordan Aquifer	27.9
BS13	MW13B	Jordan Aquifer	8.24
BS14	MW14A	Jordan Aquifer	14.1
BS17	MW17A	Jordan Aquifer	16.1
BS18	MW18A	Jordan Aquifer	14.5
BS20	PW20J-1	Jordan Aquifer	23.1
	OW20J-1	Jordan Aquifer	32.1
	OW20J-2	Jordan Aquifer	41.8
	OW20J-3	Jordan Aquifer	23.0
BS21	MW21A	Jordan Aquifer	35.7
BS22	MW22A	Jordan Aquifer	19.3
BS23	MW23A	Jordan Aquifer	25.4
BS26	MW26A	Jordan Aquifer	30.3
BS4	MW4A	Oneota Aquitard	75.6
BS5	OW5O-1	Oneota Aquitard	3.90
BS6	MW6B	Onetoa Aquitard	6.30
BS2	MW2F	Shakopee Aquifer	85.0
BS3	MW3B	Shakopee Aquifer	25.5
BS5	MW5B	Shakopee Aquifer	66.0
BS7	PW7S-1	Shakopee Aquifer	14.9
	OW7S-1	Shakopee Aquifer	8.80
	OW7S-2	Shakopee Aquifer	8.80
	OW7S-3	Shakopee Aquifer	18.2
BS8	MW8B	Shakopee Aquifer	7.40
BS9	MW9A	Shakopee Aquifer	32.1
BS10	MW10B	Shakopee Aquifer	1.05
BS18	MW18B	Shakopee Aquifer	12.2
BS20	PW20S-1	Shakopee Aquifer	24.1
	OW20S-1	Shakopee Aquifer	4.00
	OW20S-2	Shakopee Aquifer	7.60

Beta Site	Well	Hydrostratigraphic Unit	Calculated Kh (ft/d)
	OW20S-3	Shakopee Aquifer	0.500
MW20A	MW20A	Shakopee Aquifer	6.37
BS22	MW22B	Shakopee Aquifer	1.80
BS23	MW23B	Shakopee Aquifer	31.5
BS26	MW26B	Shakopee Aquifer	3.47
BS27	MW27A	Shakopee Aquifer	0.780
BS20	OW20P-1	St. Peter Aquitard	7.40
BS1	MW1B	St. Peter Aquifer	5.40
BS2	MW2E	St. Peter Aquifer	114
BS14	MW14B	St. Peter Aquifer	1.50
BS17	MW17B	St. Peter Aquifer	7.00
BS20	OW20T-1	St. Peter Aquifer	28.9
MW20B	MW20B	St. Peter Aquifer	4.20
BS22	MW22C	St. Peter Aquifer	5.80
BS23	MW23C	St. Peter Aquifer	3.20
BS26	MW26C	St. Peter Aquifer	4.80
BS27	MW27B	St. Peter Aquifer	39.0
PZH	PZH-1	St. Peter Aquifer	0.590
	PZH-2	St. Peter Aquifer	8.92
	PZH-3	St. Peter Aquifer	16.8
BS1	MW1C	Platteville Aquifer	112

Aquifer pumping tests provide more accurate information about the hydraulic conductivity in an area. The data collection was completed using water level dataloggers, which were programmed to record transient groundwater elevation (in feet) in the pumping well and observation wells. These data were analyzed using type-curve methods including Hantush and Jacob (1955) for leaky conditions; T and S are reported and converted to Kh using screened interval thickness to estimate aquifer properties (as available in AQTESOLV). **Table 4.2.2.2** summarizes the calculated horizontal conductivities for each tested and observed aquifer for pump testing. Details regarding the results and conclusions of the four aquifer pumping tests are provided in the corresponding final reports (AECOM, 2021c; AECOM, 2022b; AECOM 2023a; AECOM 2023b).

Table 4.2.2.2: Calculated Horizontal Hydraulic Conductivities from Aquifer Pumping Tests

Pumping Test	Beta Site	Well	Hydrostratigraphic Unit	Calculated Kh (ft/d)
Area 1 – Jordan Pumping Test	BS5	MW5A	Jordan Aquifer	0.900
		OW5J-1	Jordan Aquifer	1.80–2.70
		OW5J-2	Jordan Aquifer	369
		OW5J-3	Jordan Aquifer	90.0
		OW5O-1	Oneota Aquitard	55.0
		MW5B	Shakopee Aquifer	436
	BS4	MW4A	Oneota Aquitard	9.30
Area 2 – Jordan Pumping Test	BS20	OW20J-1	Jordan Aquifer	34.2–61.7
		OW20J-2	Jordan Aquifer	49.3–101
		OW20J-3	Jordan Aquifer	104–111
Area 2 – Shakopee Pumping Test	BS20	PW20S-1	Shakopee Aquifer	0.0600–0.340
		OW20S-1	Shakopee Aquifer	0.0300–0.110
Area 3 – Shakopee Pumping Test	BS7	OW7S-1	Shakopee Aquifer	1.30–4.00
		OW7S-2	Shakopee Aquifer	1.90–3.20
		OW7S-3	Shakopee Aquifer	2.50

Multiple results reflect results from step and pumping tests

The horizontal hydraulic conductivity as calculated from slug test data ranged from 0.59 to 113.7 ft/d in the St. Peter, 0.45 to 85 ft/d in the Shakopee, 3.9 to 75.61 ft/d in the Oneota, 0.84 to 127.5 ft/d in the Jordan, and 0.89 to 2.25 ft/d in the Tunnel City. The horizontal hydraulic conductivity as calculated from pumping tests ranged from 0.03 to 435.9 ft/d in the Shakopee, 9.3 to 55 ft/d in the Oneota, and 0.9 to 369 ft/d in the Jordan. Variability as it relates to Site hydrogeological features is discussed further in the following text.

As described in Section 2.5.1, Quaternary deposit composition varies significantly across the Site with both distance and depth. The greatest observed Quaternary deposit thickness in an AECOM-installed well was nearly 280 feet at beta site 13 in the buried bedrock valley.

Where observed, the Platteville Formation was typically the first encountered bedrock at as shallow as 29.5 feet bgs (beta site 27) and as deep as 94 feet bgs (beta site 23). At beta site 22, the overlying Decorah Shale was observed from 89 to 93 feet bgs. As is characteristic of the Platteville, bedding plane fractures were abundant and observed at all beta sites. In some cases, the upper portion of the formation was heavily weathered and rubbly (beta sites 1, 18, 21, and 22). The horizontal hydraulic conductivity for the Platteville monitoring well at beta site 1 as calculated from slug test data was 112.1 feet per day (ft/d). The underlying Glenwood Formation consisted of not compacted to compacted shale ranging from 3 to 5 feet in thickness.

The geological characteristics of the St. Peter observed during drilling were consistent with literature. The St. Peter was encountered as shallow as 13 feet bgs, where it is the first encountered bedrock (PZH-1), and as deep as 124 feet bgs, where it is overlain by the Platteville-Glenwood (beta site 22). Geophysical logging by MGS at beta site 1 and beta site 25 found evidence of bedding plane fractures, consistent downflow from the overlying Platteville-Glenwood, and loss of downflow attributed to both bedding plane fractures and intergranular porosity. Slug testing of wells screened in the St. Peter produced a range of horizontal hydraulic conductivity values from 0.59 to 113.7 ft/d, discussed further below.

Geological characteristics of the PDC Group, including the Shakopee Formation and the Oneota Dolomite, were largely consistent with literature. The Shakopee was encountered as deep as 277 feet bgs (beta site 22), where it is overlain by the St. Peter and the Platteville-Glenwood bedrock units in the western portion of the Site, and as shallow as 27 feet bgs (beta site 8), where it is the first encountered bedrock in the eastern portion of the Site. The Shakopee is characterized by secondary porosity features, including vugs, bedding plane fractures, and subvertical fractures. While these features are also observed in the Oneota, they are less common (MGS geophysical logs and borehole logs at beta sites 1, 2, and 10). Where the Shakopee or Oneota is the first encountered bedrock unit and/or is close to the buried bedrock valley, secondary porosity features are more common (MGS geophysical logs and borehole logs at beta sites 5, 6, and 7).

Observations of variable secondary porosity are supported by the results of aquifer pumping tests in the PDC. Horizontal hydraulic conductivity values derived from aquifer pumping tests were highest in the Shakopee and Oneota at beta site 5, located immediately west of the bedrock valley and Lake Elmo (435.9 ft/d and 9.3 ft/d, respectively). Aquifer pumping tests in the Shakopee yielded comparatively lower hydraulic conductivities at beta site 7 adjacent to the mapped shallow branch of the buried bedrock valley and Horseshoe Lake (from 1.3 ft/d to 4 ft/d). The lowest horizontal hydraulic conductivities were calculated at BS20 in the western portion of the Site, where the overlying St. Peter is intact (0.03 ft/d to 0.34 ft/d).

Geological characteristics of the Jordan were largely consistent across the Site. At most beta sites one or more bedrock units overlie the Jordan, with the deepest contact in the western portion of the Site and the shallowest in the eastern portion of the Site. There are two exceptions where the Jordan is the first encountered bedrock: within the buried bedrock valley where the Jordan is encountered at 278 feet bgs (beta site 13) and east of the Cottage Grove Fault in the Hudson-Afton Horst where the Jordan is uplifted to 58 feet bgs (beta site 15). Though some bedding plane fractures were observed in the Jordan Sandstone (beta sites 3, 5, and 6), secondary porosity features were uncommon, and intervals within the unit were often poorly cemented and prone to collapse regardless of the surrounding geological conditions (MGS geophysical logs and borehole logs at beta sites 1, 2, 6, 7 8, and 13). Flow was either absent (beta sites 5 and 10) or attributed to intergranular flow because bedding plane fractures were not observed (beta sites 1, 2, 3, 6, 8, and 10). Horizontal hydraulic conductivity values calculated from Jordan Aquifer pumping tests had ranges on similar orders of magnitude for beta sites close to the buried bedrock valley (beta site 5, 1.8 to 369.0 ft/d) and where overlying bedrock units were intact (beta site 20, 34.2 to 111.3 ft/d). It is unclear why more variability was observed at BS5.

Deeper bedrock aquifers were investigated at three beta sites: 12, 13, and 15. Beta sites 12 and 13 are located west of the Cottage Grove Fault and beta site 15 is located east of the Cottage Grove Fault where the deeper bedrock aquifers are uplifted within the Hudson-Afton Horst. The St. Lawrence Formation was characterized by bedding plane fractures and several instances of downhole flow (beta sites 12, 13, and 15). Bedding plane fractures and potential intragranular flow out of the borehole were observed in the Tunnel City Group at beta site 15 east of the Cottage Grove Fault. Intertonguing of the Lone Rock Formation with the Mazomanie Formation was also observed at this beta site. Slug testing of wells screened in the Tunnel City Group produced a range of horizontal hydraulic conductivities from 0.89 to 2.25 ft/d. The Wonewoc Sandstone contained bedding plane fractures, macropores, and potential upflow at beta site 15. Slug testing of the well screened in the Wonewoc Sandstone produced a horizontal hydraulic conductivity of 4.76 ft/d.

5 Conclusions

As required by the Settlement, hydrologic and hydrogeologic investigations and data collection to support the source assessment (RI) of the Project 1007 conveyance system and connected water bodies and groundwater aquifers were completed between August 2019 and October 2024. The Settlement investigation area includes the East Metropolitan Area communities of Afton, Baytown Township, Cottage Grove, Denmark Township, Grey Cloud Island, Hastings, Lake Elmo, Lakeland, Lakeland Shores, Maplewood, Newport, Oakdale, Prairie Island Indian Community, Saint Paul Park, West Lakeland Township, and Woodbury. The RI analyzed PFAS concentrations in sediment, soil, surface water, groundwater, and foam to determine how concentrations vary across the Site within these media and how concentrations changed with seasonal and hydrologic conditions:

- Surface water bodies under investigation per the Settlement were located within an approximately 120 square mile area across the East Metropolitan Area. Thirty-four surface water sampling events were completed from August 2019 through October 2024, and 165 unique locations were sampled and analyzed for PFAS.
- Six SML samples and 27 foam samples were collected from surface water body locations between August 2019 and March 2022.
- Sediment sampling and investigations were completed throughout the Project 1007 Corridor and at targeted water bodies located within the expanded Site between August 2019 and March 2023. During this time, 507 sediment samples were collected from 105 unique surface sediment locations and submitted for analysis of PFAS.
- Groundwater investigations included the installation of 105 wells: 54 multi-aquifer wells installed as nests, 11 single aquifer wells, 20 paired piezometers, four pumping wells, and 16 observation wells. These wells were installed into the following aquifers: Quaternary, Platteville, St. Peter, Shakopee, Jordan, Tunnel City, and Wonewoc. VAP and soil samples were collected during well installation and analyzed for PFAS. Groundwater sampling events were completed in newly installed or preexisting wells, generally, quarterly at the Site from October 2020 through October 2024. More than 1,200 groundwater samples were collected and submitted for laboratory analysis of PFAS.

PFAS impacts were found to be widespread throughout the Site, specifically within surface water, sediment, and groundwater. The migration within and between these media is contributing to the migration of PFAS from ODS and WCL into the drinking water aquifers. Based on the results and analysis presented in this report, AECOM drew the following conclusions about the migration of PFAS through the Site:

- There are several key areas of surface water infiltration to groundwater across the Project 1007 Corridor: Pre-Confluence Raleigh Creek, Eagle Point Lake, Sunfish Lake, Lake Elmo, Horseshoe Lake, and the West Lakeland Ponds. These areas of infiltration resulted in a larger groundwater plume than that resulting solely from mass flux within groundwater at the ODS and WCL disposal sites.
- The Project 1007 conveyance system facilitates the migration of PFAS-containing surface water to locations of infiltration, and subsequent migration of PFAS impacts from the Quaternary aquifer into bedrock aquifers, including the Jordan Aquifer, which is used for municipal supply by multiple communities. PFAS-containing surface water is discharged to the St. Croix River via the Project 1007 conveyance system.
- Different distributions of specific PFAS analytes (referred to as PFAS signatures) within the Site are likely the result of unique waste profiles from the two disposal sites (ODS and WCL). The mixing of

these signatures was found in surface water within the Project 1007 Corridor, indicating that impacts from both disposal sites are conveyed by Project 1007.

- PFAS impacts likely cycle between surface water and sediment. PFAS impacts in sediment are attributed to sorption from impacted surface water and are likely released to surface water and groundwater under certain conditions.
- PFAS impacts in shallow groundwater migrate into deeper bedrock aquifers, at times via increased hydraulic connectivity associated with first encountered bedrock units and the buried bedrock valley.
- High PFAS impacts in foam do not appear to impact the fate and transport of PFAS across the Site.

Plume maps based on the results of the groundwater investigation for PFOS, PFOA, PFBA, PFBS, PFHxA, and PFHxS (combined Quaternary to Jordan Aquifers) are shown in **Figures 133, 138, 143, 148, 153, and 158**, respectively.

Several data gaps were identified as part of this RI. The extent and magnitude of the PFAS plume was not completely delineated, as is shown in the plume maps on **Figures 133 through 158**. Key areas without groundwater data include areas west of ODS, the southern portion of the Site, and east of WCL. Groundwater migration within the buried bedrock valley and across the Cottage Grove Fault is not fully understood. Additionally, surface water and groundwater PFAS impacts observed in and around the Tri-Lakes appear chemically distinct from both ODS and WCL; investigation into the potential source(s) of these impacts is being conducted by the MPCA Site Assessment Program and is ongoing. Lastly, the Project 1007 investigation did not focus on either disposal site. More thorough investigations need to be completed at both ODS and WCL to completely characterize and understand the migration of PFAS impacts from these source areas.

The results reported here were used to develop the Project 1007 CSM presented in Section 5 of the FS, which further discusses PFAS migration pathways and areas where PFAS impacts from the two source areas comingle.

6 References

AECOM. 2019a. August 2019 Baseline Sampling Memo; prepared for Minnesota Pollution Control Agency, dated December 20, 2019

AECOM 2020a. Project 1007 Hydraulic Conductivity (Slug) Test Technical Memorandum.

AECOM. 2021a. Baseline Ecological Risk Assessment: prepared for Minnesota Pollution Control Agency, dated October 15, 2021.

AECOM. 2021b. Project 1007 – IAWC Investigation Summary Report; prepared for Minnesota Pollution Control Agency, dated June 30, 2021.

AECOM. 2021c. Project 1007 – Pumping Test Analysis Report: Pumping Test – Area # 1; prepared for Minnesota Pollution Control Agency, dated December 16, 2021.

AECOM. 2022a. Baseline Ecological Risk Assessment - Addendum; prepared for Minnesota Pollution Control Agency, dated October 26, 2022.

AECOM. 2022b. Project 1007 – Pumping Test Analysis Report: Pumping Test – Area # 2; prepared for Minnesota Pollution Control Agency, dated February 28, 2022.

AECOM. 2023a. Project 1007 – Pumping Test Analysis Report: Pumping Test – Area # 2 Shakopee Aquifer; prepared for Minnesota Pollution Control Agency, dated March 13, 2023.

AECOM. 2023b. Project 1007 – Pumping Test Analysis Report: Pumping Test – Area # 3 Shakopee Aquifer; prepared for Minnesota Pollution Control Agency, dated March 13, 2023.

AECOM. 2024a. Project 1007 Groundwater Flow Model Report; prepared for Minnesota Pollution Control Agency, dated January 31, 2024.

AECOM. 2024b. Project 1007 Integrated Groundwater and Surface-Water Model: Interim Report; prepared for Minnesota Pollution Control Agency, dated January 31, 2024.

ATSDR (Agency for Toxic Substances and Disease Registry). 2008. Perfluorochemical Contamination in Lake Elmo and Oakdale, Washington County, Minnesota. August 29, 2008.

Barr. 2015. 2015–2025 Valley Branch Watershed District Watershed Management Plan. Prepared for the Valley Branch Watershed District, September 2015.

Barr. 2022. Conceptual Site Model Update: Former 3M Oakdale Disposal Site. Prepared for 3M. February 28, 2002.

Barr. 2024. Conceptual Site Model Update. Former 3M Oakdale Disposal Site. Prepared for 3M. December 30, 2024.

Battelle. 2018. *Current State of the Science for Quantitative Methods to Collect Surface Microlayer Samples Formed on the Water Surfaces of Water Bodies*. WA 2-24 Engineering Technical Support Center Technical Directive 2-11. May 25, 2018.

Berg, Jim. 2019. Leaky Lakes and Buried Bedrock Valleys. Minnesota Groundwater Association Newsletter – June 2019.

Bouwer, H. and R.C. Rice. 1976. A slug test method for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells, Water Resources Research, vol. 12, no. 3, pp. 423–428.

DHI. 2025a. MIKE HYDRO Basin. Retrieved from: https://support.dhigroup.com/download/.

DHI. 2025b. MIKE SHE. Retrieved from: https://support.dhigroup.com/download/.

EGLE (Michigan Department of Environment, Great Lakes, and Energy). 2019. Surface Water Foam PFAS Sampling Guidance. July 2019.

EPA (Environmental Protection Agency). 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERLA- Interim Final. October 1988.

Hantush, M.S. and C.E. Jacob. 1955. Non-steady radial flow in an infinite leaky aquifer, *Transactions, American Geophysical Union*, 36 (1), pp. 95-100.

Hvorslev, M.J. 1951. Time Lag and Soil Permeability in Ground-Water Observations, Bull. No. 36, Waterways Exper. Sta. Corps of Engrs, U.S. Army, Vicksburg, Mississippi, pp. 1-50.

Hyder, Z, J.J. Butler, Jr., C.D. McElwee and W. Liu. 1994. Slug tests in partially penetrating wells, Water Resources Research, vol. 30, no. 11, pp. 2945-2957.

MDEQ (Michigan Department of Environmental Quality). 2018a. Surface Water PFAS Sampling Guidance.

MDEQ. 2018b. Sediment PFAS Sampling Guidance. December 2018.

MDEQ. 2018c. General PFAS Sampling Guidance.

MDNR (Minnesota Department of Natural Resources). 2022a. Lake Finder Database. [Online] Available at: https://www.dnr.state.mn.us/lakefind/index.html.

MPCA (Minnesota Pollution Control Agency). 2008. Minnesota Decision Document. 3M Oakdale Disposal Site. City of Oakdale, Washington County, Minnesota. November 4, 2008.

MGS (Minnesota Geological Survey). 2016. Geologic Atlas of Washington County, Minnesota. County Atlas Series. Atlas C-30, Part A. University of Minnesota and Minnesota Geological Survey. 2016.

Panday, Sorab, Langevin, C.D., Niswonger, R.G., Ibaraki, Motomu, and Hughes, J.D. 2017. MODFLOW-USG version 1.4.00: An unstructured grid version of MODFLOW for simulating groundwater flow and tightly coupled processes using a control volume finite-difference formulation: U.S. Geological Survey Software Release, 27 October 2017. https://dx.doi.org/10.5066/F7R20ZFJ.

URS (URS Corporation). 2013. Construction Documentation Report for Washington County Sanitary Landfill Relocation to Lined Landfill, Lake Elmo, MN. Prepared for MPCA. June 2013.

Weston, 2026. 2024 Annual Per- and Polyfluoroalkyl Substances (PFAS) Groundwater Monitoring Report for the Oakdale Abresch Site Oakdale, Minnesota. Prepared for 3M Chemical Operations, LLC. January 2026.