FINAL

NORTH POLE PER- AND POLYFLUOROALKYL SUBSTANCES WATER SAMPLING REPORT

NORTH POLE, ALASKA

DECEMBER 2019

Prepared For:

Alaska Department of Environmental Conservation
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APPROVAL PAGE

This report for reporting on per- and polyfluoroalkyl substances water sampling in North Pole, Alaska has been prepared for the Alaska Department of Environmental Conservation by Ahtna Engineering Services, LLC with support from teaming partners SPB Consulting, Arctic Data Services, and Paris Environmental. This report was prepared by a qualified environmental professional, as defined in 18 Alaska Administrative Code 75.333.

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ACRONYMS AND ABBREVIATIONS

µg/L................micrograms per liter
AAC...............Alaska Administrative Code
ADF&G..........Alaska Department of Fish and Game
ADEC.............Alaska Department of Environmental Conservation
ADS...............Arctic Data Services, LLC
Ahtna.............Ahtna Engineering Services, LLC
AWS..............alternative water solution
bgs.................below ground surface
EPA...............United States Environmental Protection Agency
FOSA............perfluorooctane sulfonamide
ft....................feet
FTS................fluorotelomer sulfonic acid
GAC..............granular activated carbon
GIS................geographic information system
IDA...............isotope dilution analyte
ITRC.............Interstate Technology Regulatory Council
MDL..............method detection limit
LCS...............laboratory control sample
LHA..............lifetime health advisory
LOQ..............limit of quantitation
MS.................matrix spike
NEtFOSAA....N-ethyl perfluorooctanesulfonamidoacetic acid
NMeFOSAA..N-methyl perfluorooctanesulfonamidoacetic acid
ng/L...............nanograms per liter
PFAS.............per- and polyfluoroalkyl substances
PFBA.............perfluorobutanoic acid
PFBS.............perfluorobutanesulfonic acid
PFDA............perfluorodecanoic acid
PFDoA..........perfluorolauric acid
PFHpA..........perfluoroheptanoic acid
PFHpS..........perfluoroheptanesulfonic acid
PFHxA..........perfluorohexanoic acid
PFHxS...........perfluorohexanesulfonic acid
PFNA............perfluorononanoic acid
PFOA............perfluorooctanoic acid
PFOS.............perfluorooctanesulfonic acid
PFPeA...........perfluoropentanoic acid
PFTeA...........perfluoromyristic acid
PFTriA..........perfluorotridecanoic acid
PFUnA..........perfluroundecanoic acid
POE...............point-of-entry
ppb.................parts per billion
ppt.................parts per trillion
PW ID...........private well identification number

QC..................quality control
RPD................relative percent difference
SWI ....Shannon & Wilson, Inc.
VPT................vertical profile transect

EXECUTIVE SUMMARY

In summer and fall 2018, samples were collected from water supply wells, monitoring wells and surface water in North Pole, Alaska, and analyzed for per- and polyfluoroalkyl substances (PFAS). The water sampling was initiated after PFAS were detected at concentrations approximately equal to the United States Environmental Protection Agency's (EPA's) lifetime health advisory level in samples from monitoring wells at the former North Pole Refinery property boundary. The Alaska Department of Environmental Conservation (ADEC) is aware that fire-fighting foams containing PFAS were historically used on the former North Pole Refinery property.

The overall objectives of this sampling project included identification and preliminary delineation of the PFAS plume migrating off the former refinery property and evaluating whether the public is protected from exposure to PFAS in drinking water.

Groundwater in the North Pole area is used as a drinking water source; however, groundwater downgradient of the former refinery is contaminated by sulfolane, an industrial chemical historically used in the refining process. Flint Hills Resources Alaska (FHRA) has provided affected property owners alternative drinking water supplies (AWS) or point-of-entry (POE) water treatment systems for sulfolane removal. The City of North Pole's piped water system is currently being expanded to encompass properties affected by sulfolane contamination now and in the future. AWS provision will cease after the connections to the water main are available for hookup in 2019 and 2020.

The PFAS sampling was performed in two phases. In summer 2018, Phase I included sampling from four water supply wells fitted with POE systems and nine groundwater monitoring wells. Phase I results indicated the presence of PFAS off the refinery property, and Phase II sampling was performed in fall 2018. Phase II included sampling from 17 water supply wells fitted with POE systems, 14 water supply wells without POE systems, 34 monitoring wells, and 4 surface water locations. All samples were analyzed for PFAS using EPA Method 537. Target analytes were identified as those reported under this method: perfluorobutanesulfonic acid (PFBS), perfluorodecanoic acid (PFDA), perfluoroheptanoic acid (PFHpA), perfluorohexanesulfonic acid (PFHxS), perfluorohexanoic acid (PFHxA), perfluorolauric acid (PFDoA), perfluoromyristic acid (PFTeA), perfluorononanoic acid (PFNA), perfluorooctanesulfonic acid (PFOS); perfluorooctanoic acid (PFOA); perfluorotridecanoic acid (PFTriA); and perfluoroundecanoic acid (PFUnA).

The 2018 PFAS sampling program established that a PFAS plume is emanating from the former refinery. In addition, there appears to be a second PFAS source area, located outside of the sulfolane plume footprint in the vicinity of the North Pole Fire Station. The sum of PFOS and PFOA concentrations exceeds the ADEC action level in monitoring wells located at the northern property boundary of the former refinery. The plume near the North Pole Fire Station exceeds both the ADEC action level and ADEC groundwater cleanup level for PFOS and PFOA. There are also elevated concentrations of other PFAS, including PFNA, PFHxS, PFHpA, PFHxA, and PFBS in both plumes.

Conclusions from the 2018 PFAS sampling program regarding protectiveness of the community from exposure to PFAS are provided below:

- Based on the pre- and post-treatment sample results from 20 water supply wells with POE systems, people drinking water treated by POE systems are not exposed to PFAS above the ADEC action level. The POEs, designed to treat sulfolane, are also effectively treating PFAS under the current operating conditions.

- PFOS and PFOA were not detected in treated water from water supply wells fitted with POE systems.

- The piped water expansion area and current AWS provision area appear to be protecting residents and businesses from exposure to PFAS above the ADEC action level. Although the PFAS groundwater plume is not completely delineated, concentrations of all PFAS in sampled locations that are outside of the AWS provision area or the piped water expansion area are low (less than 5 parts per trillion [ppt]).

- Although sampling showed the piped water expansion area to be protective for exposure to PFAS, the protectiveness is contingent upon property owners connecting to the system. The potential for exposure remains if property owners do not hook up to piped water. Future development of properties within the area of PFAS contamination that were not included in the expanded piped water distribution area could also pose potential exposure risk. Non-potable use of untreated groundwater may pose risk of expanding the area of contamination.

Conclusions from the PFAS sampling program regarding the extent of the PFAS contamination in groundwater and surface water are provided below:

- Sample results show groundwater contaminated by PFAS, including PFNA, PFOS, PFOA, PFHxS, PFHpA, PFHxA, and PFBS, emanating from the former refinery. The PFAS plume appears to originate on the former refinery property, which is outside the investigation area covered in this report. The PFOS and PFOA concentrations on the former refinery property exceed the ADEC groundwater cleanup level of 400 ppt, and the PFAS concentrations in property boundary monitoring wells exceed the ADEC action level of 70 ppt for the sum of PFOS and PFOA.

- PFAS concentrations migrating off the former refinery are expected to increase from the 2018 levels as a result of the 2016 - 2017 shutdown of the onsite pump-and-treat system.

- In addition to the plume originating on the former refinery, PFAS-contaminated groundwater is present in MW-316-15, located near the North Pole Fire Station. The sum of PFOS and PFOA from the MW-316-15 sample are above ADEC's action level. MW-316-15 results for all detected PFAS are significantly higher than results from all other locations sampled during this project.

- PFNA concentrations are notably high in both North Pole groundwater plumes.

- Elevated levels of PFAS were detected in surface water samples in Kimberly Lake, located to the northwest of the former refinery. The Kimberly Lake PFAS levels are similar to PFAS concentrations in nearby groundwater.

- Low concentrations of PFAS were detected in Badger Slough water samples. Similar PFAS concentrations were detected in the southern and middle samples (SS and SM). The northern sample (SN), which is located downgradient of the sulfolane plume, exhibited a relatively higher total PFAS concentration and greater percentage of PFNA.

- Both PFOS and PFNA are known to bioaccumulate in fish, which can create a route of human exposure through fish consumption. Fish sampled from Kimberly Lake and analyzed for PFAS showed PFOS concentrations ranged from 47 to 68 parts per billion (ppb) and PFNA concentrations ranged from 16 to 22 ppb, orders of magnitude above the concentrations in surface water samples. In April 2019, the Alaska Department of Fish and Game closed Kimberly Lake to sport fishing and will not continue to stock the lake.

Recommendations for follow-up activities regarding protectiveness of the community from exposure to PFAS and delineation of the PFAS plumes are provided below:

- Collect samples from POE systems with very low or non-detected sulfolane concentrations and potentially relatively high PFAS concentrations (for example, from properties around Kimberly Lake) to ensure that the POE system maintenance schedule, determined for sulfolane, is also protective of PFAS in these areas. Note that FHRA is planning to decommission the POE systems in this area by December 31, 2019.

- Consider future PFAS monitoring of water supply wells outside the piped water expansion area to ensure that drinking water supplies remain below ADEC action levels or future state or federal levels.

- Notify property owners within the North Pole piped water expansion area about DEC's Groundwater Advisory to prevent future exposure and potential spreading of contamination.

- Evaluate potential bioaccumulation of PFAS in fish and other ecological receptors in surface water bodies used for sport and subsistence fishing, including fish from Badger Slough and other surface water bodies in the PFAS plume area.

- Sample all depths of monitoring well nests along and near the former refinery property boundary to determine the extent of PFAS above ADEC action levels with depth and to assess the effect of the 2016-2017 shutdown of the onsite pump-and-treat system.

- Evaluate temporal trends by resampling selected high-concentration water wells and distal wells, such as MW-191 and MW-194.

- Improve PFAS plume delineation by sampling additional locations, specifically in the subpermafrost and in the area where the former refinery PFAS plume may border the MW-316 plume. ADEC communicated information about the MW-316-15 PFAS to the City of North Pole early in 2019, along with recommendations for characterization activities to evaluate the nature and extent of this plume.

- Investigate PFAS in surface water bodies on and to the north-northwest of the former refinery.

1.0 INTRODUCTION

Ahtna Engineering Services, LLC (Ahtna) is reporting on water supply well water, monitoring well water, and surface water samples collected by Shannon & Wilson, Inc. (SWI) in North Pole, Alaska (Figure 1) in summer and fall 2018, and analyzed for per- and polyfluoroalkyl substances (PFAS). The water sampling was initiated after PFAS were detected in samples from wells at the former North Pole Refinery property boundary at the United State Environmental Protection Agency (EPA) Lifetime Health Advisory (LHA) level.

This project was performed for the Alaska Department of Environmental Conservation (ADEC) under the Hazardous Substance Assessment and Cleanup Term Contract number 18-3007-18, Notice-to-Proceed number 180000951. This report describes the sampling activities and results. Ahtna performed this project with assistance from their teaming partners SPB Consulting, Arctic Data Services, LLC (ADS), and Paris Environmental LLC.

1.1 Project Objectives

ADEC is aware that fire-fighting foams containing PFAS were historically used on the former North Pole Refinery property. The overall objectives of this sampling project included identification and delineation of the PFAS plume off the former refinery property and evaluating whether the public is protected from exposure to PFAS. The groundwater in the North Pole area is used as a drinking water source.

Groundwater downgradient of the former refinery is contaminated by sulfolane, an industrial chemical used in the refining process on the refinery. Since 2009, residents and businesses in the area have been provided with alternative drinking water supplies (AWS) or point-of-entry (POE) water treatment systems for sulfolane removal. The POE systems use granular activated carbon (GAC) to remove sulfolane from drinking water. GAC has also been shown to effectively remove PFAS from drinking water (EPA, 2019) and works well on longer-chain PFAS such as perfluorooctanesulfonic acid (PFOS) and perfluorooctanoic acid (PFOA), although it is less effective on short-chain PFAS such as perfluorobutanesulfonic acid (PFBS) and perfluorobutanoic acid (PFBA). POE systems require periodic changeout of the GAC media to ensure continued contaminant removal from the drinking water. An expansion of the City of North Pole's piped water system is underway to permanently provide sulfolane-free drinking water to residents and businesses impacted by the sulfolane groundwater plume.

The objectives for this PFAS sampling project were developed in consideration of the current and future responses to the sulfolane contamination. Specific project goals include the following:

<u>Delineation</u>: Perform preliminary plume delineation sampling to inform locations and depths for potential future sampling, with a primary focus on the plume extent.

<u>Protectiveness</u>: Confirm that people aren't drinking water with PFAS above ADEC action levels by collecting samples to evaluate the following:

- Adequacy of current AWS coverage;
- Protectiveness of point-of-entry (POE) systems; and
- Adequacy of piped water expansion areas.

1.2 Scope of Work

The following tasks were executed in two phases of sampling to meet the project objectives:

Phase I

Phase I took advantage of an existing monitoring program and sampled a small number of water wells in the North Pole area for PFAS. Test wells for this preliminary sampling were selected to look for any indication of PFAS across a wide range of groundwater conditions in the sulfolane plume area.

Phase I sampling included the following:

- 4 water supply wells fitted with POE treatment systems, and
- 9 groundwater monitoring wells.

For each supply water well, two samples – an untreated and a treated water sample – were collected.

Phase II

Following Phase I results indicating the presence of PFAS off the refinery property, Phase II was conducted to complete the following:

- Further evaluate presence of PFAS in water supply wells treated with POE systems;
- Evaluate PFAS removal in water treated with POE systems at different stages of GAC life, ranging from recently changed-out GAC to fully spent GAC requiring changeout;
- Collect information towards delineation of the PFAS groundwater plume off the refinery property; and
- Determine whether PFAS are present in samples from selected surface water bodies.

Phase II sampling included the following:

- 17 water supply wells fitted with POE treatment systems,
- 14 water supply wells without treatment systems,
- 34 groundwater monitoring wells (including one supply well used exclusively as a monitoring well), and
- 4 surface water sampling locations.

1.3 Target Analytes

The PFAS analyzed in water were the following 12 PFAS target analytes reported under EPA Method 537 (EPA, 2009):

- perfluorobutanesulfonic acid (PFBS);
- perfluorodecanoic acid (PFDA);
- perfluoroheptanoic acid (PFHpA);
- perfluorohexanesulfonic acid (PFHxS);
- perfluorohexanoic acid (PFHxA);
- perfluorolauric acid (PFDoA);
- perfluoromyristic acid (PFTeA);

- perfluorononanoic acid (PFNA);
- perfluorooctanesulfonic acid (PFOS);
- perfluorooctanoic acid (PFOA);
- perfluorotridecanoic acid (PFTriA); and
- perfluoroundecanoic acid (PFUnA).

PFOS, PFOA, PFNA, PFHxS, PFHpA and PFBS were chosen as compounds of interest, because Alaska had developed action levels for these PFAS in groundwater (ADEC, 2018a) at the time of sampling. That memo has since been updated (ADEC, 2019b) and includes action levels for PFOS and PFOA, only.

1.4 Cleanup and Screening Levels

Groundwater cleanup levels for PFOS and PFOA are available from Table C, 18 Alaska Administrative Code (AAC) 75.345 (ADEC, 2018b). The groundwater cleanup level for PFOS and PFOA under 18 AAC 75.345 is 0.40 micrograms per liter (µg/L), which is equal to 400 nanograms per liter (ng/L) or parts per trillion (ppt). No cleanup levels for the remaining target analytes exists under 18 AAC 75, as amended through October 27, 2018.

In 2016, EPA published LHAs under the Safe Drinking Water Act for two PFAS, PFOS and PFOA. These LHAs were created to assist state and local officials and drinking water system operators in evaluating risks from these contaminants in drinking water, so they can take appropriate action to protect residents. The EPA recommends people not drink water containing a total concentration of PFOS plus PFOA (PFOS+PFOA) above 0.07 µg/L (70 ppt).

In 2018, ADEC set action levels for six PFAS compounds, including PFOS and PFOA (ADEC, 2018a). On April 9, 2019, ADEC published a revised technical memorandum on action levels for PFAS that supersedes the 2018 action levels memorandum and aligns the ADEC action levels with EPA's LHA levels, setting an action level for two analytes, PFOS and PFOA, of 0.07 µg/L. ADEC's technical memorandum was most recently updated in October 2019 to address sampling and reporting requirements (ADEC, 2019b).

1.5 Regulatory Framework

The regulatory framework for this project has been developed by consideration of the following regulations and guidance documents.

- *Action Levels for PFAS in Water and Guidance on Sampling Groundwater and Drinking Water*, ADEC Division of Spill Prevention and Response, Contaminated Sites Program and Division of Environmental Health, Drinking Water Program, October 2, 2019 (ADEC, 2019b).
- *18 AAC 75, Oil and Other Hazardous Substances Pollution Control*, October 27, 2018 (ADEC, 2018b).
- *Action Plan for Per- and Polyfluoroalkyl Substances (PFAS)*, ADEC, December 2018 (ADEC, 2018c).
- *Data Review and Validation Guidelines for Perfluoroalkyl Substances (PFASs) Analyzed Using EPA Method 537*, EPA, November 2018 (EPA, 2018b).

- *Treatment of Non-Detects and Blank Detections in Per- and Polyfluoroalkyl Substances (PFAS) Analysis*, ADEC, March 2019 (ADEC, 2019a).

1.6 Project Organization

This project was managed by Jim Fish of the ADEC and Andrew Weller, PE of Ahtna. Stephanie Buss of SPB Consulting and Jane Paris of Paris Environmental LLC drafted the document. Andrew Weller performed a senior review of the report. Leslie Davis of Ahtna provided geographic information system (GIS) support. Rodney Guritz of Arctic Data Services, LLC (ADS) evaluated data quality. These persons all meet the definition of “qualified environmental professional” in accordance with 18 AAC 75.333.

Since this work entailed sampling of wells that are currently part of the annual groundwater monitoring performed by SWI for Flint Hills Resources - Alaska, SWI collected all samples and submitted the samples to Eurofins TestAmerica Laboratories in West Sacramento, California (EuroFins TestAmerica) for PFAS analysis using modified EPA Method 537. SWI completed ADEC data review checklists for all sample-delivery groups. SWI provided all copies of the laboratory reports and completed data review checklists to ADEC and Ahtna. This information was also provided to Flint Hills Resources-Alaska by SWI.

2.0 BACKGROUND

This section describes the water sampling conducted in the summer and fall/winter 2018 in the North Pole area, off the former-North Pole Refinery property.

2.1 NPR Summary

Soil and groundwater at the former North Pole Refinery have been affected by petroleum spills throughout the refinery's operation, from the late 1970s until the refinery was shut down in 2014. The terminal's land still contains fuel product trapped in the soil and groundwater, however, petroleum components in the soil and groundwater have not migrated off the property.

The soil and groundwater are also affected by sulfolane. This industrial solvent was used in the refining process from 1985 until 2014. Spills and other releases of sulfolane started shortly after its use began. In 2009, dissolved sulfolane was found in wells beyond the refinery property. The "plume" of groundwater containing sulfolane beyond the North Pole Terminal property is currently approximately 2 miles wide, 3.5 miles long and over 300 feet deep. It continues to migrate to the north-northwest.

Fire-fighting foams containing PFAS were historically used on the former refinery. A fire training area operated historically in the western portion of the former refinery; contaminated soil was excavated from the former fire training area in 2015 and properly disposed at a hazardous waste facility in Oregon. Fire-fighting foams containing PFAS were reportedly also used elsewhere on the refinery.

There is a potential for currently unknown local PFAS sources in the general North Pole area, such as fire training and response off the refinery property, use of consumer products, waste-water treatment, and industrial processes. Air transport and deposition from distant sources is another potential source of PFAS. PFAS have been found throughout the Arctic, in both animals and plants (Muir *et al.*, 2019), and can migrate to the Arctic through ocean and air currents (ITRC, 2018).

2.2 Previous Investigations

PFAS have been sampled in groundwater and soil from the former-North Pole Refinery since 2012. Onsite PFAS investigations include the following:

- Phase I – Hydro-Punch and Monitoring Well Sampling (Arcadis, 2013a),
- Phase II – Monitoring Well Sampling (Arcadis, 2013a),
- Phase III – Soil and MW-321 Sampling (Arcadis, 2013b),
- Pump-and-Treat System Sampling (Arcadis, 2015a, 2015b, 2015c),
- Fire Training Area Excavation (Arcadis, 2015d), and
- 2017 and 2018 Onsite Groundwater Monitoring (Arcadis 2018a, 2018b).

Historical groundwater results show monitoring well and hydropunch samples above the ADEC groundwater cleanup levels downgradient of the Fire Training Area. Groundwater results from MW-321, at Lagoon C, which has been sampled multiple times between 2012 and 2018, are consistently above ADEC groundwater cleanup levels for PFOS and PFOA (Arcadis, 2013a, 2013b, 2018a, 2018b). Groundwater results from some vertical profile transect (VPT) wells, located downgradient of the onsite pump-and-treat system, were above the EPA LHA of 70 ppt (Arcadis, 2013a).

PFAS samples taken from the influent and effluent of the pump-and-treat system in 2014 and 2015 showed PFOS and PFOA in the GAC-East influent above the EPA LHA. Effluent from GAC-East and GAC-West influent were below the LHA (Arcadis, 2015a, 2015b, 2015c). GAC-East and GAC-West refer to the two sections of the onsite pump-and-treat system; GAC-West was shut down in summer 2016 and GAC-East was shut down in summer 2017.

Soil results in the Fire Training Area were above ADEC soil cleanup levels for PFOS and PFOA (Arcadis, 2013b). That area was excavated in 2015 and confirmation samples showed contamination remaining in-place above the cleanup levels along the northern and eastern boundaries of the former fire training area (Arcadis, 2015d).

In 2017, groundwater results at the property boundary showed concentrations of PFOS and PFOA approximately equal to the LHA of 70 ppt (Arcadis 2018a). There is potential for these PFAS concentrations to increase after the 2016 and 2017 shutdown of the pump-and-treat system. In 2018, groundwater results from the property boundary monitoring wells showed a maximum PFOS + PFOA concentration at 90 ppt (MW-358-20), above the LHA and ADEC action level of 70 ppt (Arcadis, 2018b).

2.3 Environmental Setting

The sampling was conducted in the location of combined Chena and Tanana river floodplains. The City of North Pole receives an average of 12 inches of rainfall per year. The near-surface soils consist primarily of interlayered sands, gravelly sand, and sandy gravels with some silt to about 30 feet (ft) below ground surface (bgs).

There is a shallow water table aquifer underlying the former refinery and much of the North Pole area. Shallow groundwater generally flows to the north-northwest off the former refinery. The shallow groundwater flow then splits into a northerly component and a northwesterly component. The horizontal groundwater gradient is approximately 0.001 feet/foot.

Discontinuous permafrost is present in the area. The soils underlying the former refinery are mostly free of permafrost, although some remnant chunks of permafrost were encountered at various depths during drilling. A large mass of permafrost extends northward beginning near the northern boundary of the former refinery property. An aquifer is present below the permafrost, and little is known about its horizontal flow direction or gradient. Studies performed by UAF have shown an upward vertical gradient in the subpermafrost. The subpermafrost aquifer is contaminated by sulfolane from the former refinery, in spite of the upward gradient. The contamination is believed to have migrated downward from shallow groundwater by localized downward gradients resulting from flow around the remnant permafrost chunks. Taliks in the permafrost, including along the Tanana River and Badger Slough, as well as in other areas known and unknown provide conduits for migration between the supra- and subpermafrost aquifers.

Some of the water samples from this program were collected from the subpermafrost.

3.0 METHODOLOGY

This section summarizes the sampling and sample preparation activities completed in summer and fall/winter 2018.

All sample collection was conducted by SWI personnel. SWI field notes and sampling logs are provided in Appendix A. Sample locations are shown in Figure 1.

Per SWI, groundwater samples were collected in accordance with the *Onsite Revised Sampling and Analysis Plan* (Arcadis, 2016) and SWI's standard PFAS sampling procedures used for other PFAS sampling in the Fairbanks area. Water supply wells with POE systems were sampled prior to and following GAC treatment, resulting in untreated and treated sample pairs from each location. Often the post-treatment sample was taken from the kitchen sink to avoid potential PFAS contamination from tubing at the sampling ports. Monitoring wells were purged and sampled using continuous pumping at a rate of 3.5 liters per minute (L/min). Purge water was treated with GAC and disposed of at each well location on the ground, per SWI's standard procedures and in accordance with ADEC instructions. Surface water samples were collected from approximately 1.25 to 1.5 feet under the surface.

3.1 Water Supply Well Sampling

Water supply well sample locations identified by private well identification number (PW ID), well depth (if known), presence of POE treatment system, and date of sample collection are provided in Table 1. The PW IDs were previously assigned by Flint Hills for sulfolane sampling purposes, in order to protect private well owners' privacy.

Four private water wells, all with POE treatment systems, were sampled as part of Phase I. Phase II consisted of 31 water well samples and five duplicate samples. Of the 31 Phase II water well samples, 17 were fitted with POE treatment systems. For those water wells with POE systems, samples were taken both pre- and post-GAC treatment.

PW-1374 was sampled in both Phase I and Phase II.

TABLE 1: WATER SUPPLY WELL SAMPLE LOCATIONS

PW ID	Well Depth (ft)	Presence of POE Treatment System (Yes/No)	Date of Sample Collection
Phase I			
561	Unknown	Yes	8/3/2018
618	110	Yes	7/24/2018
757	60	Yes	7/24/2018
1374	55	Yes	7/17/2018
Phase II			
159	38	Yes	10/05/2018
217	238	Yes	10/11/2018
271	48	No	11/02/2018
277	45	No	10/26/2018
290	205	No	10/29/2018

PW ID	Well Depth (ft)	Presence of POE Treatment System (Yes/No)	Date of Sample Collection
376	Unknown	Yes	10/22/2018
531	Unknown	No	11/02/2018
532	Unknown	No	10/23/2018
599	Unknown	Yes	11/28/2018
608	Unknown	Yes	11/28/2018
608 (Duplicate)	Unknown	Yes	11/28/2018
617	Unknown	Yes	11/02/2018
649	236	Yes	12/3/2018
656	50	Yes	11/06/2018
657	50	Yes	10/04/2018
927	320	No	11/20/2018
927 (Duplicate)	320	No	11/20/2018
947	Unknown	Yes	10/15/2018
974	40	No	10/23/2018
974 (Duplicate)	40	No	10/23/2018
976	38	No	10/23/2018
978	218	No	10/23/2018
979	Unknown	No	10/23/2018
1095	37	Yes	10/26/2018
1106	40	Yes	10/10/2018
1154	38	No	10/23/2018
1155	216	Yes	11/02/2018
1155 (Duplicate)	216	Yes	11/02/2018
1185	Unknown	No	10/09/2018
1195	40	No	10/29/2018
1374	55	Yes	10/10/2018
1374 (Duplicate)	55	Yes	10/10/2018
1395	Unknown	Yes	10/19/2018
1466	Unknown	No	10/29/2018
1899	Unknown	Yes	11/14/2018
2227	40	Yes	11/13/2018

3.2 Monitoring Well Sampling

Monitoring well locations, sample identification, well depth, and date of sample collection are provided in Table 2. Note that PW-1230, although developed as a private well, has recently been used exclusively for monitoring the sulfolane plume and is discussed as a monitoring well in this report.

Nine monitoring wells (and two duplicates) were sampled as part of Phase I. Phase II consisted of 34 monitoring well samples and three duplicate samples. MW-150B-25 was sampled during both Phase I and Phase II. A number of the monitoring wells sampled are in multi-level nests in which several depths were sampled at a given location. For instance, MW-150B-25 refers to the 25-foot depth of the MW-150 well nest, and MW-150C-65 refers to the 65-foot depth in the same well nest.

TABLE 2: MONITORING WELL SAMPLE LOCATIONS

Sample ID	Monitoring Well	Well Depth (ft)	Date of Sample Collection
Phase I			
MW-150A-10	MW-150A-10	10	7/19/2018
MW-150B-25	MW-150B-25	25	7/19/2018
MW-150B-25 (Duplicate)	MW-150B-25	25	7/19/2018
MW-314-15	MW-314-15	15	7/20/2018
MW-332-150	MW-332-150	150	7/20/2018
MW-346-65	MW-346-65	65	7/20/2018
MW-353-100	MW-353-100	100	7/20/2018
MW-353-15	MW-353-15	15	7/20/2018
MW-353-65	MW-353-65	65	7/20/2018
2440Tanana-2018 PFAS	PW-1230	231	7/20/2018
9999Tanana-2018PFAS (Duplicate)	PW-1230	231	7/20/2018
Phase II			
MW-150B-25	MW-150B-25	25	10/24/2018 14:27
MW-150C-60	MW-150C-60	60	10/24/2018 13:55
MW-151A-15	MW-151A-15	15	10/24/2018 11:22
MW-151B-25	MW-151B-25	25	10/24/2018 10:52
MW-151C-60	MW-151C-60	60	10/24/2018 10:11
MW-152A-15	MW-152A-15	15	10/23/2018 17:25
MW-152B-25	MW-152B-25	25	10/23/2018 16:55
MW-153A-15	MW-153A-15	15	10/24/2018 12:58
MW-253A-15 (Duplicate)	MW-153A-15	15	10/24/2018 12:48
MW-153B-55	MW-153B-55	55	10/24/2018 12:27
MW-155A-15	MW-155A-15	15	10/23/2018 15:32
MW-155B-65	MW-155B-65	65	10/23/2018 16:01
MW-156A-15	MW-156A-15	15	10/22/2018 16:05
MW-158A-15	MW-158A-15	15	10/22/2018 15:00
MW-184-45	MW-184-45	45	10/22/2018 13:26
MW-189A-15	MW-189A-15	15	10/23/2018 14:19
MW-189B-60	MW-189B-60	60	10/23/2018 12:45
MW-191A-15	MW-191A-15	15	10/23/2018 10:59
MW-191B-60	MW-191B-60	60	10/23/2018 10:22
MW-193A-15	MW-193A-15	15	10/24/2018 15:21
MW-293A-15 (Duplicate)	MW-193A-15	15	10/24/2018 15:11
MW-194A-15	MW-194A-15	15	10/23/2018 16:20
MW-194B-40	MW-194B-40	40	10/23/2018 15:45
MW-311-15	MW-311-15	15	10/23/2018 12:15
MW-311-46	MW-311-46	46	10/23/2018 11:50
MW-316-15	MW-316-15	15	10/22/2018 15:03
MW-316-56	MW-316-56	56	10/24/2018 14:26
MW-318-20	MW-318-20	20	10/22/2018 11:57
MW-327-15	MW-327-15	15	10/22/2018 16:14
MW-328-151	MW-328-151	151	10/24/2018 10:53
MW-356-20	MW-356-20	20	10/23/2018 14:36
MW-356-65	MW-356-65	65	10/23/2018 14:09
MW-356-90	MW-356-90	90	10/23/2018 13:41

Sample ID	Monitoring Well	Well Depth (ft)	Date of Sample Collection
MW-357-15	MW-357-15	15	10/22/2018 13:33
MW-357-115 (Duplicate)	MW-357-15	15	10/22/2018 13:23
MW-357-150	MW-357-150	150	10/23/2018 10:15
MW-357-65	MW-357-65	65	10/23/2018 9:47

3.3 Surface Water Sampling

Surface water samples from Kimberly Lake and Badger Slough were tested for PFAS. One sample and one duplicate were collected from Kimberly Lake. Kimberly Lake is a groundwater-fed lake to the north-northwest of the former North Pole Refinery. Three samples, one upstream, one downstream and one midstream of the sulfolane plume, were collected from Badger Slough. Badger Slough lies to the east of the refinery and flows in a generally north- to northeasterly direction. . Surface water sample identification, location, and date of sample collection are provided in Table 3.

TABLE 3: SURFACE WATER SAMPLE LOCATIONS

Surface Water Sample ID No.	Sample Location	Date of Sample Collection
KL01-2018 PFAS	Kimberly Lake	10/12/2018
KL 101-2018 PFAS (Duplicate)	Kimberly Lake	10/12/2018
BS Midstream-2018PFAS	SM	10/12/2018
BS Upstream-2018PFAS	SS	10/12/2018
BS Downstream-2018PFAS	SN	10/12/2018

3.4 GAC Sampling

Purge water from sampling monitoring wells was treated with a portable GAC system developed and utilized by SWI specifically for PFAS sampling. After treatment, the purge water was disposed of on the ground. SWI had two sampling crews working simultaneously; each crew had its own purge water treatment system. Water from both purge water treatment systems was sampled near the end of the sample event to assess PFAS removal by GAC and ensure PFAS breakthrough was not occurring above ADEC action levels. The sample identification, well location, and date of sample collection are provided in Table 4.

TABLE 4: GAC TREATED PURGE WATER SAMPLES

Sample ID	Monitoring Well	Date of Sample Collection
GAC-193A-15	MW-193A-15	10/24/2018
GAC2-150B-25	MW-150B-25	10/24/2018

3.5 Laboratory Analysis

SWI submitted groundwater and surface water samples for PFAS analysis. Samples submitted prior to September 2018 were analyzed under the modified EPA Method 537 (EPA, 2009). Samples received after this date were analyzed using a modification of the revised method, Method 537.1 (EPA, 2018a).

Project samples were submitted to EuroFins TestAmerica for analysis by modified EPA Method 537. The modified method uses an isotope dilution method with analytical results adjusted based upon recovery of the isotope dilution analytes. Phase I water samples were analyzed using a modification to EPA Method 537 (EPA, 2009). In November 2018, EPA's method was revised and a modification to EPA Method 537.1 (EPA, 2018a) was used for the Phase II water samples.

Samples were analyzed for the full suite of PFAS reported under Method 537, including the 12 target analytes identified in Section 1.3. Non-detected results are reported at two times the method detection limit (MDL). For the sum of PFOS and PFOA, non-detected results are included in the sum at two times the MDL.

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4.0 RESULTS

4.1 Monitoring Well and Non-POE PFAS Results

To address the goal of initially identifying the extent of the PFAS plume off the former refinery property, monitoring wells and non-POE bearing water wells were sampled and analyzed for PFAS. This data, combined with the untreated water samples from properties with POE systems, was used to define the PFAS plume boundary.

Forty-two monitoring wells (plus 5 duplicate samples) were sampled in Phases I and II. One monitoring well (MW-150B-25) was sampled in both Phase I and Phase II. Thirty-four supply wells (plus 5 duplicate samples) were sampled in Phase I and II, either prior to POE treatment or without POE treatments installed. One supply water well (PW-1374) was sampled in both Phase I and Phase II. Results from these untreated water samples are presented in Table 5. Figures 2 through 8 show these untreated water sample results for PFOS + PFOA, PFOS, PFOA, PFNA, PFHxS, PFHpA and PFBS, respectively.

A comparison of the Phase I and Phase II samples from MW-150B-25 and PW-1374 shows no significant differences in PFAS concentrations between the two events, with the exception of the PFOS concentration in MW-150B-25, which decreased from 46 ppt (Phase I) to 29 ppt (Phase II). All the other PFAS concentrations in both locations were similar in the two events.

The highest PFAS concentrations were detected in MW-316-15 with a PFOS + PFOA concentration of 1,070 ppt, above ADEC's action level of 70 ppt. The concentrations of the detected PFAS at this location are: PFOS at 790 ppt, PFOA at 280 ppt, PFNA at 2,400 ppt, PFHxS at 440 ppt, PFHpA at 180 ppt, PFBS at 43 ppt, PFHxA at 180 ppt, PFDA at 12 ppt, PFTeA at 0.3 J ppt, and PFUnA at 16 ppt. The PFAS concentrations in MW-316-56 were much lower than at the 15-ft level. Sulfolane has not been detected in MW-316 at either depth since 2013 (there were some sulfolane detections below 5 ppb in 2012 and 2013), and the PFAS in this well is not considered to reflect migration off the former refinery. Figures 2 through 9 show the location of MW-316 relative to the former refinery and other sample locations and support the conclusion that this contamination does not reflect migration off the former refinery. It should also be noted that samples from PW-1230 and PW-1155, located to the northwest and north of MW-316, are subpermafrost sample locations that provide no information about shallow PFAS concentrations at their respective locations.

Of the other samples besides MW-316, the maximum concentration of the sum of PFOS and PFOA is 63 ppt at MW-150B-25. PFOS was detected in 91% and PFOA was detected in 79% of the samples excluding MW-316. The following PFAS were also detected in at least 75% of the wells sampled: PFNA (83%), PFHxS (100%), PFHpA (77%), PFBS (89%), and PFHxA (75%). PFDA was detected in 14 well samples and PFTeA was detected in 5 of the well samples.

Figures 2 through 8 display the results of the sampling efforts that are the subject of this report; PFAS results from samples collected on the former refinery property are not displayed on these figures. Note that the water well symbols surrounded by black circles denote subpermafrost sample locations; symbols without circles are either suprapermafrost wells or wells of unknown depth.

Important observations from Figures 2 through 8, not including MW-316-15 discussed above, are as follows:

- Figure 2 shows the highest concentrations of PFOS + PFOA, exceeding half of the ADEC action level (35 ppt), migrating along a narrow pathway to the northwest of the former refinery. In addition, the PFOS + PFOA concentration in PW-1230, a subpermafrost well completed at 231 feet bgs, also exceeded 35 ppt. The furthest north sampled location, MW-327-15, has a somewhat elevated PFOS + PFOA concentration relative to the wells further south. The highest PFOS + PFOA concentration was 63 ppt, detected in a sample from MW-150B-25, near the former refinery.
- Figures 3 and 4 show the PFOS and PFOA concentrations individually, rather than summed as on Figure 2. These figures show that PFOS and PFOA individually display a similar spatial distribution to each other, with the higher concentrations mostly occurring near and south of the Richardson Highway. The maximum PFOS concentration was 46 ppt, detected in a sample from MW-150B-25. The maximum PFOA concentration was 20 ppt, detected in the sample from MW-155B-65.
- Figure 5 shows the highest concentrations of PFNA (exceeding 35 ppt), migrating along a narrow pathway to the northwest of the former refinery, similar to PFOS + PFOA. In addition, two other wells to the north of MW-316-15, PW-947 and PW-1185, contained PFNA above 35 ppt. The maximum PFNA concentration of 57 ppt was detected in the sample from MW-155A-15.
- Figures 6 and 7 show the concentrations of PFHxS and PFHpA, respectively. PFHpA (Figure 7) shows a similar distribution as PFOS and PFOA, while PFHxS shows somewhat higher concentrations over a larger area north of the Richardson Highway. PFHxS was detected in every sample, although some of the detections are B-flagged noting that the compound was also detected in laboratory blanks. The maximum PFHxS concentration of 27 ppt was detected in the sample from MW-153A-15. The maximum PFHpA concentration of 30 ppt was also detected in MW-153A-15.
- Figure 8 displays the PFBS concentrations. PFBS concentrations were generally low, with a maximum concentration of 7 ppt in the sample from MW-153A-15. In addition, 6.2 ppt PFBS was detected in MW-311-15, which had very low detections of all other PFAS.

These figures show groundwater contaminated by PFAS, including PFNA, PFOS, PFOA, PFHxS, PFHpA, and PFBS, emanating from the former refinery. The upgradient extent of the PFAS plume appears to be on the former refinery and outside the investigation area covered in this report. Independent of the sampling documented in this report, a small number of onsite monitoring wells (10 samples from six well nests) were sampled for PFAS in 2018 by FHR contractors (ARCADIS, 2018b). Figure 9 displays the PFOS + PFOA results for these six onsite wells in addition to the offsite untreated PFOS + PFOA results. PFOS + PFOA concentrations on the former refinery property exceed the ADEC action level of 70 ppt, and the upgradient extent of the PFAS plume emanating from the former refinery also exceeds the ADEC action level.

PFNA concentrations are notably high in both North Pole groundwater plumes. Figure 10 shows the percentage of PFOS, PFOA, PFNA, PFHxS, PFHxA, PFHpA, and PFBS detected in the water samples, including the on-refinery samples reported by ARCADIS (ARCADIS, 2018b). The size of the percentage “pie” symbols reflects the total PFAS concentration quartile; with the largest pies representing the upper quartile, the medium pies representing the middle two quartiles, and the smallest pies for the lower quartile. Note that, for ease of display, only the sample depth with the highest PFAS concentration is displayed for multi-level monitoring well nests. In most of the water samples shown on this figure, the percentage of PFNA ranges from approximately 25% to greater than 50% of the total PFAS detected. In many samples, the concentration of PFNA exceeds the concentration of each other individual PFAS. PFNA is not typically present in military specification, or mil-spec, fire-fighting foam (Field and Goodrow, 2019). Mil-spec fire-fighting foam would not be required on the refinery, and it is possible that proprietary cold weather or alcohol-resistant formulations could contain notable quantities of PFNA, but this is unknown at this time. Sample locations that did not show a predominance of PFNA are summarized below and generally discussed in order of location from north to south. Although there are insufficient data for definitive conclusions, the differing PFAS percentages suggest the potential for different PFAS sources. It should also be noted that the PFAS concentrations discussed below were generally relatively low.

- The PFAS percentages in MW-327-15 and MW-189A-15, both located north of the sulfolane plume, were similar. Neither contained detectable PFNA.

- Predominantly PFBS was detected in MW-311-15, located to the north-northwest beyond the limits of the sulfolane plume. PFNA was not detected.

- PFAS concentrations in PW-299, PW-271, PW-277, and MW-328-151, located along the northern sulfolane plume boundary, and in PW-1195, PW-531, and MW-357-15, located outside of the eastern sulfolane plume boundary, were below 5 ppt and the percentages are not included in this discussion.

- Predominantly PFHxS was detected in MW-314-15, PW-532, and MW-356-20, located across Badger Slough to the northeast of the sulfolane plume. PFNA was not detected.

- Within the limits of the sulfolane plume south of Badger Road, PFAS concentrations were below 5 ppt in PW-927. PW-927 is a 300-foot deep subpermafrost water supply well, and the percentages are not included in this discussion.

- PW-1899, a recently-installed shallow water supply well, had a low percentage of PFNA and also did not contain detectable sulfolane.

- Subpermafrost PW-649 and MW-332-150, located near the edge of a permafrost talik, contained similar PFAS percentages with low PFNA.

- MW-184-45, located to the south of MW-316, exhibits a low percentage of PFNA.

4.2 Surface Water PFAS Results

To address the goal of evaluating PFAS in selected surface water bodies, water samples from Kimberly Lake and Badger Slough were analyzed for PFAS. Results are presented in Table 6 and shown in Figures 2 through 8 for PFOS + PFOA, PFOS, PFOA, PFNA, PFHxS, PFHpA and PFBS, respectively.

In two samples from Kimberly Lake (a primary and a duplicate sample), PFOS, PFOA, PFNA, PFHxS, PFHpA, PFBS, PFHxA, and PFDA were detected. PFNA was detected at the highest concentration (47 ppt and 50 ppt), followed by PFHxA (26 ppt and 27 ppt), PFOS (24 ppt), PFHpA (16 ppt and 19 ppt), PFOA (16 ppt and 17 ppt), PFHxS (14 ppt and 15 ppt), PFBS (1.9 ppt and 2.0 ppt), and PFDA (0.44 J ppt and 0.46 J ppt). The sum of PFOS and PFOA were 40 ppt and 41 ppt.

In three samples from Badger Slough (midstream, upstream and downstream), PFOS, PFOA, PFNA, PFHxS, PFHpA, PFBS, and PFHxA were detected. PFNA was detected at the highest concentration (2.8 J ppt to 5.0 ppt), followed by PFHxS (4.0 ppt to 4.6 ppt), followed by PFOS (2.0 ppt to 3.0 ppt), PFOA (1.8 ppt to 2.7 ppt), and PFHxA (0.64 J ppt to 2.8 ppt). The sum of PFOS and PFOA ranged from 3.8 ppt to 5.7 ppt. The highest PFOS + PFOA was found in the downstream Badger Slough sample (SN at 5.7 ppt). The upstream (SS) and midstream (SM) PFOS + PFOA concentrations were similar at 4.2 ppt and 3.8 ppt, respectively.

PFAS percentages for the surface water samples are shown on Figure 10.

- In Badger Slough, the southern and middle samples (SS and SM) showed similar PFAS percentages and total PFAS concentrations. The northern sample (SN), which is located downgradient of the sulfolane plume, exhibited a higher total PFAS concentration and greater percentage of PFNA.
- The PFAS percentages and total PFAS concentrations in Kimberly Lake are very similar to those in upgradient, nearby monitoring wells MW-155B-65, illustrating the connectivity between Kimberly Lake and adjacent groundwater.

4.3 Water Wells with POE Systems PFAS Results

To address the goal of protectiveness, samples were collected to evaluate whether responses to sulfolane contamination in well water are also protecting the community from PFAS contamination in well water. The following were specifically addressed: whether POE systems are effective at removing PFAS from well water; whether the boundaries of the piped water expansion area also cover the PFAS-contaminated area; and whether the area currently supplied with alternative drinking water includes the area of PFAS-contaminated groundwater.

4.3.1 POE System Effectiveness

POE systems use GAC media to remove sulfolane from drinking water. The GAC media requires periodic changeout to ensure continued contaminant removal from the drinking water. The effective lifespan of the GAC media is based on the sulfolane concentrations and volume of water treated. GAC has been shown to also effectively remove PFAS from drinking water (EPA, 2019) and works well on longer-chain PFAS such as PFOS and PFOA.

Results of both the pre- and post-POE treatment water samples are provided in Table 7. All samples were analyzed for the target analytes listed in Section 1.3. Pre- and post-treatment samples from PW-561 were also analyzed for an additional 9 PFAS.

A comparison of the pre- and post-POE treatment system results shows that the POE systems effectively removed PFAS from the water. The maximum PFOS + PFOA concentration detected in untreated water is 41 ppt at PW-1095. The treated water sample from the same location did not contain detectable PFOS or PFOA.

Results of post-POE treatment water samples are provided in Table 8. Figure 11 shows the locations of all POE systems sampled and that PFOS and PFOA were not detected in any of the post-POE treatment samples.

Of the 21 samples of post-POE system treated water, the following PFAS were detected:

- PFNA detected in 3 samples ranging from 0.31 J to 1.0 J ppt,
- PFHxS detected in 19 samples ranging from 0.20 J to 0.65 JB ppt,
- PFHpA detected in 3 samples ranging from 0.34 J to 0.92 J ppt,
- PFHxA detected in 3 samples ranging from 0.75 J to 2.0 ppt, and
- PFTeA detected in 1 sample at 0.26 J ppt.

Perfluorobutanoic acid (PFBA) and 6:2 fluorotelomer sulfonic acid (FTS) and were detected in the single sample tested (PW-561) at 7.5 JB ppt and 0.53 JB ppt, respectively. No other PFAS were detected in any post-treatment sample.

To ensure that the POE system maintenance schedule, designed for sulfolane, is also protective for PFAS, samples were collected at various stages of GAC life, including just before changeout when the GAC is nearing the end of its effective life for sulfolane removal. Table 9 below displays the GAC life remaining at the time of PFAS sampling for the Phase II samples. Similar information was not available from SWI for the Phase I samples. All POE systems tested effectively removed PFAS, including PFOS and PFOA to non-detect, regardless of the GAC life remaining at the time of sampling. The POE systems removed both long and short-chain PFAS.

TABLE 9: POINT OF ENTRY SYSTEM AND GAC LIFE

PW-ID[a]	Category	GAC Service Date (estimate or actual)	%GAC Life Remaining	Sample Date
0159	GAC Changeout	10/5/18	1	10/5/18
0217	Deep POEs	6/15/19	68	10/11/18
0376	< 50% GAC Life Remaining	10/22/18	20	10/22/18
0599	> 50% GAC Life Remaining	3/3/19	57	11/28/18
0608	> 50% GAC Life Remaining	2/17/19	54	11/28/18
0617	< 50% GAC Life Remaining	11/2/18	39	11/2/18
0649	Deep POEs	7/29/19	80	12/3/18
0656	< 50% GAC Life Remaining	11/6/18	41	11/6/18
0657	GAC Changeout	10/9/18	1	10/4/18
0947	GAC Changeout	10/16/18	2	10/15/18
1095	< 50% GAC Life Remaining	10/26/18	36	10/26/18

PW-ID[a]	Category	GAC Service Date (estimate or actual)	%GAC Life Remaining	Sample Date
1106	GAC Changeout	10/12/18	10	10/10/18
1155	Deep POEs	1/4/19	48	11/2/18
1374	Resample Phase I (GAC Changeout)	10/12/18	3	10/10/18
1395	< 50% GAC Life Remaining	10/22/18	22	10/19/18
2227	GAC Changeout	11/13/18	1	11/13/18

Notes:
a – Table only includes samples from Phase II. PW-1899 not included because the 2018 sample was the first sample from that well and no information on GAC life was available. Data on Phase I samples not available from SWI.

4.3.2 Adequacy of AWS Provision and Piped Water Expansion Area

Water samples were collected from wells beyond the limits of the sulfolane plume (Figure 1) to evaluate the presence of PFAS. Samples were collected from properties outside of the AWS-provision area and outside of the city's piped water expansion area. PW-1154 and PW-1466, located beyond the west-northwest boundary of the sulfolane plume near the Richardson Highway (Figure 2), fall into this category. PW-531, PW-1195, and PW-532, located on the east side of Badger Slough beyond the northeast boundary of the sulfolane plume (Figure 2), also fall into this category.

As shown on Figure 2, the maximum concentration of PFOS + PFOA from these five locations is 3.8 ppt, well below the ADEC action level of 70 ppt. Figures 3 through 8 show that concentrations of other PFAS are similarly low or not detected in these locations. These results suggest that the AWS and piped water expansion areas appear to be protective of exposure to PFAS concentrations above the ADEC action level in groundwater locations sampled.

4.4 Purge Water PFAS Results

Two purge water samples were analyzed for PFAS following GAC treatment and prior to disposal. Sample results are presented in Table 10. PFOS and PFHxS were detected in both GAC treated purged water samples, PFOS was detected at 0.8 J ppt and 1.8 J ppt, and PFHxS was detected at 0.35 JB ppt and 5.0 ppt. Five additional PFAS (PFHxA, PFHpA, PFOA, PFNA, and PFBS) were also detected at low concentrations in GAC-193A-15.

5.0 QUALITY ASSURANCE ASSESSMENT

Laboratory analysis was completed by Eurofins TestAmerica and SWI completed the ADEC laboratory checklists. Laboratory reports with completed ADEC laboratory checklist are presented in Appendix B. A detailed Data Quality Summary, completed by ADS, is presented in Appendix C.

5.1 Data Quality Summary

SWI validated the data in accordance with and completed ADEC's laboratory data review checklists for each sample delivery group submitted for the Phase I and Phase II PFAS sampling project. ADS reviewed the checklists and validation procedures and summarized the data quality. As part of the their review, ADS utilized EPA's *Data Review and Validation Guidelines for Perfluoroalkyl Substances (PFASs) Analyzed Using EPA Method 537* (EPA, 2018b) and ADEC's *Treatment of Non-Detects and Blank Detections in Per- and Polyfluoroalkyl Substances (PFAS) Analysis* (ADEC, 2019a).The data quality assessment evaluated sensitivity, precision, accuracy, representativeness, comparability, and completeness. Those items are discussed in this subsection.

In summary, there were no indications given by SWI's review that any data quality indicators were significantly impacted during their review. Precision, accuracy, representativeness, comparability, completeness, and sensitivity were deemed acceptable. Most affected data are qualified due to blank detections, and the impact to data usability is minor. Therefore, the data are usable for the purposes of this project, as qualified.

Sensitivity
Sensitivity describes the ability of the sampling and analytical methodology to meet detection and/or quantitation limit objectives. Sensitivity was considered acceptable for the purposes of this project; no limit of quantitation (LOQs) exceeded relevant project action levels set at EPA's LHA and ADEC groundwater cleanup levels for PFOS and PFOA.

Precision
Precision is a measure of the reproducibility of repetitive measurements. Precision was evaluated based on laboratory quality control (QC) sample relative percent difference (RPD). There were no laboratory QC sample RPD failures that affected project-sample data quality. However, there was a small number of field duplicate RPD failures affecting project-sample data quality. The impact to data usability from these failures is minimal, as most of the affected analytes do not have applicable ADEC cleanup levels.

Accuracy
Accuracy is a measure of the correctness, or the closeness, between the true value and the quantity detected. Accuracy was evaluated based on analyte recoveries for laboratory QC samples and recovery of isotope dilution analyte (IDA) spikes for project samples. There were no laboratory QC sample (laboratory control sample [LCS] or matrix spike [MS]) recovery failures and only one IDA recovery failure identified in the course of SWI's review that affected project-sample data quality.

Many samples were qualified due to method blank detections. Following SWI's initial review, the ADEC published a technical memorandum titled *Treatment of Non-Detects and Blank Detections in Per- and Polyfluoroalkyl Substances (PFAS) Analysis* (ADEC, 2019a), in which different qualifying conventions were recommended. For this summary, and for final qualification for data reporting, a conservative approach is taken that is consistent with ADEC recommendations. Any detected result within 10x the method blank concentration is qualified with a 'B' flag and remains reported at the detected concentration. These 'B' flags are retained and carried over to any total results that included 'B'-flagged results in the summation. The 'B' flag indicates the result is an estimate, biased high, and may be a false-positive detection, due to laboratory-based contamination of the sample. Results affected by blank contamination (below or above the LOQ) may be used if they are below 0.07 µg/L for PFOS and PFOA.

There were a significant number of method blank detections, most of which were PFHxS, detected below the LOQ. All results affected by blank contamination were qualified 'B' to indicate to the data user that the results may be biased high and may be false-positive detections.

Although there were a significant number of blank detections, the impact to data usability is relatively minor as most affected analytes do not have relevant project action levels. Overall accuracy is deemed acceptable for the purposes of this project.

Representativeness

Representativeness describes the degree to which data accurately and precisely represent site characteristics. Representativeness is affected by factors such as sample frequency and matrix or contaminant heterogeneity, as well as analytical performance (including sensitivity, accuracy, and precision), sample preservation, handling, and holding times, and sample cross-contamination. Samples were collected in accordance with the work plan requirements, and measurement quality objectives were generally met for all analyses and reported results. Many project-sample results were qualified due to laboratory-based contamination. These results are considered estimated with a high bias and are not wholly representative of site conditions. Additionally, a small number of results were qualified due to field duplicate RPD failures. The impact to data usability for qualified results was generally minor, and overall representativeness is deemed acceptable for purposes of this project.

Comparability

Comparability describes whether two data sets can be considered equivalent with respect to project goals. Comparability is affected by factors such as sampling methodology and analytical performance (including sensitivity, accuracy, and precision). Comparability was evaluated by checking that standard analytical methods were employed, and analytical performance was acceptable. The project sample dataset is deemed generally comparable; however, the project team should evaluate overall comparability with the larger scope of work completed.

Completeness

Completeness describes the amount of valid data obtained from the sampling event(s). It is calculated as the percentage of usable measurements compared to the total number of measurements. The dataset is 100% complete, with no data rejected in the course of SWI's review.

6.0 CONCLUSIONS AND RECOMMENDATIONS

The 2018 PFAS sampling program established the presence of a PFAS plume emanating from the former refinery. In addition, there appears to be a second PFAS source area, located outside of the sulfolane plume footprint in the vicinity of the North Pole Fire Station. The sum of PFOS and PFOA concentrations exceeds the ADEC action level in monitoring wells located at the northern property boundary of the former refinery.. The plume near the North Pole Fire Station exceeds both the ADEC action level and ADEC groundwater cleanup level for PFOS and PFOA. There are also elevated concentrations of other PFAS, including PFNA, PFHxS, PFHpA, PFHxA, and PFBS in both plumes.

6.1 Protectiveness

Conclusions from the PFAS sampling program regarding protectiveness of the community from exposure to PFAS are provided below:

- Based on the pre- and post-treatment samples from 20 water supply wells with POE systems, people drinking water treated by POE systems are not exposed to PFAS above the ADEC action level. The POEs, designed to treat sulfolane, are also effectively treating PFAS under the current operating conditions.

- PFOS and PFOA were not detected in treated water from supply wells fitted with POE systems.

- The piped water expansion area and current AWS provision area appear to be protecting residents and businesses from exposure to PFAS above the ADEC action level. Although the PFAS groundwater plume is not completely delineated, concentrations of all PFAS in sampled locations that are outside the AWS provision area or the piped water expansion area are low (less than 5 ppt).

- Although sampling showed the piped water expansion area to be protective for exposure to PFAS, the protectiveness is contingent upon property owners connecting to the system. The potential for exposure remains if property owners do not hook up to piped water. Future development of properties within the area of PFAS contamination that were not included in the expanded piped water distribution area could also pose potential exposure risk. Non-potable use of untreated groundwater may pose risk of expanding the area of contamination.

Recommendations regarding protectiveness of the community from exposure to PFAS are provided below:

- Collect samples from POE systems with very low or non-detected sulfolane concentrations and potentially relatively high PFAS concentrations (for example, from properties around Kimberly Lake) to ensure that the POE system maintenance schedule, determined for sulfolane, is also protective of PFAS in these areas. Note that FHRA is planning to decommission the POE systems in this area by December 31, 2019.

- Consider future PFAS monitoring of water wells outside the piped water expansion area to ensure that drinking water supplies remain below ADEC action levels or future federal or state levels.

- Notify property owners within the North Pole piped water expansion area about DEC's Groundwater Advisory (ADEC, 2018d) to prevent future exposure and potential spreading of contamination. The ADEC groundwater advisory is included in Appendix D.

6.2 PFAS Groundwater Plume

Conclusions from the PFAS sampling program regarding the extent of the PFAS contamination in groundwater are provided below:

- Sample results show groundwater contaminated by PFAS, including PFNA, PFOS, PFOA, PFHxS, PFHpA, PFHxA, and PFBS, emanating from the former refinery. The PFAS plume appears to originate on the former refinery property, which is outside the investigation area covered in this report. The PFOS and PFOA concentrations on the former refinery property exceed the ADEC groundwater cleanup level of 400 ppt, and the PFAS concentrations in property boundary monitoring wells exceed the ADEC action level of 70 ppt for the sum of PFOS and PFOA.

- PFAS concentrations migrating off the former refinery are expected to increase from the 2018 levels as a result of the 2016 - 2017 shutdown of the onsite pump-and-treat system.

- In addition to the plume originating on the former refinery, PFAS-contaminated groundwater is present in MW-316-15, located near the North Pole Fire Station. This contamination is discussed further in Section 6.3.

- PFNA concentrations are notably high in both North Pole groundwater plumes.

Recommendations for follow-up activities related to PFAS plume delineation are provided below:

- Sample all depths of monitoring well nests along and near the former refinery property boundary to determine the extent of PFAS above ADEC action levels with depth and to assess the effect of the 2016-2017 shutdown of the onsite pump-and-treat system.

- Evaluate temporal trends by resampling selected high-concentration water wells and distal wells, such as MW-191 and MW-194.

- Improve PFAS plume delineation by sampling additional locations, specifically in the subpermafrost and in the area where the former refinery PFAS plume may abut the MW-316 plume.

6.3 PFAS in MW-316-15

Conclusions from the PFAS sampling program regarding the PFAS contamination in MW-316-15 are provided below:

- The sum of PFOS and PFOA concentrations from MW-316-15 are above ADEC's action level of 70 ppt. MW-316-15 results for all detected PFAS are significantly higher than results from all other locations sampled during this project. The concentrations of PFAS at the 56-foot interval of MW-316 are much lower than at the 15-ft level and are within the range of other results from this investigation.

- The source of the MW-316 area plume has not been identified, although the City of North Pole's fire station, located a short distance upgradient of MW-316, is suspected as a potential source. The two groundwater plumes appear to commingle; the Phase I/II data do not provide enough detail to determine the border between the two plumes, nor is the MW-316 plume delineated.

Recommendations for follow-up activities regarding the PFAS in MW-316-15 were communicated by ADEC to the City of North Pole earlier in 2019 and are summarized below:

- Water supply wells located across the Richardson Highway to the east-northeast of MW-316 should be sampled to ensure protectiveness, although they are not expected to be downgradient of the MW-316 source. Some of these properties are on AWS and some are not.

- Monitoring wells and water supply wells located to the north and northwest of MW-316 should be sampled for plume delineation. ADEC recommended 16 wells for sampling, including three multi-level well nests.

- Source characterization activities should be performed at the North Pole Fire Station, located upgradient of MW-316.

6.4 PFAS in Surface Water

Conclusions from the PFAS sampling program regarding PFAS in surface water are provided below:

- Elevated levels of PFAS were detected in surface water samples in Kimberly Lake, including PFNA, PFOS, PFOA, PFHxS, PFHpA, PFHxA, and PFBS. The levels of these PFAS are similar to concentrations in nearby groundwater, illustrating the connectivity between Kimberly Lake and adjacent groundwater.

- Low concentrations of PFAS were detected in Badger Slough water samples. Similar PFAS concentrations were detected in the southern and middle samples (SS and SM). The northern sample (SN), which is located downgradient of the sulfolane plume, exhibited a relatively higher total PFAS concentration and greater percentage of PFNA.

- Both PFOS and PFNA are known to bioaccumulate in fish, which can create a route of human exposure through fish consumption. In December 2018, Alaska Department of Fish and Game (ADF&G) sampled three rainbow trout from Kimberly Lake and analyzed them for PFAS. PFOS concentrations in fish ranged from 47 to 68 parts per billion (ppb) and PFNA concentrations ranged from 16 to 22 ppb (ADEC, 2019c), orders of magnitude above the concentrations in surface water. In April 2019, ADF&G closed Kimberly Lake to sport fishing and will not continue to stock the lake (ADF&G, 2019).

Recommendations for follow-up activities regarding PFAS in surface water are provided below:

- Investigate PFAS in surface water bodies on and to the north northwest of the former refinery.
- Evaluate potential bioaccumulation of PFAS in fish and other ecological receptors in surface water bodies used for sport and subsistence fishing, including fish from Badger Slough and other surface water bodies in the PFAS plume area.

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TABLES

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Table 5. Monitoring Wells and Water Supply Wells PFAS Results[a]
North Pole PFAS Water Sampling

Location ID	Sample Date	QC Type	PFOS	PFOA	PFNA	PFHxS	PFHpA	PFBS	PFHxA	PFDA	PFDoA	PFTeA	PFTriA	PFUnA	PFOS + PFOA[c]	Total Detected PFAS[d]
MW-150A-10	7/19/2018		28	14	43	15	16	2.2	22	0.40 J	0.90 U	0.48 U	2.2 U	1.8 U	42	141
MW-150B-25	7/19/2018	Primary	40	17	51	17	17	2.7	24	0.68 J	0.96 U	0.52 U	2.2 U	1.9 U	57	161
MW-150B-25	7/19/2018	Duplicate	46	17	54	17	17	2.5	24	0.53 J	0.94 U	0.50 U	2.2 U	1.9 U	63	169
MW-150B-25	10/24/2018		29	17	56	16	17	2.5	23	0.77 J	1.1 U	0.58 U	2.6 U	2.2 U	46	178
MW-150C-60	10/24/2018		23	18	55	18	18	1.9	24	0.62 J	1.0 U	0.54 U	2.4 U	2.0 U	41	159
MW-151A-15	10/24/2018		21	8.8	33	9.3	9.1	1.7 J	11	0.47 J	1.1 U	0.56 U	2.6 U	2.2 U	30	94
MW-151B-25	10/24/2018		17	8.1	28	8.8	7.4	1.4 J	9.1	0.43 J	1.1 U	0.58 U	2.6 U	2.2 U	25	80
MW-151C-60	10/24/2018		13	9.7	27	12	9.0	1.2 J	12	0.38 J	1.1 U	0.58 U	2.6 U	2.2 U	23	84
MW-152A-15	10/23/2018		9.0	3.0	10	10	2.6	2.5	3.9	0.62 U	1.1 U	0.58 U	2.6 U	2.2 U	12	41
MW-152B-25	10/23/2018		6.3	3.0	11	5.7	2.5	2.2	2.7	0.62 U	1.1 U	0.58 U	2.6 U	2.2 U	9.3	33
MW-153A-15	10/24/2018	Primary	18	15	36	27	28	7.0	55	0.50 J	1.1 U	0.56 U	2.6 U	2.2 U	33	187
MW-153A-15	10/24/2018	Duplicate	18	16	34	26	30	5.2	58	0.50 J	1.1 U	0.56 U	2.4 U	2.2 U	34	188
MW-153B-55	10/24/2018		17	14	42	15	14	2.2	17	0.39 J	1.1 U	0.58 U	2.6 U	2.2 U	31	122
MW-155A-15	10/23/2018		32	16	57	15	19	1.8 J	30	0.75 J	1.1 U	0.58 U	2.6 U	2.2 U	48	172
MW-155B-65	10/23/2018		24	20	56	20	25	2.5	37	0.66 J	1.1 U	0.58 U	2.6 U	2.2 U	44	185
MW-156A-15	10/22/2018		25	14	41	12	13	2.0	19	0.61 J	0.96 U	0.50 U	2.2 U	1.9 U	39	127
MW-158A-15	10/22/2018		8.9 B	5.7	16	5.8	9.3	2.1	11	0.54 U	0.94 U	0.50 U	2.2 U	1.9 U	15 B	59
MW-184-45	10/22/2018		3.4 B	2.5	0.45 J	7.4	2.2	1.0 J	3.6	0.54 U	0.94 U	0.38 J	2.2 U	1.9 U	5.9 B	21
MW-189A-15	10/23/2018		1.2 J	3.5	0.37 J	3.7	0.72 J	5.4	3.7	0.64 U	1.1 U	0.60 U	2.6 U	2.2 U	4.7 J	19
MW-189B-60	10/23/2018		1.8 J	1.7 U	0.56 U	2.1 B	0.50 U	0.58 J	1.2 U	0.64 U	1.1 U	0.60 U	2.6 U	2.2 U	3.5 J	4.5
MW-191A-15	10/23/2018		1.7 J	1.7 U	0.43 J	4.5	0.50 U	0.89 J	1.1 U	0.62 U	1.1 U	0.58 U	2.6 U	2.2 U	3.4 J	7.5
MW-191B-60	10/23/2018		4.0	2.1	4.1	3.9	1.6 J	0.56 J	2.2	0.62 U	1.1 U	0.58 U	2.6 U	2.2 U	6.1	18
MW-193A-15	10/24/2018	Primary	7.5 J	5.9	6.8	8.4	8.4	1.7 J	14	0.64 U	1.1 U	0.58 U	2.6 U	2.2 U	13 J	53
MW-193A-15	10/24/2018	Duplicate	2.7 J	5.4	7.9	8.8	7.6	1.6 J	13	0.60 U	1.1 U	0.36 J B	2.6 U	2.2 U	8.1 J	47
MW-194A-15	10/23/2018		3.9	5.5	8.1	6.9	4.9	1.2 J	8.8	0.66 U	1.2 U	0.62 U	2.8 U	2.4 U	9.4	39
MW-194B-40	10/23/2018		7.3	8.2	16	11	7.5	1.7 J	12	0.62 U	1.1 U	0.58 U	2.6 U	2.2 U	16	64
MW-311-15	10/23/2018		1.1 U	1.7 U	0.54 U	0.41 J B	0.50 U	6.2	1.2 U	0.62 U	1.1 U	0.58 U	2.6 U	2.2 U	2.8 U	6.6
MW-311-46	10/23/2018		1.1 U	1.7 U	0.56 U	0.38 J B	0.52 U	0.40 U	1.2 U	0.64 U	1.1 U	0.33 J	2.6 U	2.2 U	2.8 U	0.71
MW-314-15	7/20/2018		1.4 J B	1.4 U	0.44 U	5.1	0.42 U	2.0	0.96 U	0.52 U	0.90 U	0.48 U	2.2 U	1.8 U	2.8 J B	8.5
MW-316-15	10/22/2018		790	280	2400	440	180	43	180	12	1.0 U	0.30 J	10 U	16	1070	4341
MW-316-56	10/24/2018		2.4	2.4	1.0 J	6.2	2.1	0.75 J	3.4	0.64 U	1.1 U	0.34 J B	2.6 U	2.2 U	4.8	19
MW-318-20	10/22/2018		3.3 B	1.5 J	2.1	2.5 B	1.4 J	0.44 J	1.7 J	0.54 U	0.98 U	0.52 U	2.2 U	1.9 U	4.8 J B	13
MW-327-15	10/22/2018		2.2 B	4.2	0.67 J	9.3	2.7	4.1	5.1	0.56 U	0.98 U	0.52 U	2.4 U	2.0 U	6.4 B	28
MW-328-151	10/24/2018		1.3 J	1.7 U	0.34 J	0.33 J B	0.50 U	0.40 U	1.1 U	0.41 J	1.1 U	0.58 U	2.6 U	2.2 U	3.0 J	2.4
MW-332-150	7/20/2018		1.6 B	1.6	0.58 J	3.8	1.1 J	0.83 J	3.4	0.50 U	0.88 U	0.46 U	2.2 U	1.8 U	3.2 B	13
MW-346-65	7/20/2018		1.2 J B	2.4	8.6	3.7	1.6 J	0.64 J	3.3	0.52 U	0.92 U	0.48 U	2.2 U	1.8 U	3.6 J B	21
MW-353-15	7/20/2018		21	6.5	13	8.1	5.6	1.8	8.0	0.50 U	0.90 U	0.48 U	2.2 U	1.8 U	28	64
MW-353-65	7/20/2018		12	7.6	22	8.5	5.8	1.4 J	7.6	0.52 U	0.94 U	0.50 U	2.2 U	1.9 U	20	65
MW-353-100	7/20/2018		12	7.5	24	8.4	5.9	1.5 J	8.4	0.52 U	0.90 U	0.48 U	2.2 U	1.8 U	20	68
MW-356-20	10/23/2018		1.1 J	1.7 U	0.56 U	4.2	0.52 U	1.3 J	1.2 U	0.64 U	1.1 U	0.60 U	2.6 U	2.2 U	2.8 J	6.6
MW-356-65	10/23/2018		1.7 J	1.7 U	0.54 U	3.8	0.50 U	0.85 J	1.2 U	0.62 U	1.1 U	0.58 U	2.6 U	2.2 U	3.4 J	6.4
MW-356-90	10/23/2018		1.4 J	1.7 U	0.54 U	3.6	0.50 U	0.81 J	1.2 U	0.62 U	1.1 U	0.58 U	2.6 U	2.2 U	3.1 J	5.8
MW-357-15	10/22/2018	Primary	1.4 J B	1.6 U	0.50 U	0.87 J B	0.46 U	0.36 U	1.1 U	0.56 U	1.0 U	0.52 U	2.4 U	2.0 U	3.0 J B	2.3
MW-357-15	10/22/2018	Duplicate	1.7 J B	1.6 U	0.50 U	0.79 J B	0.46 U	0.36 U	1.1 U	0.58 U	1.0 U	0.54 U	2.4 U	2.0 U	3.3 J B	2.5
MW-357-150	10/23/2018		1.2 U	1.8 U	0.58 U	0.32 J B	0.54 U	0.42 U	1.2 U	0.66 U	1.2 U	0.62 U	2.8 U	2.4 U	3.0 U	0.32
MW-357-65	10/23/2018		1.1 U	1.7 U	0.54 U	0.57 J B	0.50 U	0.40 U	1.2 U	0.62 U	1.1 U	0.58 U	2.6 U	2.2 U	2.8 U	0.57
PW-159	10/5/2018		25	13	55	16	12	1.6 J	18	0.56 U	0.98 U	0.52 U	2.4 U	2.0 U	38	141
PW-217	10/11/2018		9.2	6.9	15	8.8	5.6	1.4 J	9.3	0.52 U	0.92 U	0.48 U	2.2 U	1.8 U	16	56
PW-271	11/2/2018		0.61 J	1.5 U	0.42 J	0.77 J B	0.43 J	0.34 U	0.93 J	0.54 U	0.96 U	0.50 U	2.2 U	1.9 U	2.1 J	3.2
PW-277	10/26/2018		0.94 U	1.5 U	0.26 J	0.46 J B	0.44 U	0.34 U	1.0 U	0.54 U	0.96 U	0.35 J	2.2 U	1.9 U	2.4 U	1.1

Table 5. Monitoring Wells and Water Supply Wells PFAS Results[a]
North Pole PFAS Water Sampling

Location ID	Sample Date	QC Type	PFOS	PFOA	PFNA	PFHxS	PFHpA	PFBS	PFHxA	PFDA	PFDoA	PFTeA	PFTriA	PFUnA	PFOS + PFOA[c]	Total Detected PFAS[d]
PW-290	10/29/2018		0.90 U	1.4 U	0.46 U	**0.31 J B**	0.42 U	0.34 U	0.98 U	0.52 U	0.92 U	0.48 U	2.2 U	1.9 U	2.3 U	**0.31**
PW-376	10/22/2018		**5.1**	**3.1**	**20**	**8.0**	**2.7**	**1.4 J**	**5.2**	0.54 U	0.96 U	0.50 U	2.2 U	1.9 U	**8.2**	**46**
PW-531	11/2/2018		**0.78 J**	1.4 U	0.46 U	**3.1 B**	0.42 U	**0.44 J**	0.98 U	0.52 U	0.92 U	0.48 U	2.2 U	1.9 U	**2.2 J**	**4.3**
PW-532	10/23/2018		**0.81 J**	**1.1 J**	0.46 U	**3.5**	0.42 U	**0.93 J**	0.98 U	0.52 U	0.92 U	0.50 U	2.2 U	1.9 U	**1.9 J**	**6.3**
PW-561[b]	8/3/2018		**2.5**	**2.4**	**7.7**	**3.8**	**1.4 J**	**0.85 J**	**3.8**	0.56 U	1.0 U	0.54 U	2.4 U	2.0 U	**4.9**	**22**[e]
PW-599	11/28/2018		**7.5**	**6.2**	**13**	**8.0**	**4.9**	**1.4 J**	**6.8**	0.54 U	0.98 U	0.52 U	2.4 U	2.0 U	**14**	**48**
PW-608	11/28/2018	Primary	**20**	**15**	**41**	**18**	**17**	**2.6**	**25**	0.54 U	0.96 U	0.50 U	2.2 U	1.9 U	**35**	**139**
PW-608	11/28/2018	Duplicate	**19**	**15**	**46**	**18**	**18**	**2.7**	**24**	0.54 U	0.98 U	0.52 U	2.2 U	1.9 U	**34**	**143**
PW-617	11/2/2018		**18**	**17**	**41**	**24**	**17**	**3.9**	**30**	0.54 U	0.96 U	0.50 U	2.2 U	1.9 U	**35**	**151**
PW-618	7/24/2018		**14**	**9.9**	**23**	**13**	**11**	**1.5 J**	**17**	0.52 U	0.92 U	0.48 U	2.2 U	1.8 U	**24**	**89**
PW-649	12/3/2018		**0.85 J**	**3.1**	**0.54 J**	**2.9 B**	**1.7**	**0.64 J**	**3.6**	0.52 U	0.94 U	0.50 U	2.2 U	1.9 U	**4.0 J**	**13**
PW-656	11/6/2018		**3.4**	**4.4**	**6.8**	**5.4**	**3.9**	**0.67 J**	**5.2**	0.52 U	0.94 U	0.50 U	2.2 U	1.9 U	**7.8**	**30**
PW-657	10/4/2018		**2.8**	**4.0**	**5.3**	**5.3**	**3.0**	**0.87 J**	**6.1**	0.56 U	1.0 U	0.54 U	2.4 U	2.0 U	**6.8**	**27**
PW-757	7/24/2018		**0.73 J**	**1.4 J**	**4.8**	**1.8 B**	**0.54 J**	**0.25 J**	**1.8**	0.50 U	0.90 U	0.48 U	2.2 U	1.8 U	**2.1 J**	**11**
PW-927	11/20/2018	Primary	1.0 U	**0.90 J**	0.52 U	**0.88 J B**	**0.43 J**	**0.35 J**	**1.0 J**	0.60 U	1.1 U	0.56 U	2.4 U	2.2 U	**1.9 J**	**3.6**
PW-927	11/20/2018	Duplicate	1.0 U	1.6 U	**0.28 J**	**0.83 J B**	**0.32 J**	**0.20 J**	**1.1 J**	0.60 U	1.0 U	0.56 U	2.4 U	2.0 U	2.6 U	**2.7**
PW-947	10/15/2018		**3.0**	**4.6**	**38**	**8.3**	**3.6**	**1.4 J**	**6.2**	0.56 U	1.0 U	0.54 U	2.4 U	2.0 U	**7.6**	**65**
PW-974	10/23/2018	Primary	**2.4**	**1.1 J**	**1.6 J**	**3.0 B**	**0.32 J**	**0.31 J**	1.0 U	0.56 U	0.98 U	0.52 U	2.4 U	2.0 U	**3.5 J**	**8.7**
PW-974	10/23/2018	Duplicate	**2.5**	**0.89 J**	**1.6 J**	**3.1 B**	**0.44 J**	**0.41 J**	1.0 U	0.54 U	0.96 U	0.50 U	2.2 U	1.9 U	**3.4 J**	**8.9**
PW-976	10/23/2018		**3.0**	**1.3 J**	**2.4**	**3.6**	**1.0 J**	**0.60 J**	**1.8**	0.54 U	0.96 U	0.50 U	2.2 U	1.9 U	**4.3 J**	**14**
PW-978	10/23/2018		**3.7**	**1.2 J**	**1.9**	**3.0 B**	**0.58 J**	**0.46 J**	**0.91 J**	0.54 U	0.96 U	0.50 U	2.2 U	1.9 U	**4.9 J**	**12**
PW-979	10/23/2018		**2.7**	**1.0 J**	**2.0**	**3.5**	**0.22 J**	**0.36 J**	0.96 U	0.52 U	0.92 U	0.48 U	2.2 U	1.8 U	**3.7 J**	**9.8**
PW-1095	10/26/2018		**25**	**16**	**50**	**16**	**19**	**2.4**	**24**	0.56 U	0.98 U	0.52 U	2.4 U	2.0 U	**41**	**152**
PW-1106	10/10/2018		**1.2 J**	**1.2 J**	**1.5 J**	**2.7 B**	**0.75 J**	**2.8**	**2.3**	0.54 U	0.94 U	0.50 U	2.2 U	1.9 U	**2.4 J**	**12**
PW-1154	10/23/2018		**2.3**	**1.2 J**	**2.1**	**3.8**	**0.31 J**	**0.75 J**	**0.78 J**	0.54 U	0.96 U	0.52 U	2.2 U	1.9 U	**3.5 J**	**11**
PW-1155	11/2/2018	Primary	**6.6**	**6.3**	**12**	**7.9**	**5.4**	**1.5 J**	**7.6**	**0.48 J**	0.92 U	0.48 U	2.2 U	1.9 U	**13**	**48**
PW-1155	11/2/2018	Duplicate	**6.7**	**5.1**	**12**	**6.7**	**5.2**	**0.95 J**	**8.1**	0.52 U	0.94 U	0.50 U	2.2 U	1.9 U	**12**	**45**
PW-1185	10/9/2018		**9.1**	**6.6**	**41**	**19**	**6.1**	**2.3**	**13**	**0.58 J**	1.0 U	0.52 U	2.4 U	2.0 U	**16**	**98**
PW-1195	10/29/2018		**0.72 J**	1.4 U	0.46 U	**3.0 B**	0.42 U	**0.80 J**	0.98 U	0.52 U	0.94 U	0.50 U	2.2 U	1.9 U	**2.1 J**	**4.5**
PW-1230	7/20/2018	Primary	**29**	**9.2**	**30**	**15**	**7.8**	**2.1**	**12**	0.54 U	0.98 U	0.52 U	2.4 U	1.9 U	**38**	**105**
PW-1230	7/20/2018	Duplicate	**32**	**9.8**	**33**	**15**	**8.6**	**2.4**	**13**	0.54 U	0.98 U	0.52 U	2.4 U	1.9 U	**42**	**114**
PW-1374	10/10/2018	Primary	**16**	**13**	**35**	**19**	**14**	**2.2**	**22**	0.54 U	0.94 U	0.50 U	2.2 U	1.9 U	**29**	**121**
PW-1374	10/10/2018	Duplicate	**16**	**15**	**37**	**18**	**14**	**2.2**	**23**	0.56 U	1.0 U	0.52 U	2.4 U	2.0 U	**31**	**125**
PW-1374	7/17/2018		**17**	**14**	**34**	**18**	**17**	**2.5**	**23**	0.50 U	0.88 U	0.46 U	2.0 U	1.8 U	**31**	**126**
PW-1395	10/19/2018		**2.4**	**1.5 J**	**6.5**	**4.2**	**0.90 J**	**0.78 J**	**2.0**	0.52 U	0.92 U	0.48 U	2.2 U	1.9 U	**3.9 J**	**18**
PW-1466	10/29/2018		**2.7**	**1.1 J**	**2.3**	**3.4**	**0.53 J**	**0.66 J**	**0.53 J**	0.56 U	0.98 U	0.52 U	2.4 U	2.0 U	**3.8 J**	**11**
PW-1899	11/14/2018		**0.40 J**	**3.2**	**0.61 J**	**7.5**	**1.8**	**0.99 J**	**9.0**	1.7 U	0.94 U	0.56 U	0.76 U	0.76 U	**3.6 J**	**24**
PW-2227	11/13/2018		**2.3 J**	**3.3**	**3.0 J**	**4.9 J**	**2.5**	**1.4 J**	**5.2**	4.6 U	2.6 U	1.5 U	2.0 U	2.0 U	**5.6 J**	**23**

For PFAS defintions, see acronym page.
all results in ng/L or ppt

Key:
Blank cell = not tested
Bold = detected value
ng/L = nanograms per liter
ppt = parts per trillion
QC = quality control sample

Data Flags:
B = estimated result based on blank contamination
J = estimated result
U = not detected at reported 2xMDL

Table 5. Monitoring Wells and Water Supply Wells PFAS Results[a]
North Pole PFAS Water Sampling

Location ID	Sample Date	QC Type	PFOS	PFOA	PFNA	PFHxS	PFHpA	PFBS	PFHxA	PFDA	PFDoA	PFTeA	PFTriA	PFUnA	PFOS + PFOA[c]	Total Detected PFAS[d]

a - For water supply wells with POE systems, only pre-treatment results are presented. See Table 7 for list of pre- and post-treatment results.

b - Sample was analyzed for additional analytes. See Table 7 for list of full results.

c - PFOS + PFOA is the sum of PFOS and PFOA; ND is included at 2xMDL for summation.

d- Total Detected PFAS is the sum of all **detected** PFAS; nondetected PFAS are not included in the summation. Data flags are not included.

e - Additional analytes shown on Table 8 were not included in the Total Detected PFAS.

Table 6. Surface Water PFAS Results
North Pole PFAS Water Sampling

Location ID	Sample Date	QC Type	PFOS	PFOA	PFNA	PFHxS	PFHpA	PFBS	PFHxA	PFDA	PFDoA	PFTeA	PFTriA	PFUnA	PFOS + PFOA	Total Detected PFAS[a]
KL 101	10/12/2018	Duplicate	**24**	**16**	**50**	**14**	**16**	**2.0**	**26**	**0.44 J**	1.0 U	0.54 U	2.4 U	2.0 U	**40**	148
KL 102	10/12/2018	Primary	**24**	**17**	**47**	**15**	**19**	**1.9**	**27**	**0.46 J**	1.0 U	0.52 U	2.4 U	2.0 U	**41**	151
SM	10/12/2018		**2.0**	**1.8**	**0.35 J**	**4.0**	**0.37 J**	**0.77 J**	**0.64 J**	0.54 U	0.96 U	0.50 U	2.2 U	1.9 U	**3.8**	10
SN	10/12/2018		**3.0**	**2.7**	**5.0**	**4.6**	**1.7 J**	**0.90 J**	**2.8**	0.56 U	0.98 U	0.52 U	2.4 U	2.0 U	**5.7**	21
SS	10/12/2018		**2.4**	**1.8**	**0.28 J**	**4.6**	**0.28 J**	**0.95 J**	**0.73 J**	0.54 U	0.96 U	0.52 U	2.2 U	1.9 U	**4.2**	11

For PFAS defintions, see acronym page.

all results in ng/L or ppt

Key:

Bold = detected value

ng/L = nanograms per liter

ppt = parts per trillion

QC = quality control sample

Data Flags:

J = estimated result

U = not detected at reported 2xMDL

a - Total Detected PFAS is the sum of all **detected** PFAS; nondetected PFAS are not included in the summation. Data flags are not included.

Table 7. Water Supply Well Point of Entry PFAS Results, Pre- and Post-Treatment
North Pole PFAS Water Sampling

Location ID	Sample Date	QC Type	Sample Type	PFOS	PFOA	PFNA	PFHxS	PFHpA	PFBS	PFHxA	PFDA	PFDoA	PFTeA	PFTriA	PFUnA	6:2 FTS	8:2 FTS	NEtFOSAA	NMeFOSAA	PFBA	PFDS	PFHpS	FOSA	PFPeA	PFOS + PFOA[a]
PW-159	10/5/2018		untreated	**25**	**13**	**55**	**16**	**12**	**1.6 J**	**18**	0.56 U	0.98 U	0.52 U	2.4 U	2.0 U										**38**
PW-159	10/5/2018		treated	0.94 U	1.5 U	0.46 U	**0.21 J B**	0.44 U	0.34 U	1.0 U	0.54 U	0.96 U	0.50 U	2.2 U	1.9 U										2.4 U
PW-217	10/11/2018		untreated	**9.2**	**6.9**	**15**	**8.8**	**5.6**	**1.4 J**	**9.3**	0.52 U	0.92 U	0.48 U	2.2 U	1.8 U										**16**
PW-217	10/11/2018		treated	0.94 U	1.5 U	0.48 U	**0.21 J B**	0.44 U	0.36 U	1.0 U	0.54 U	0.96 U	0.50 U	2.2 U	1.9 U										2.4 U
PW-376	10/22/2018		untreated	**5.1**	**3.1**	**20**	**8.0**	**2.7**	**1.4 J**	**5.2**	0.54 U	0.96 U	0.50 U	2.2 U	1.9 U										**8.2**
PW-376	10/22/2018		treated	0.94 U	1.5 U	0.46 U	**0.24 J B**	0.44 U	0.34 U	1.0 U	0.54 U	0.94 U	0.50 U	2.2 U	1.9 U										2.4 U
PW-561	8/3/2018		untreated	**2.5**	**2.4**	**7.7**	**3.8**	**1.4 J**	**0.85 J**	**3.8**	0.56 U	1.0 U	0.54 U	2.4 U	2.0 U	**18 B**	3.6 U	3.4 U	5.6 U	**3.1 B**	0.58 U	0.34 U	0.64 U	**4.1**	**4.9**
PW-561	8/3/2018		treated	0.96 U	1.5 U	0.48 U	**0.25 J B**	0.44 U	0.36 U	1.0 U	0.56 U	0.98 U	0.52 U	2.4 U	2.0 U	**7.5 J B**	3.6 U	3.4 U	5.6 U	**0.53 J B**	0.58 U	0.34 U	0.62 U	0.88 U	2.5 U
PW-599	11/28/2018		untreated	**7.5**	**6.2**	**13**	**8.0**	**4.9**	**1.4 J**	**6.8**	0.54 U	0.98 U	0.52 U	2.4 U	2.0 U										**14**
PW-599	11/28/2018		treated	0.90 U	1.4 U	0.44 U	**0.27 J B**	0.42 U	0.34 U	0.96 U	0.52 U	0.92 U	**0.26 J**	2.2 U	1.8 U										2.3 U
PW-608	11/28/2018	Primary	untreated	**20**	**15**	**41**	**18**	**17**	**2.6**	**25**	0.54 U	0.96 U	0.50 U	2.2 U	1.9 U										**35**
PW-608	11/28/2018	Duplicate	untreated	**19**	**15**	**46**	**18**	**18**	**2.7**	**24**	0.54 U	0.98 U	0.52 U	2.2 U	1.9 U										**34**
PW-608	11/28/2018		treated	0.88 U	1.4 U	0.44 U	**0.23 J B**	0.42 U	0.32 U	0.96 U	0.52 U	0.90 U	0.48 U	2.2 U	1.8 U										2.3 U
PW-617	11/2/2018		untreated	**18**	**17**	**41**	**24**	**17**	**3.9**	**30**	0.54 U	0.96 U	0.50 U	2.2 U	1.9 U										**35**
PW-617	11/2/2018		treated	0.90 U	1.4 U	0.44 U	**0.21 J B**	0.42 U	0.34 U	0.96 U	0.52 U	0.92 U	0.48 U	2.2 U	1.8 U										2.3 U
PW-618	7/24/2018		untreated	**14**	**9.9**	**23**	**13**	**11**	**1.5 J**	**17**	0.52 U	0.92 U	0.48 U	2.2 U	1.8 U										**24**
PW-618	7/24/2018		treated	0.92 U	1.4 U	**0.63 J**	**0.65 J B**	**0.92 J**	0.34 U	**2.0**	0.52 U	0.94 U	0.50 U	2.2 U	1.9 U										2.3 U
PW-649	12/3/2018		untreated	**0.85 J**	**3.1**	**0.54 J**	**2.9 B**	**1.7**	**0.64 J**	**3.6**	0.52 U	0.94 U	0.50 U	2.2 U	1.9 U										**4.0 J**
PW-649	12/3/2018		treated	0.90 U	1.4 U	0.46 U	**0.23 J B**	0.42 U	0.34 U	0.96 U	0.52 U	0.92 U	0.48 U	2.2 U	1.8 U										2.3 U
PW-656	11/6/2018		untreated	**3.4**	**4.4**	**6.8**	**5.4**	**3.9**	**0.67 J**	**5.2**	0.52 U	0.94 U	0.50 U	2.2 U	1.9 U										**7.8**
PW-656	11/6/2018		treated	0.90 U	1.4 U	0.46 U	**0.27 J B**	0.42 U	0.34 U	0.96 U	0.52 U	0.92 U	0.48 U	2.2 U	1.8 U										2.3 U
PW-657	10/4/2018		untreated	**2.8**	**4.0**	**5.3**	**5.3**	**3.0**	**0.87 J**	**6.1**	0.56 U	1.0 U	0.54 U	2.4 U	2.0 U										**6.8**
PW-657	10/4/2018		treated	0.92 U	1.5 U	**0.31 J**	**0.45 J B**	**0.39 J**	0.34 U	**1.3 J**	0.54 U	0.94 U	0.50 U	2.2 U	1.9 U										2.4 U
PW-757	7/24/2018		untreated	**0.73 J**	**1.4 J**	**4.8**	**1.8 B**	**0.54 J**	**0.25 J**	**1.8**	0.50 U	0.90 U	0.48 U	2.2 U	1.8 U										**2.1 J**
PW-757	7/24/2018		treated	0.86 U	1.4 U	0.44 U	**0.27 J B**	0.40 U	0.32 U	0.94 U	0.50 U	0.88 U	0.46 U	2.0 U	1.8 U										2.3 U
PW-947	10/15/2018		untreated	**3.0**	**4.6**	**38**	**8.3**	**3.6**	**1.4 J**	**6.2**	0.56 U	1.0 U	0.54 U	2.4 U	2.0 U										**7.6**
PW-947	10/15/2018		treated	0.90 U	1.4 U	**1.0 J**	**0.48 J B**	**0.34 J**	0.34 U	**0.75 J**	0.52 U	0.92 U	0.48 U	2.2 U	1.9 U										2.3 U
PW-1095	10/26/2018		untreated	**25**	**16**	**50**	**16**	**19**	**2.4**	**24**	0.56 U	0.98 U	0.52 U	2.4 U	2.0 U										**41**
PW-1095	10/26/2018		treated	0.96 U	1.5 U	0.48 U	**0.21 J B**	0.44 U	0.36 U	1.0 U	0.56 U	0.98 U	0.52 U	2.4 U	2.0 U										2.5 U
PW-1106	10/10/2018		untreated	**1.2 J**	**1.2 J**	**1.5 J**	**2.7 B**	**0.75 J**	**2.8**	**2.3**	0.54 U	0.94 U	0.50 U	2.2 U	1.9 U										**2.4 J**
PW-1106	10/10/2018		treated	0.92 U	1.4 U	0.46 U	**0.25 J B**	0.42 U	0.34 U	0.98 U	0.52 U	0.94 U	0.50 U	2.2 U	1.9 U										2.3 U
PW-1155	11/2/2018	Primary	untreated	**6.6**	**6.3**	**12**	**7.9**	**5.4**	**1.5 J**	**7.6**	**0.48 J**	0.92 U	0.48 U	2.2 U	1.9 U										**13**
PW-1155	11/2/2018	Duplicate	untreated	**6.7**	**5.1**	**12**	**6.7**	**5.2**	**0.95 J**	**8.1**	0.52 U	0.94 U	0.50 U	2.2 U	1.9 U										**12**
PW-1155	11/2/2018		treated	0.90 U	1.4 U	0.46 U	**0.20 J B**	0.42 U	0.34 U	0.96 U	0.52 U	0.92 U	0.48 U	2.2 U	1.8 U										2.3 U
PW-1374	7/17/2018		untreated	**17**	**14**	**34**	**18**	**17**	**2.5**	**23**	0.50 U	0.88 U	0.46 U	2.0 U	1.8 U										**31**
PW-1374	7/17/2018		treated	0.90 U	1.4 U	0.46 U	**0.23 J B**	0.42 U	0.34 U	0.96 U	0.52 U	0.92 U	0.48 U	2.2 U	1.8 U										2.3 U
PW-1374	10/10/2018	Primary	untreated	**16**	**13**	**35**	**19**	**14**	**2.2**	**22**	0.54 U	0.94 U	0.50 U	2.2 U	1.9 U										**29**
PW-1374	10/10/2018	Duplicate	untreated	**16**	**15**	**37**	**18**	**14**	**2.2**	**23**	0.56 U	1.0 U	0.52 U	2.4 U	2.0 U										**31**
PW-1374	10/10/2018		treated	0.92 U	1.4 U	0.46 U	**0.24 J B**	0.42 U	0.34 U	0.98 U	0.52 U	0.92 U	0.48 U	2.2 U	1.9 U										2.3 U
PW-1395	10/19/2018		untreated	**2.4**	**1.5 J**	**6.5**	**4.2**	**0.90 J**	**0.78 J**	**2.0**	0.52 U	0.92 U	0.48 U	2.2 U	1.9 U										**3.9 J**
PW-1395	10/19/2018		treated	0.92 U	1.4 U	0.46 U	**0.29 J B**	0.42 U	0.34 U	0.98 U	0.52 U	0.94 U	0.50 U	2.2 U	1.9 U										2.3 U
PW-1899	11/14/2018		untreated	**0.40 J**	**3.2**	**0.61 J**	**7.5**	**1.8**	**0.99 J**	**9.0**	1.7 U	0.94 U	0.56 U	0.76 U	0.76 U										**3.6 J**
PW-1899	11/14/2018		treated	0.70 U	0.52 U	0.70 U	0.70 U	0.70 U	0.52 U	0.70 U	1.6 U	0.86 U	0.52 U	0.70 U	0.70 U										1.2 U
PW-2227	11/13/2018		untreated	**2.3 J**	**3.3**	**3.0 J**	**4.9 J**	**2.5**	**1.4 J**	**5.2**	4.6 U	2.6 U	1.5 U	2.0 U	2.0 U										**5.6 J**
PW-2227	11/13/2018		treated	0.66 U	0.50 U	0.66 U	0.66 U	0.66 U	0.50 U	0.66 U	1.5 U	0.84 U	0.50 U	0.66 U	0.66 U										1.2 U

For PFAS defintions, see acronym page.

all results in ng/L or ppt

Key:
Blank cell = not tested
Bold = detected value
ng/L = nanograms per liter
ppt = parts per trillion
QC = quality control sample

Data Flags:
B = estimated result based on blank contamination
J = estimated result
U = not detected at reported 2xMDL

a - PFOS + PFOA is the sum of PFOS and PFOA; ND is included at 2xMDL for summation.

Table 8. Water Supply Well Point of Entry PFAS Results, Post-Treatment
North Pole PFAS Water Sampling

Location ID	Sample Date	QC Type	Sample Type	PFOS	PFOA	PFNA	PFHxS	PFHpA	PFBS	PFHxA	PFDA	PFDoA	PFTeA	PFTriA	PFUnA	6:2 FTS	8:2 FTS	NEtFOSAA	NMeFOSAA	PFBA	PFDS	PFHpS	FOSA	PFPeA	PFOS + PFOA[a]
PW-159	10/5/2018		treated	0.94 U	1.5 U	0.46 U	**0.21 J B**	0.44 U	0.34 U	1.0 U	0.54 U	0.96 U	0.50 U	2.2 U	1.9 U										2.4 U
PW-217	10/11/2018		treated	0.94 U	1.5 U	0.48 U	**0.21 J B**	0.44 U	0.36 U	1.0 U	0.54 U	0.96 U	0.50 U	2.2 U	1.9 U										2.4 U
PW-376	10/22/2018		treated	0.94 U	1.5 U	0.46 U	**0.24 J B**	0.44 U	0.34 U	1.0 U	0.54 U	0.94 U	0.50 U	2.2 U	1.9 U										2.4 U
PW-561	8/3/2018		treated	0.96 U	1.5 U	0.48 U	**0.25 J B**	0.44 U	0.36 U	1.0 U	0.56 U	0.98 U	0.52 U	2.4 U	2.0 U	**7.5 J B**	3.6 U	3.4 U	5.6 U	**0.53 J B**	0.58 U	0.34 U	0.62 U	0.88 U	2.5 U
PW-599	11/28/2018		treated	0.90 U	1.4 U	0.44 U	**0.27 J B**	0.42 U	0.34 U	0.96 U	0.52 U	0.92 U	**0.26 J**	2.2 U	1.8 U										2.3 U
PW-608	11/28/2018		treated	0.88 U	1.4 U	0.44 U	**0.23 J B**	0.42 U	0.32 U	0.96 U	0.52 U	0.90 U	0.48 U	2.2 U	1.8 U										2.3 U
PW-617	11/2/2018		treated	0.90 U	1.4 U	0.44 U	**0.21 J B**	0.42 U	0.34 U	0.96 U	0.52 U	0.92 U	0.48 U	2.2 U	1.8 U										2.3 U
PW-618	7/24/2018		treated	0.92 U	1.4 U	**0.63 J**	**0.65 J B**	**0.92 J**	0.34 U	**2.0**	0.52 U	0.94 U	0.50 U	2.2 U	1.9 U										2.3 U
PW-649	12/3/2018		treated	0.90 U	1.4 U	0.46 U	**0.23 J B**	0.42 U	0.34 U	0.96 U	0.52 U	0.92 U	0.48 U	2.2 U	1.8 U										2.3 U
PW-656	11/6/2018		treated	0.90 U	1.4 U	0.46 U	**0.27 J B**	0.42 U	0.34 U	0.96 U	0.52 U	0.92 U	0.48 U	2.2 U	1.8 U										2.3 U
PW-657	10/4/2018		treated	0.92 U	1.5 U	**0.31 J**	**0.45 J B**	**0.39 J**	0.34 U	**1.3 J**	0.54 U	0.94 U	0.50 U	2.2 U	1.9 U										2.4 U
PW-757	7/24/2018		treated	0.86 U	1.4 U	0.44 U	**0.27 J B**	0.40 U	0.32 U	0.94 U	0.50 U	0.88 U	0.46 U	2.0 U	1.8 U										2.3 U
PW-947	10/15/2018		treated	0.90 U	1.4 U	**1.0 J**	**0.48 J B**	**0.34 J**	0.34 U	**0.75 J**	0.52 U	0.92 U	0.48 U	2.2 U	1.9 U										2.3 U
PW-1095	10/26/2018		treated	0.96 U	1.5 U	0.48 U	**0.21 J B**	0.44 U	0.36 U	1.0 U	0.56 U	0.98 U	0.52 U	2.4 U	2.0 U										2.5 U
PW-1106	10/10/2018		treated	0.92 U	1.4 U	0.46 U	**0.25 J B**	0.42 U	0.34 U	0.98 U	0.52 U	0.94 U	0.50 U	2.2 U	1.9 U										2.3 U
PW-1155	11/2/2018		treated	0.90 U	1.4 U	0.46 U	**0.20 J B**	0.42 U	0.34 U	0.96 U	0.52 U	0.92 U	0.48 U	2.2 U	1.8 U										2.3 U
PW-1374	7/17/2018		treated	0.90 U	1.4 U	0.46 U	**0.23 J B**	0.42 U	0.34 U	0.96 U	0.52 U	0.92 U	0.48 U	2.2 U	1.8 U										2.3 U
PW-1374	10/10/2018		treated	0.92 U	1.4 U	0.46 U	**0.24 J B**	0.42 U	0.34 U	0.98 U	0.52 U	0.92 U	0.48 U	2.2 U	1.9 U										2.3 U
PW-1395	10/19/2018		treated	0.92 U	1.4 U	0.46 U	**0.29 J B**	0.42 U	0.34 U	0.98 U	0.52 U	0.94 U	0.50 U	2.2 U	1.9 U										2.3 U
PW-1899	11/14/2018		treated	0.70 U	0.52 U	0.70 U	0.70 U	0.70 U	0.52 U	0.70 U	1.6 U	0.86 U	0.52 U	0.70 U	0.70 U										1.2 U
PW-2227	11/13/2018		treated	0.66 U	0.50 U	0.66 U	0.66 U	0.66 U	0.50 U	0.66 U	1.5 U	0.84 U	0.50 U	0.66 U	0.66 U										1.2 U

For PFAS defintions, see acronym page.

all results in ng/L or ppt

Key:

Blank cell = not tested

Bold = detected value

ng/L = nanograms per liter

ppt = parts per trillion

QC = quality control sample

a - PFOS + PFOA is the sum of PFOS and PFOA; ND is included at 2xMDL for summation.

Data Flags:

B = estimated result based on blank contamination

J = estimated result

U = not detected at reported 2xMDL

Table 10. GAC Treated Purge Water PFAS Results
North Pole PFAS Water Sampling

Location ID	Sample Date	QC Type	Sample Type	PFOS	PFOA	PFNA	PFHxS	PFHpA	PFBS	PFHxA	PFDA	PFDoA	PFTeA	PFTriA	PFUnA	PFOS + PFOA[a]
GAC-193A-15	10/24/2018			**1.8 J**	**3.2**	**4.4**	**5.0**	**4.4**	**0.94 J**	**7.9**	0.60 U	1.1 U	0.56 U	2.6 U	2.2 U	**5.0 J**
GAC2-150B-25	10/24/2018			**0.80 J**	1.7 U	0.52 U	**0.35 J B**	0.50 U	0.40 U	1.1 U	0.60 U	1.1 U	0.56 U	2.6 U	2.2 U	**2.5 J**

For PFAS defintions, see acronym page.

all results in ng/L or ppt

Key:

Blank cell = not tested

Bold = detected value

ng/L = nanograms per liter

ppt = parts per trillion

QC = quality control sample

Data Flags:

B = estimated result based on blank contamination

J = estimated result

U = not detected at reported 2xMDL

a - PFOS + PFOA is the sum of PFOS and PFOA; ND is included at 2xMDL for summation.

FIGURES

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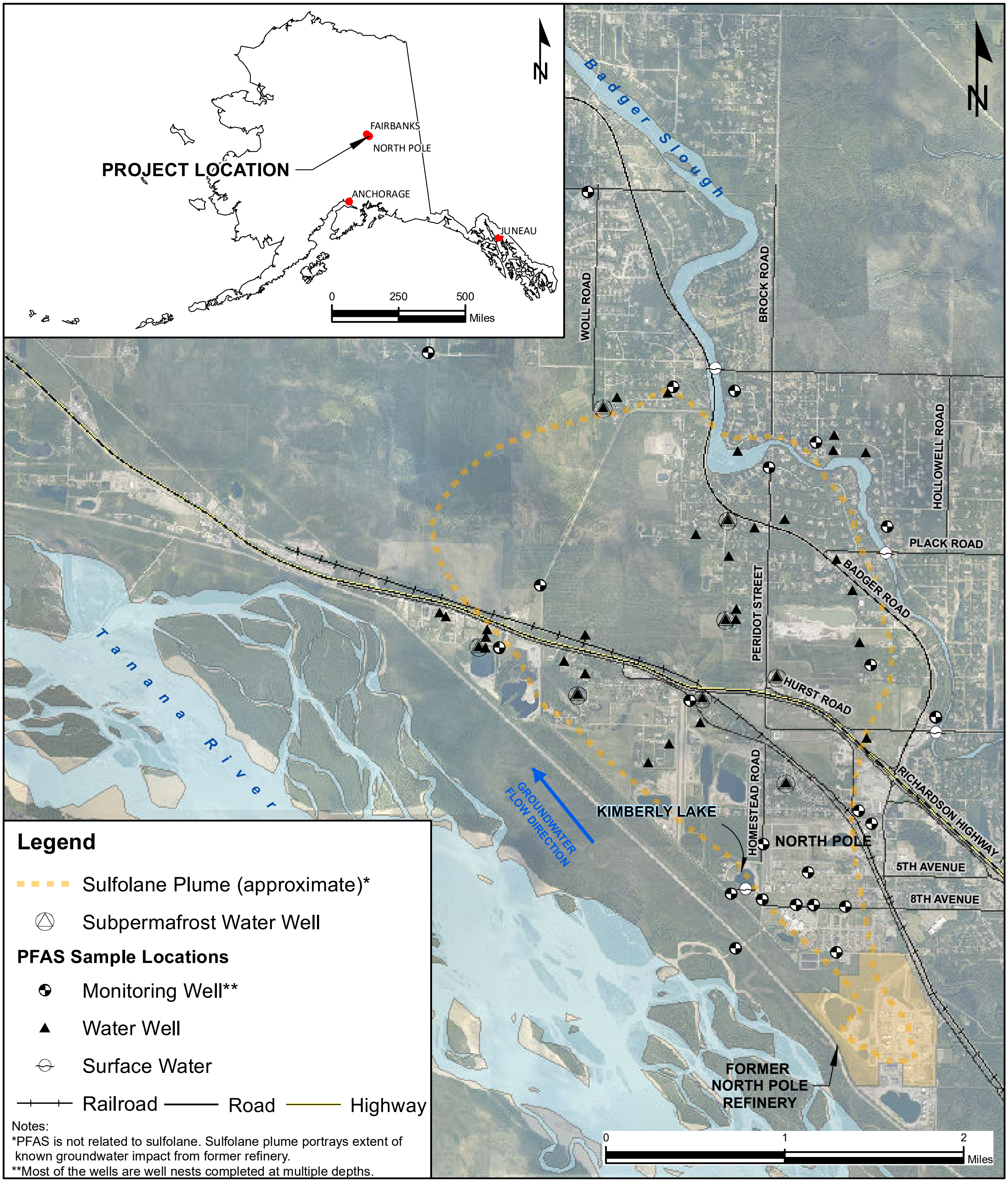
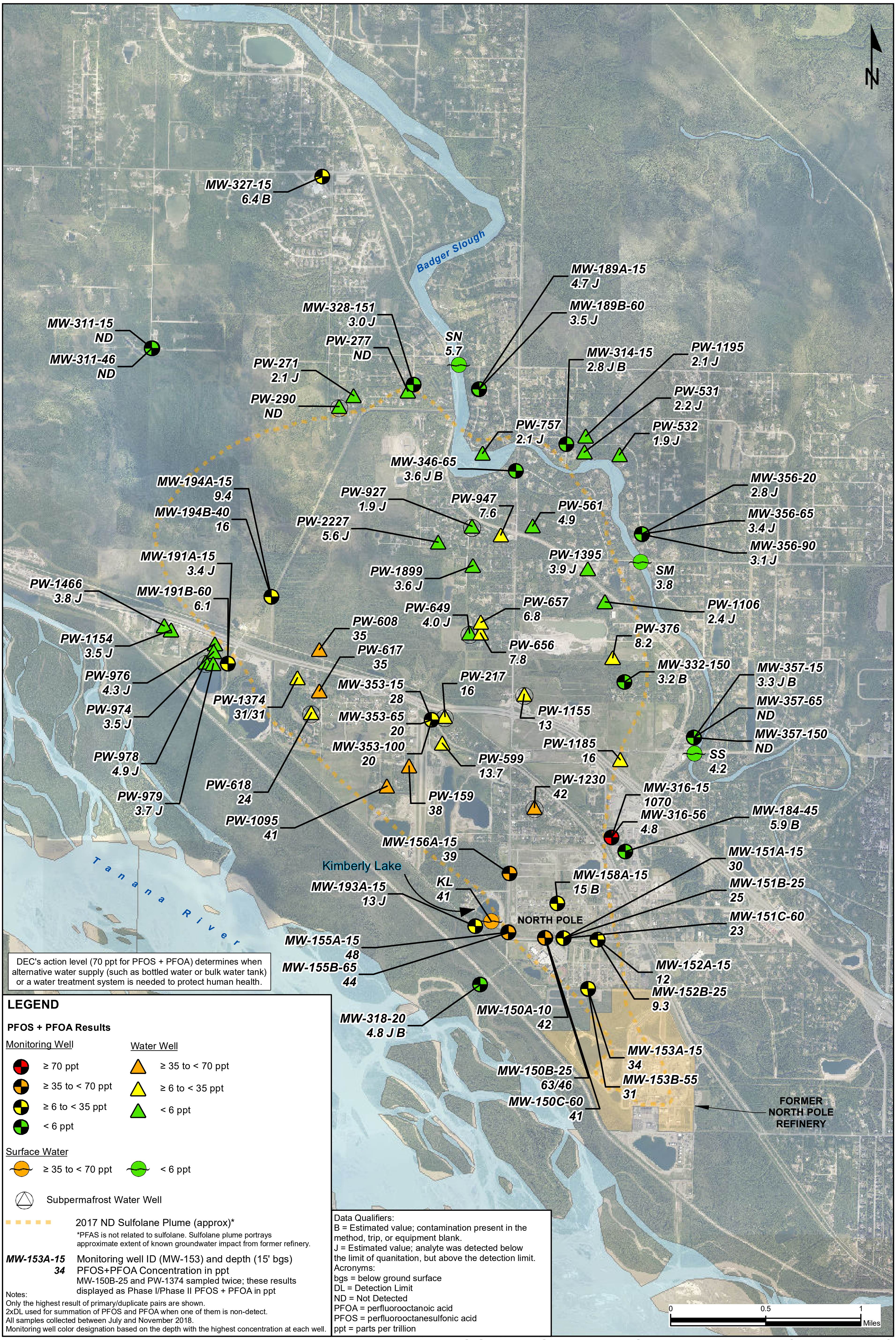


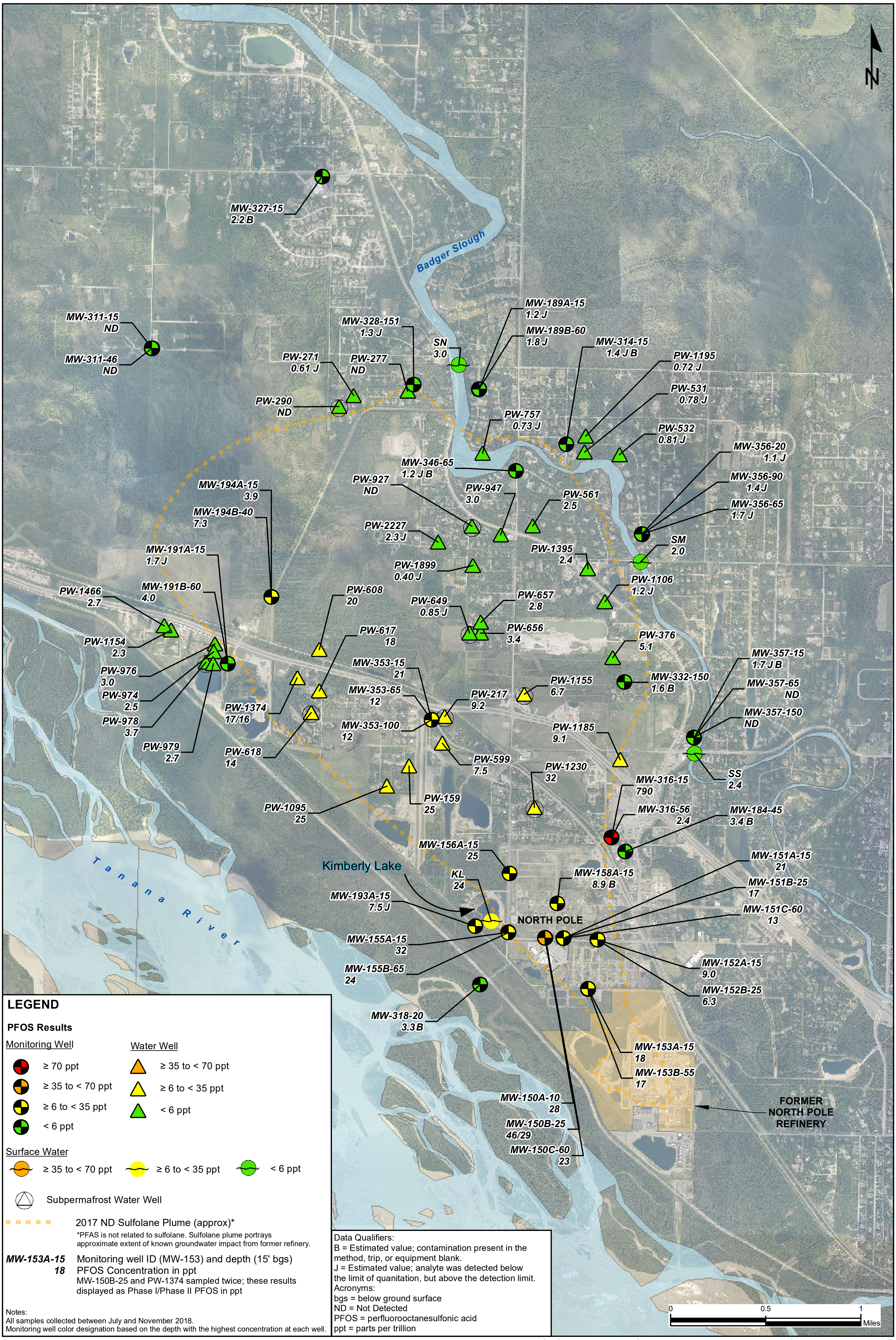
Site Vicinity
2018 North Pole PFAS Water Sampling

Figure 1



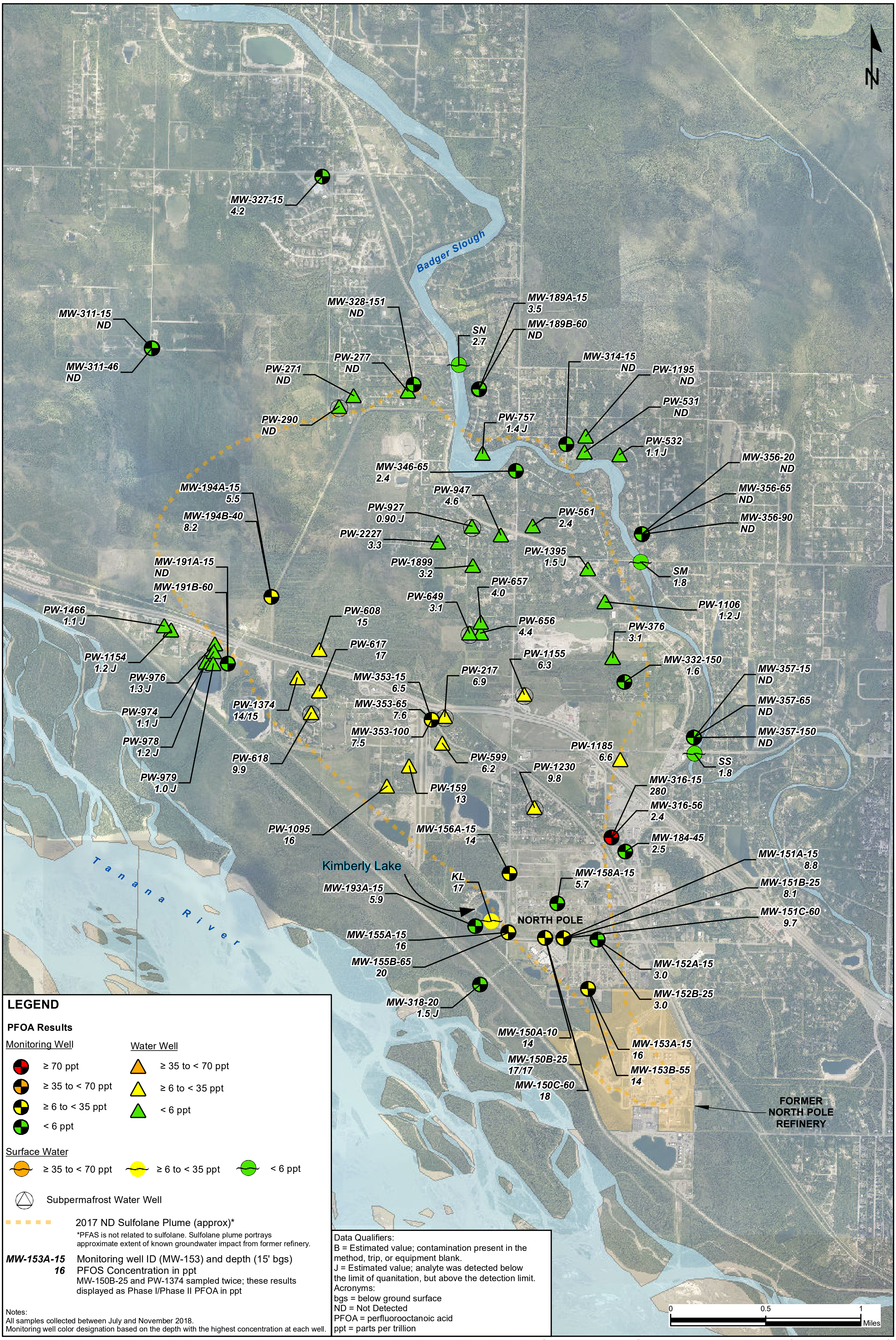
PFOS + PFOA Water Sample Results (Untreated)
2018 North Pole PFAS Water Sampling

Figure 2



PFOS Water Sample Results (Untreated)
2018 North Pole PFAS Water Sampling

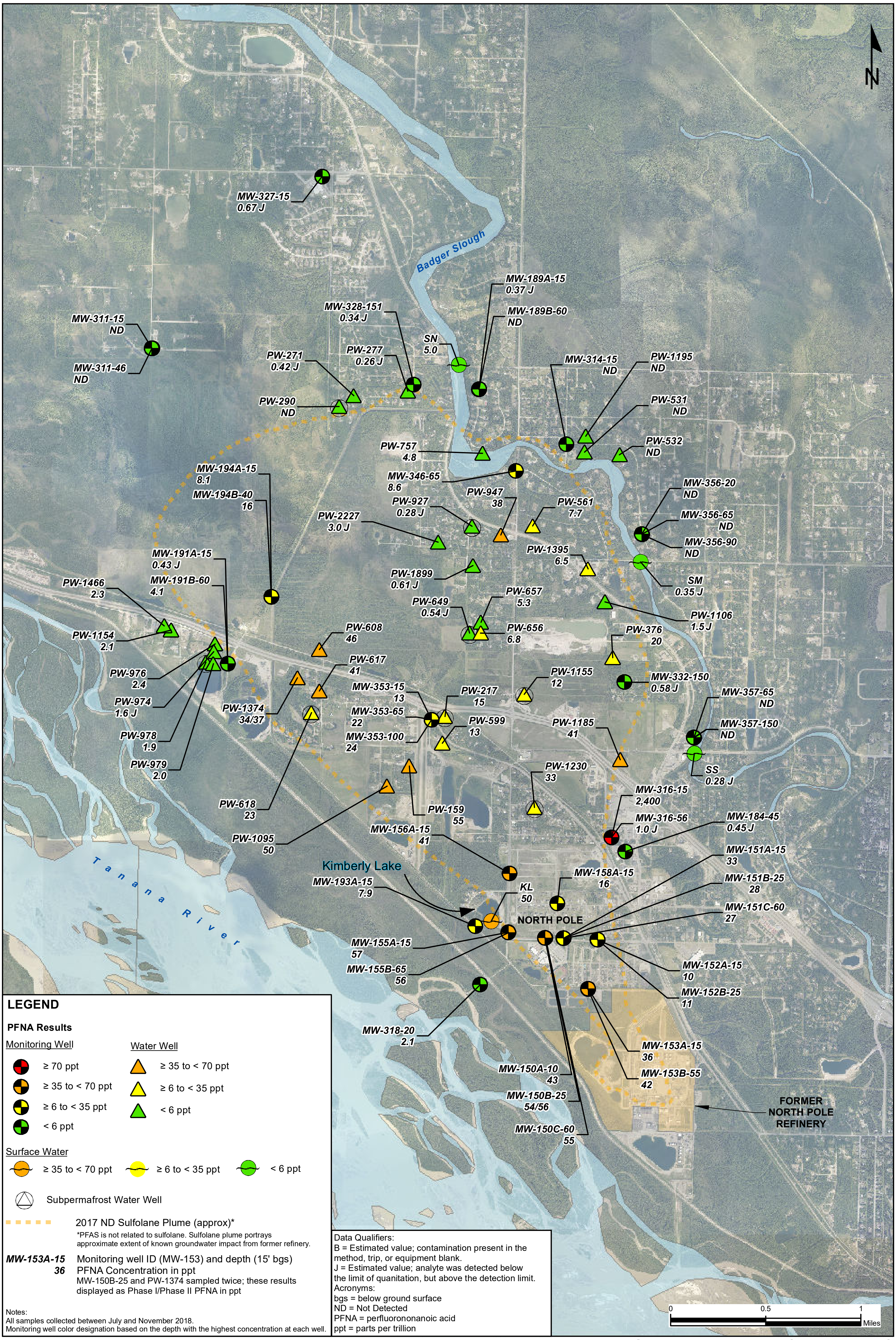
Figure 3



PFOA Water Sample Results (Untreated)
2018 North Pole PFAS Water Sampling

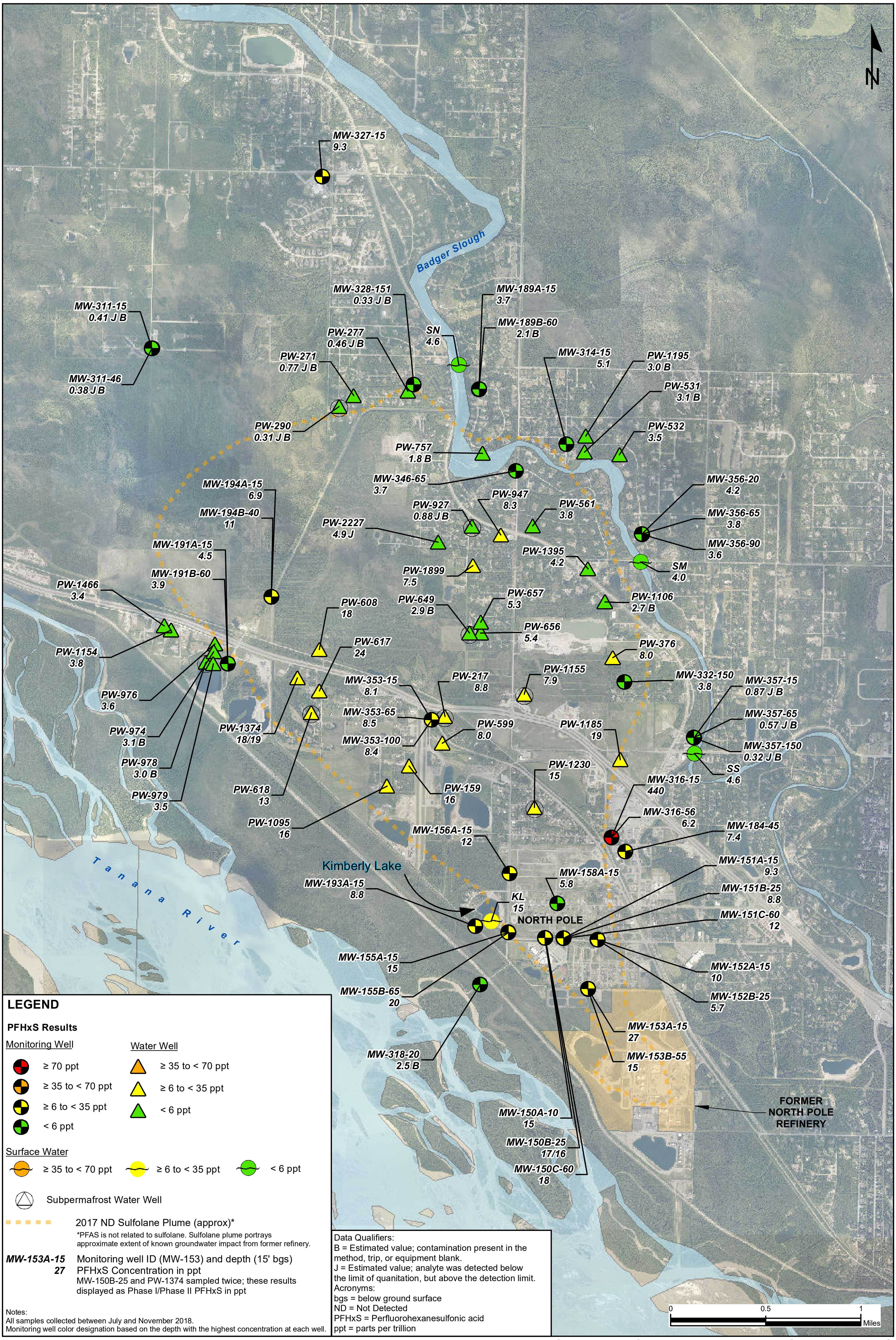
Figure 4

Prepared by jbrann, 12/2/2019; K:\Flint Hills\MXD\PFAS Water Sampling Report\F4_PFOA_Results.mxd



PFNA Water Sample Results (Untreated)
2018 North Pole PFAS Water Sampling

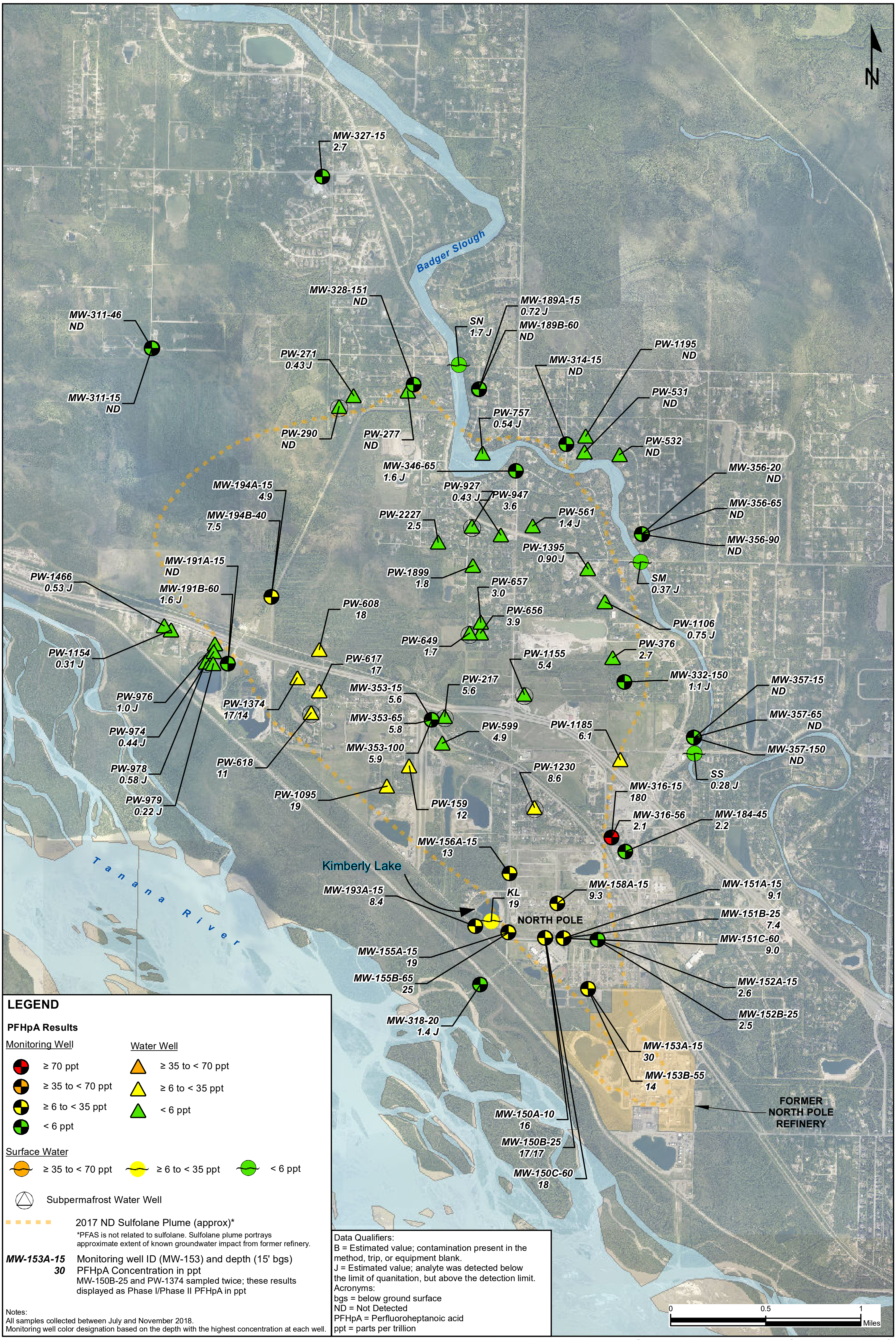
Figure 5



PFHxS Water Sample Results (Untreated)
2018 North Pole PFAS Water Sampling

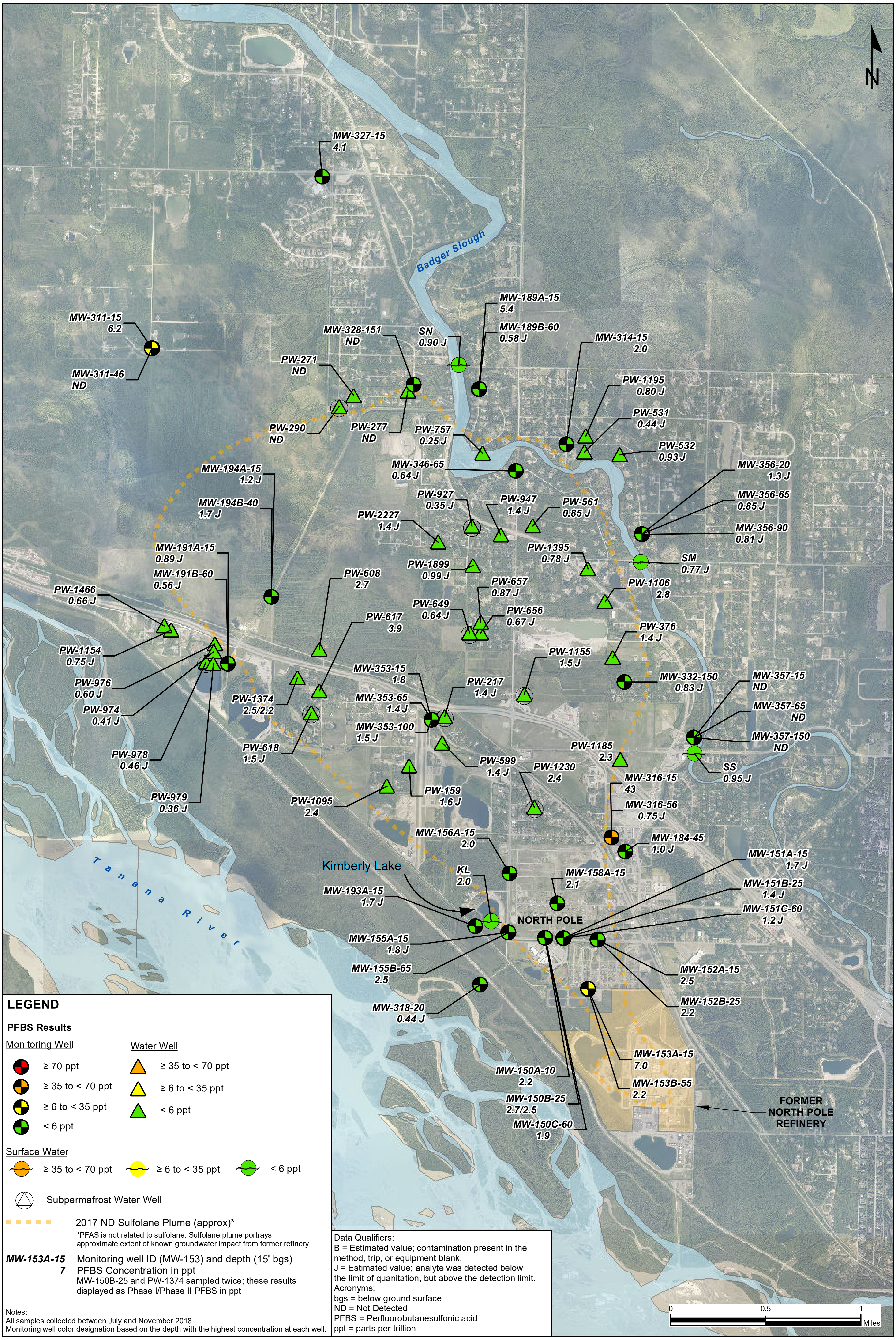
Figure 6

Prepared by jbrann, 12/2/2019; K:\Flint Hills\MXD\PFAS Water Sampling Report\F6_PFHxS_Results.mxd



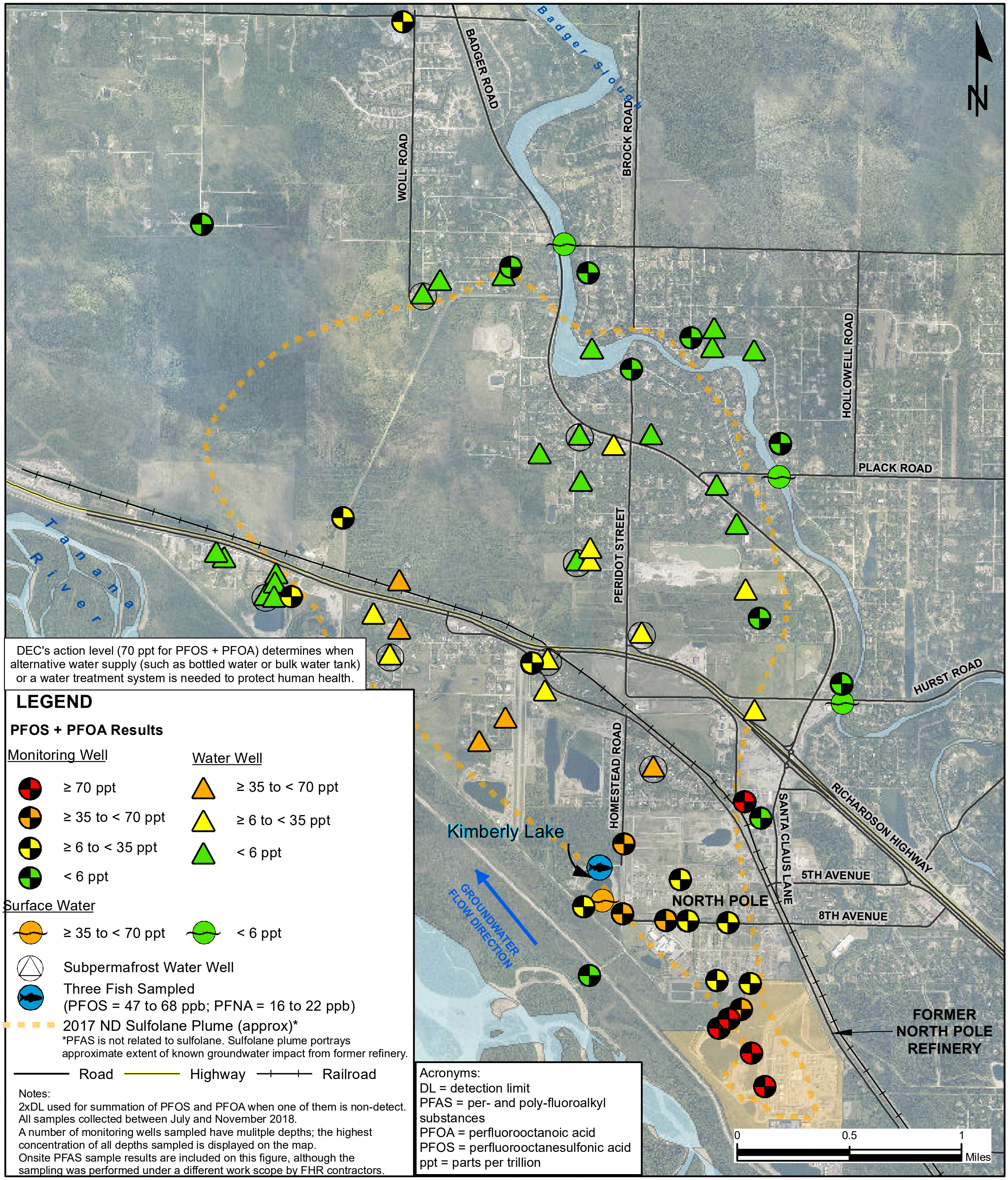
PFHpA Water Sample Results (Untreated)
2018 North Pole PFAS Water Sampling

Figure 7



PFBS Water Sample Results (Untreated)
2018 North Pole PFAS Water Sampling

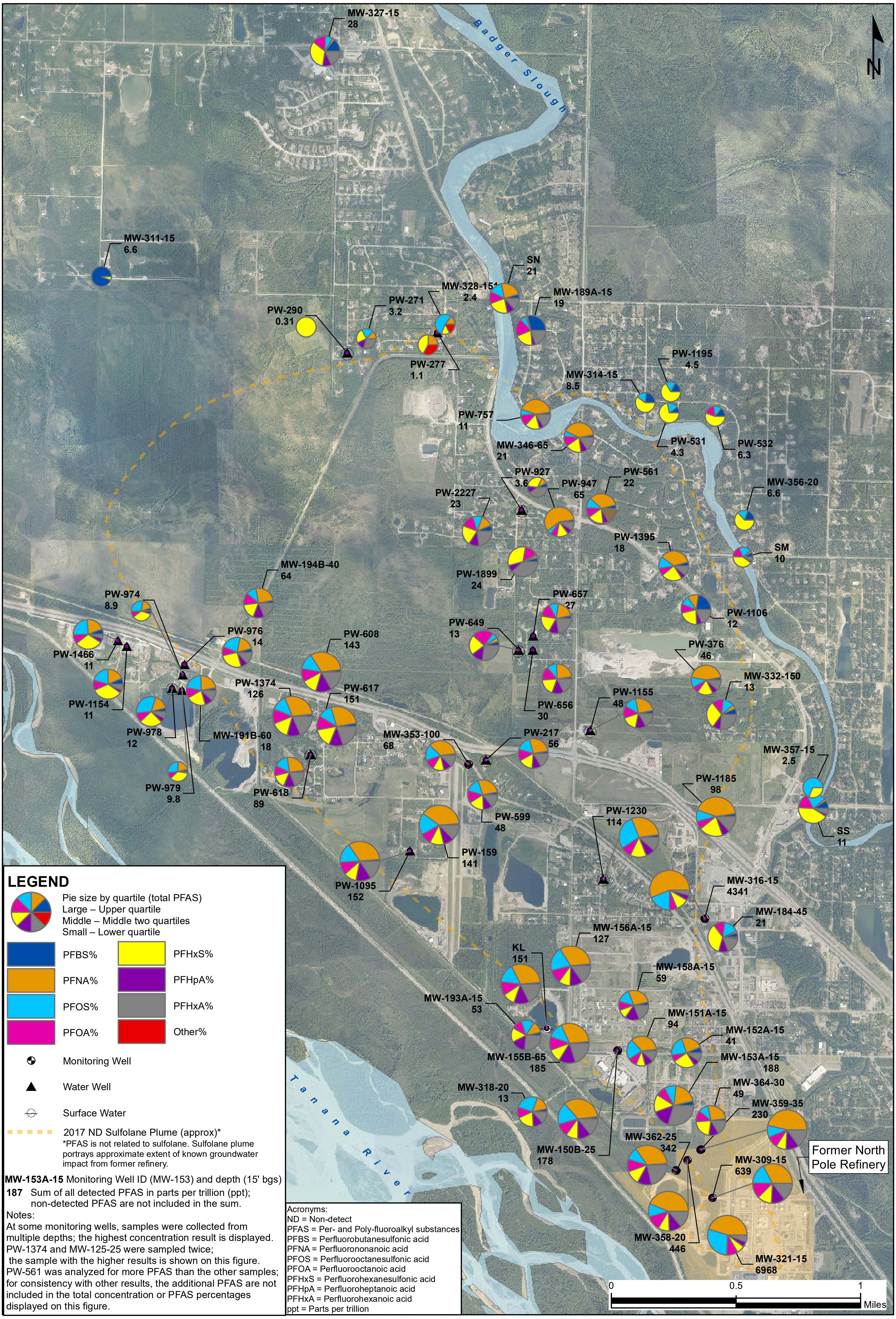
Figure 8



Complete PFOS+PFOA Water Sample Results (Untreated)
2018 North Pole PFAS Water Sampling

Figure 9

Prepared by jbrann, 12/6/2019; K:\Flint Hills\MXD\PFAS Water Sampling Report\F9_CompletePFOS-PFOA_Results.mxd



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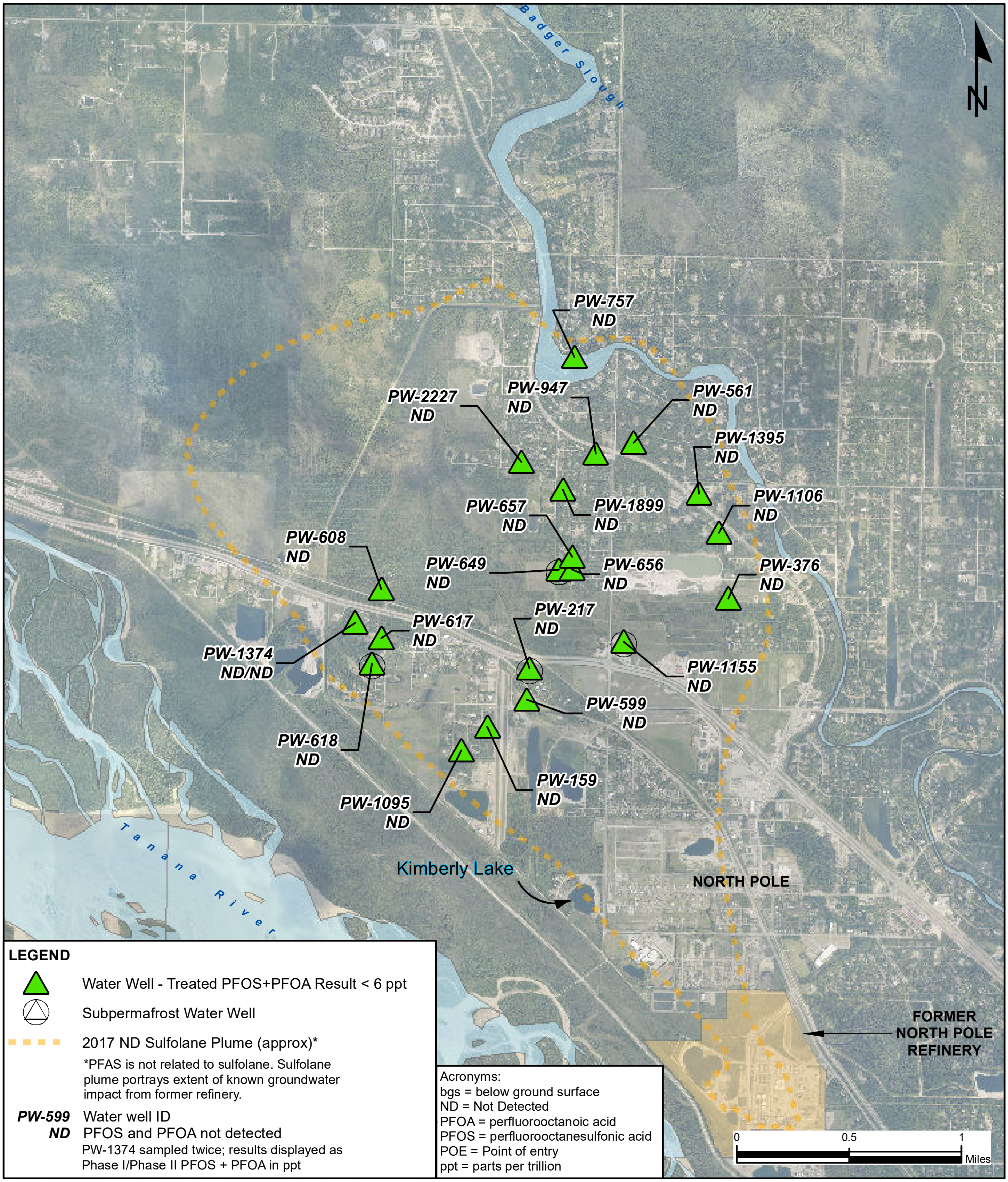
2018 Detected PFAS Results by Percent
2018 North Pole PFAS Water Sampling

Figure 10



Treated POE System Water Sample PFOS + PFOA Results
2018 North Pole PFAS Water Sampling

Figure 11

Prepared by jbrann, 12/6/2019; K:\Flint Hills\MXD\PFAS Water Sampling Report\F11_PFOS-PFOA_TreatedResults.mxd

APPENDIX A – SWI SAMPLE LOGS

Available upon request.

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APPENDIX B – LABORATORY ANALYTICAL REPORTS AND ADEC CHECKLISTS

Available upon request.

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APPENDIX C – DATA QUALITY SUMMARY MEMO

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Arctic Data Services LLC

302 Cushman St., Ste # 203
Fairbanks, AK 99701
907-457-3147

Date:	6/6/2019
Project name:	FHRA North Pole Refinery Phase I & II Offsite PFAS Sampling
Laboratories:	Eurofins TestAmerica Laboratories, Inc. – Sacramento, CA
Sample Delivery Groups:	See SDG List at the end of this memo
Reviewed by:	Alex Thompson
Title:	Chemist
Final Review by:	Rodney Guritz
Title:	Principal Chemist
To:	Ms. Leslie Davis Ahtna Engineering Services 1896 Marika Road, Suite 8 Fairbanks, Alaska 99709

Data Quality Summary

This letter summarizes the findings of a data quality review conducted by Shannon & Wilson, Inc. (S&W), and summarized by Arctic Data Services, LLC (ADS) for the above-referenced project data. S&W completed Alaska Department of Environmental Conservation (ADEC) laboratory data review checklists for each sample delivery group (SDG) submitted for Phase I (two SDGs) and Phase II (34 SDGs) sampling of off-site monitoring wells and private wells for per- and polyfluoroalkyl substances (PFAS) analysis for this project. For each SDG, the laboratory analyzed for 12 select PFAS analytes by modified EPA Method 537. This memo summarizes key data validation findings; no additional review or independent quality control/quality assurance (QA/QC) checks, beyond the anomalies identified in the checklists, were completed by ADS. However, adjustments were made to the qualifying criteria for sample results affected by blank contamination (see *Method Blanks* section, below). The purpose of this letter is to summarize the current state and quality of laboratory data, as concluded by S&W. ADS does not guarantee the accuracy of any of the findings from S&Ws data review, nor does ADS guarantee the quality of S&Ws data quality assessment.

Sample Analysis Summary

Analytical results for 36 SDGs were reviewed by S&W. Project samples were submitted to Eurofins TestAmerica Laboratories in West Sacramento, California (TAL) for analysis of the following PFAS by modified EPA Method 537.

- Perfluorohexanoic acid (PFHxS),
- perfluoroheptanoic acid (PFHpA),
- perfluorooctanoic acid (PFOA),
- perfluorononanoic acid (PFNA),

- perfluorodecanoic acid (PFDA),
- perfluoroundecanoic acid (PFUnA)
- perfluorododecanoic acid (PFDoA),
- perfluorotridecanoic acid (PFTriA),
- perfluortetradecanoic acid (PFTeA),
- perfluorobutanesulfonic acid (PFBS),
- perfluorohexanesulfonic acid (PFHxS),
- and perfluorooctanesulfonic acid (PFOS).

Surface water samples were submitted in a separate SDG and were analyzed for the above PFAS analytes, as well as the following: perfluorobutanoic acid (PFBA), perfluoropentanoic acid (PFPeA), perfluoroheptanesulfonic acid (PFHpS), perfluorodecanesulfonic acid (PFDS), perfluoroctane sulfonamide (FOSA), N-methyl perfluorooctane sulfonamidoacetic acid (NMeFOSAA), N-ethyl perfluorooctane sulfonamidoacectic acid (NEtFOSAA), 6:2 fluorotelomer sulfonate (6:2 FTS), and 8:2 fluorotelomersulfonate (8:2 FTS). Point-of-entry system and private well samples were submitted in batches to the laboratory, however they are reported as separate SDGs to maintain confidentiality of private-well results. Reports for SDGs with the same 8-digit number prefix (ex. 320-44239) were analyzed simultaneously or in succession, and include many of the same analytical and preparatory batch QC samples.

Sample Preservation, Handling, Custody, and Holding Times

Sample receipt forms were reviewed by S&W to check that samples were received in good condition, properly preserved, and within the required temperature range. Chain of custody (COC) forms were reviewed by S&W to confirm that custody was not breached during sample handling. Dates of sample collection, preparation, and analysis were compared to check that method holding times were not exceeded.

There were no sample preservation, handling, custody, or holding time failures identified by S&W which may have affected project-sample data quality. However, a number of SDGs (320-44239-X, 320-44463-X, 320-44669-5) had sample ID inconsistencies between the sample containers and COC, or sample receiving notices issued by the laboratory. Each issue was resolved through coordination between the client and laboratory, and no data are considered affected.

Analytical Sensitivity

Analytical sensitivity was evaluated by S&W. Sensitivity was evaluated by comparing laboratory reporting limits to EPA lifetime drinking water health advisory levels (LHA) and the ADEC groundwater cleanup levels (GCLs) for applicable PFAS compounds (PFOS and PFOA). The laboratory reported non-detect results at the limit of quantitation (LOQ).

There were no non-detect results for which the LOQ exceeded relevant LHA levels or ADEC GCLs.

Laboratory QC Samples

Method Blanks

The laboratory analyzed and reported a method blank for each preparatory batch, to check for laboratory-based sample contamination. S&W reviewed method blank sample data, and qualified data by comparing concentrations of analytes detected in the method blank, and concentrations of analytes detected in project samples. S&W considered results affected by laboratory-based contamination if the target analyte was detected within ten times (10x) or five times (5x) the concentration of the method blank. Sample results within 10x the method blank concentration, but greater than 5x the concentration were qualified with a 'JH' flag, indicating the result is estimated, biased high. Sample results within 5x the method blank concentration were considered non-detect, and qualified with a 'UB' flag at the LOQ or the detected sample concentration, if above the LOQ.

Following S&W's initial review, the ADEC published a technical memorandum titled *Treatment of Non-Detects and Blank Detections in Per- and Polyfluoroalkyl Substances (PFAS) Analysis* (March 2019), in which different qualifying conventions were recommended. The ADEC recommends using data without qualification in the following cases: blank detections are below the lab's LOQ; blank detections are above the lab's LOQ AND the sum of the five PFAS (including the non-detects) is more than 10 times greater than the blank detection; or blank detections are above the lab's LOQ AND the sum of the five PFAS (including the non-detects) is less than 0.07 µg/L. They recommend using caution and flagging affected data with a 'B' flag when blank detections are above the lab's LOQ AND the sum of the five PFAS (including the non-detects) is less than 10 times greater than the blank detection BUT greater than 0.07 µg/L.

For this summary, and for final qualification for data reporting, a conservative approach is taken that is consistent with the above ADEC recommendations. Any detected result within 10x the method blank concentration is qualified with a 'B' flag, and remains reported *at the detected concentration*. These 'B' flags are retained and carried over to any total results that included 'B'-flagged results in the summation. The 'B' flag indicates the result is an estimate, biased high, and may be a false-positive detection, due to laboratory-based contamination of the sample. Results affected by blank contamination (below or above the LOQ) may be used as long as they are below 0.07 µg/L; however, in our professional opinion, *all* results affected by blank contamination should be qualified 'B' to indicate to the data user that the results may be biased high and may be false-positive detections.

There were a significant number of method blank detections, a majority of which were PFHxS, detected below the LOQ. Project sample results associated with MB detections are qualified as described above.

- **TAL 320-41470-1.** PFHxS was detected at estimated concentrations below the LOQ in the method blank. PFHxS results for the following samples are considered affected: 2375 Richardson-2018PFAS-PostTreat, 2291 Keeney-2018PFAS-PostTreat, 1855 Christine-2018PFAS-Posttreat, and 1855 Christine-2018PFAS-PreTreat. Additionally, PFHxS results for the equipment blank sample EB-150B-25 are considered affected.

- **TAL 320-41851-1.** PFBA, PFTeA, PFHxS and 6:2 FTS were detected at estimated concentrations below the LOQ in the method blanks associated with this work order. The following results are considered affected: PFBA (samples 2691Regal-2018PFAS-PostTreat and 2691Regal-2018PFAS-PreTreat), PFHxS (sample 2691Regal-2018PFAS-PostTreat), and 6:2 FTS (samples 2691Regal-2018PFAS-PostTreat and 2691Regal-2018PFAS-PreTreat).

- **TAL 320-44239-X.** PFHxS was detected at estimated concentrations below the LOQ in the method blank associated with the following work orders. Affected samples are listed under the SDG they were submitted/reported in.

  - **TAL 320-44239-1.** The PFHxS result for sample 2601 Kalsipell-2018PFAS-P2Post is affected.

  - **TAL 320-44239-2.** The PFHxS result for sample 2378 Grumman-2018PFAS-P2Post is affected.

  - **TAL 320-44239-4.** The PFHxS result for sample 2375 Richardson-2018PFAS-P2Post is affected.

  - **TAL 320-44239-5.** The PFHxS result for samples 2985 Badger-2018PFAS-P2Post and 2985 Badger-2018PFAS-P2Pre are affected.

  - **TAL 320-44239-6.** The PFHxS result for sample 2310 Old Richardson-2018PFAS-P2Post is affected.

  - **TAL 320-44239-7.** The PFHxS result for sample 1977 Peridot-2018PFAS-P2Post is affected.

- **TAL 320-44461-1.** PFHxS and PFOS were detected at estimated concentrations below the LOQ in the method blanks associated with this work order. PFHxS results for the following samples were affected: MW-318-20, MW-357-15 and MW-357-115. PFOS results for the following samples were affected: MW-184-45, MW-318-20, MW-327-15, MW-357-15, MW-357-115, and MW-158A-15.

- **TAL 320-44463-X.** PFTeA and PFHxS were detected at estimated concentrations below the LOQ in the method blank associated with the following work orders. No PFTeA results were detected within 10 times the method blank concentration, however a number of PFHxS results are considered affected.

  - **TAL 320-44463-1.** The PFHxS result for sample 2936 Badger-2018PFAS-P2Post is affected.

  - **TAL 320-44463-2.** The PFHxS result for sample 2890 Glacier State-2018PFAS-P2Post is affected.
  - **TAL 320-44463-3.** The PFHxS result for sample 2131 Edward-2018PFAS-P2 is affected.
  - **TAL 320-44463-5.** PFHxS results for samples 2136 Edward-2018PFAS-P2 and 9999 Edward-2018PFAS-P2 are affected.

- **TAL 320-44669-X.** PFHxS was detected at an estimated concentration below the LOQ in the method blank associated with the following work orders.
  - **TAL 320-44669-1.** The PFHxS result for sample 2412 Piper-2018PFAS-P2 Post is affected.
  - **TAL 320-44669-2.** The PFHxS result for sample 2476 Sunflower-2018 PFAS-P2 is affected.
  - **TAL 320-44669-3.** The PFHxS result for sample 1750 Blackburn-2018 PFAS-P2 is affected.
  - **TAL 320-44669-4.** The PFHxS result for sample 2361 Sunflower-2018 PFAS-P2 is affected.

- **TAL 320-44672-1.** PFHxS was detected at an estimated concentration below the LOQ in the method blank sample 320-257176/1-A. PFTeA and PFHxS were detected at estimated concentrations below the LOQ in method blank sample 320-257182/1-A. PFHxS results for the following project samples and field QC samples are affected: MW-357-65, MW-357-150, MW-311-46, MW-311-15, EB-191A-15, MW-328-151, EB-328-151, MW-189B-60, and GAC2-150B-25. PFTeA results for project samples MW316-56 and MW-239A-15 are affected.

- **TAL 320-45051-X.** PFHxS was detected at an estimated concentration below the LOQ in the method blank associated with the following work orders.
  - **TAL 320-45051-1.** The PFHxS result for sample 2571 Kalispell-2018PFAS-P2Post is affected.
  - **TAL 320-45051-2.** The PFHxS result for sample 2382 Sunflower-2018PFAS-P2 is affected.
  - **TAL 320-45051-3.** The PFHxS result for sample 2246 Keeney-2018PFAS-P2Post is affected.
  - **TAL 320-45051-4.** The PFHxS result for sample 1755 Blackburn-2018PFAS-P2 is affected.
  - **TAL 320-45051-5.** The PFHxS result for sample 2244 Peridot-2018PFAS-P2Post is affected.

Arctic Data Services, LLC

- **TAL 320-45632-1.** PFHxS was detected at an estimated concentration below the LOQ in the method blank associated with this work order. PFHxS results for project samples 2584 Stonecrest-2018PFAS-P2 and 9999 Stonecrest-2018PFAS-P2 are affected.

- **TAL 320-45876-X.** PFHxS was detected at an estimated concentration below the LOQ in the method blank associated with the following work orders.

    - **TAL 320-45876-1.** The PFHxS result for sample 2315#2 Old Richardson-2018PFAS-P2Post is affected.

    - **TAL 320-45876-2.** The PFHxS result for sample 2390#1 Richardson-2018PFAS-P2Post is affected.

    - **TAL 320-45876-3.** The PFHxS results for samples 2578 Kalispell-2018PFAS-P2Post and 2578 Kalispell-2018PFAS-P2Pre are affected.

Laboratory Control Samples and Matrix Spike Samples

The laboratory analyzed and reported an LCS for each preparatory batch, to assess laboratory extraction efficiency and analytical accuracy. In some cases, LCS duplicates (LCSDs) were used to assess analytical precision. LCS and LCSD recovery information and LCS/LCSD RPD information (where available) were reviewed. The laboratory also analyzed matrix spike (MS) and matrix spike duplicate (MSD) samples for select batches, to assess analytical accuracy and potential matrix interference. MS/MSD recovery is only evaluated if the MS/MSD analysis was performed using a project sample.

While there were no LCS/LCSD or MS/MSD recovery or relative percent difference (RPD) failures affecting project sample data quality; SDGs 320-45444-1 and 320-45444-2 did not have an LCSD, or MS/MSD analyzed, so batch precision could not be assessed for these work orders.

Isotope Dilution Analyte Recovery

The modified EPA 537 method performed by the laboratory for PFAS analysis uses an isotope dilution method; in which isotopically labelled analytes (isotope dilution analytes [IDAs]) are spiked in project samples prior to solid phase extraction and analysis. Analytical results are adjusted based upon the recovery of these IDAs. IDA recovery failures impact data quality. IDA recovery limits are set to ensure the analysis is in control.

The following IDA recovery failures affected project-sample data quality.

- **TAL 320-45444-2.** The project sample 2598-Goldenrod-2018P2Pre had an IDA recovery failure for 13C3-PFBS. The result for the associated analyte (PFBS) is considered estimated and is qualified with a 'J' flag.

Field QC Samples

Field Duplicates

Field duplicates were submitted with select work orders. The field duplicate collection frequency met the required minimum frequency in accordance with the approved work plan. Field duplicate samples are analyzed to evaluate overall precision. All RPD calculations were performed by S&W.

The following field duplicate RPD failures affected project-sample data quality.

- **TAL 320-44672-1.** RPDs in the Field duplicate sample pair MW-193A-15/MW-293A-15 exceeded MQOs for PFOS. PFOS results for the sample are considered estimated, and flagged 'J' for the duplicate pair

- **TAL 320-45632-1.** RPDs in the field duplicate sample pair 2584 Stonecrest-2018PFAS-P2/ 9999 Stonecrest-2018PFAS-P2 exceeded the MQO for PFBS. PFBS results are considered estimated, and flagged 'J' for the duplicate pair.

Equipment Blanks

Equipment blanks (EB) are submitted alongside project samples where reusable sampling equipment was employed, to check for potential cross contamination during sampling.

The following equipment blank detections affected project-sample data quality.

- **TAL 320-41470-1.** PFTeA, PFHxS, and PFOS were detected below the LOQ in the equipment blank sample. Samples are not affected by the EB detection of PFHxS, as it is attributable to MB contamination. PFTeA was not detected in the project samples, so PFTeA results are not affected. The project samples affected by the PFOS detection are MW-332-150, MW-346-65, and MW-314-15. PFOS results are considered estimated, biased high for these samples, and qualified with a 'B' flag at the detected concentrations.

  TAL 320-44672-1. PFHxS was detected below the LOQ in EB samples EB-191A-15 and EB-328-151. Project samples were not affected by the EB detection of PFHxS, as it is attributable to MB contamination.

Other QC Anomalies

The initial laboratory report for work order 320-41470-1 was recalled by the laboratory due to an analyst error. The results in this work order were not corrected for low sample volume recovery from clogged solid phase extraction (SPE) columns. A revised report was issued by the laboratory for the work order, however the data review checklist completed by S&W was completed prior to the revision, and was not updated. Results for a number of PFAS analytes in the initial data review were qualified due to field duplicate RPD failures of the duplicate sample pair MW-150B-25/MW-250B-25. There were no RPD failures for either of the included duplicate pairs in the revised report, and no data are qualified due to field duplicate RPD failures for this SDG.

Summary of Data Quality Indicators

The following sections summarize the findings of the above review with respect to the six data quality indicators: sensitivity, precision, accuracy, representativeness, comparability, and completeness.

Sensitivity

Sensitivity describes the ability of the sampling and analytical methodology to meet detection and/or quantitation limit objectives. Sensitivity was considered acceptable for the purposes of this project; no LOQs exceeded relevant PALs.

Precision

Precision is a measure of the reproducibility of repetitive measurements. Precision was evaluated based on laboratory QC-sample RPDs. There were no laboratory QC sample RPD failures that affected project-sample data quality. However, there was a small number of field duplicate RPD failures affecting project-sample data quality. The impact to data usability from these failures is minimal, as the majority of the affected analytes do not have applicable ADEC cleanup levels.

Accuracy

Accuracy is a measure of the correctness, or the closeness, between the true value and the quantity detected. Accuracy was evaluated based on analyte recoveries for laboratory QC samples and recovery of IDA spikes for project samples. There were no laboratory QC sample (LCS/MS) recovery failures and only one IDA recovery failure identified in the course of S&W's review that affected project-sample data quality. A large number of samples were qualified due to method blank detections, see the *Method Blanks* section above. However, the impact to data usability is relatively minor as the majority of affected analytes do not have relevant project action limits. Overall accuracy is deemed acceptable for the purposes of this project.

Representativeness

Representativeness describes the degree to which data accurately and precisely represent site characteristics. Representativeness is affected by factors such as sample frequency and matrix or contaminant heterogeneity, as well as analytical performance (including sensitivity, accuracy, and precision), sample preservation, handling, and holding times, and sample cross-contamination. Samples were collected in accordance with the work plan requirements, and measurement quality objectives were generally met for all analyses and reported results. A number of project-sample results were qualified due to laboratory-based contamination; see the *Method Blanks* section above. These results are considered estimated with a high bias, and are not wholly representative of site conditions. Additionally, a small number of results were qualified due to field duplicate RPD failures. The impact to data usability for qualified results was generally minor, and overall representativeness is deemed acceptable for purposes of this project.

Comparability

Comparability describes whether two data sets can be considered equivalent with respect to project goals. Comparability is affected by factors such as sampling methodology and analytical performance (including sensitivity, accuracy, and precision). Comparability was evaluated by checking that standard analytical methods were employed and analytical performance was acceptable. The project sample dataset is deemed generally comparable; however, the project team should evaluate overall comparability with the larger scope of work completed.

Completeness

Completeness describes the amount of valid data obtained from the sampling event(s). It is calculated as the percentage of usable measurements compared to the total number of measurements. The dataset is 100% complete, with no data rejected in the course of S&W's review.

Conclusions and Limitations

There were no indications given by S&Ws review that any data quality indicators were significantly impacted during their review, and that precision, accuracy, representativeness, comparability, completeness, and sensitivity were deemed acceptable. The majority of affected data is qualified due to blank detections, and the impact to data usability is minor. Therefore, the data are usable for the purposes of this project, as qualified.

This data quality assessment was written for the sole purpose of summarizing the findings of data review and validation conducted by S&W for the off-site data collection. We make no warranty, express or implied, of the conclusions presented in this report, or the completeness, accuracy, or validity of third-party information. Further, data quality indicators such as representativeness and comparability are affected by factors beyond the scope of a single analytical dataset; these elements are also dependent on the sampling design and heterogeneity (spatial and temporal) of a given site. Evaluation of these indicators as well as overall completeness of the dataset in the context of project DQOs should be conducted by the broader project team. A data quality assessment helps reduce the risk of reliance on data of compromised quality, but it does not eliminate that risk.

Attachments

Table 1 – Summary of Qualified Data
ADEC Laboratory Data Review Checklists

SDG List:

320-41470-1
320-41851-1
320-44239-1
320-44239-2
320-44239-3
320-44239-4
320-44239-5
320-44239-6
320-44239-7
320-44245-1
320-44461-1 rev 1
320-44463-1 rev 1
320-44463-2 rev 1
320-44463-3 rev 1
320-44463-4 rev 1
320-44463-5 rev 1
320-44463-6 rev 1
320-44463-7 rev 1
320-44463-8 rev 1
320-44669-1
320-44669-2
320-44669-3
320-44669-4
320-44669-5
320-44672-1 rev 1
320-45051-1 rev 1
320-45051-2 rev 1
320-45051-3 rev 1
320-45051-4 rev 1
320-45051-5 rev 1
320-45444-1
320-45444-2
320-45632-1
320-45876-1
320-45876-2
320-45876-3

Table 1
Summary of Qualified Data
NPR PFAS Phase I / II
Data Quality Assessment

SDG	Sample ID	Analyte	CAS	DL	LOQ	Result	Original Flag	Units	QC Flag	Final Qualified Result	Note
320-44669-3	1750 Blackburn-2018 PFAS-P2	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.14	1.7	3.0	B	ng/L	B	3.0 B	1
320-45051-4	1755 Blackburn-2018PFAS-P2	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.14	1.7	3.1	B	ng/L	B	3.1 B	1
320-41470-1	1855Christine-2018PFAS-Posttreat	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.14	1.6	0.27	J B	ng/L	J B	0.27 J B	1
320-41470-1	1855Christine-2018PFAS-Pretreat	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.14	1.6	1.8	B	ng/L	B	1.8 B	1
320-44239-7	1977 Peridot-2018PFAS-P2Post	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.14	1.7	0.48	J B	ng/L	J B	0.48 J B	1
320-44463-3	2131 Edward-2018PFAS-P2	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.15	1.7	3.0	B	ng/L	B	3.0 B	1
320-44463-5	2136 Edward-2018PFAS-P2	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.15	1.8	3.0	B	ng/L	B	3.0 B	1
320-45051-5	2244 Peridot-2018PFAS-P2Post	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.14	1.7	0.2	J B	ng/L	J B	0.2 J B	1
320-45051-3	2246 Keeney-2018PFAS-P2Post	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.14	1.7	0.21	J B	ng/L	J B	0.21 J B	1
320-41470-1	2291Keeney-2018PFAS-PostTreat	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.14	1.7	0.65	J B	ng/L	J B	0.65 J B	1
320-44239-6	2310 Old Richardson-2018PFAS-P2Post	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.15	1.8	0.21	J B	ng/L	J B	0.21 J B	1
320-45876-1	2315#2 Old Richardson-2018 PFAS-P2 Post	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.14	1.7	0.27	J B	ng/L	J B	0.27 J B	1
320-44669-4	2361 Sunflower-2018 PFAS-P2	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.14	1.7	0.31	J B	ng/L	J B	0.31 J B	1
320-44239-4	2375 Richardson-2018PFAS-P2Post	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.14	1.7	0.24	J B	ng/L	J B	0.24 J B	1
320-41470-1	2375Richardson-2018PFAS-PostTreat	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.14	1.7	0.23	J B	ng/L	J B	0.23 J B	1
320-44239-2	2378 Grumman-2018PFAS-P2Post	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.15	1.7	0.21	J B	ng/L	J B	0.21 J B	1
320-45051-2	2382 Sunflower-2018PFAS-P2	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.15	1.7	0.77	J B	ng/L	J B	0.77 J B	1
320-45876-2	2390#1 Richardson-2018 PFAS-P2 Post	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.14	1.6	0.23	J B	ng/L	J B	0.23 J B	1
320-44669-1	2412 Piper-2018 PFAS-P2 Post	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.15	1.8	0.21	J B	ng/L	J B	0.21 J B	1
320-44669-2	2476 Sunflower-2018 PFAS-P2	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.15	1.7	0.46	J B	ng/L	J B	0.46 J B	1
320-45051-1	2571 Kalispell-2018PFAS-P2Post	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.14	1.7	0.27	J B	ng/L	J B	0.27 J B	1
320-45876-3	2578 Kalispell-2018 PFAS-P2 Post	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.14	1.7	0.23	J B	ng/L	J B	0.23 J B	1
320-45876-3	2578 Kalispell-2018 PFAS-P2 Pre	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.14	1.7	2.9	B	ng/L	B	2.9 B	1
320-45632-1	2584Stonecrest-2018PFAS-P2	Perfluorobutanesulfonic acid (PFBS)	375-73-5	0.19	1.9	0.35	J	ng/L	J	0.35 J	3
320-45632-1	2584Stonecrest-2018PFAS-P2	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.16	1.9	0.88	J B	ng/L	J B	0.88 J B	1
320-45444-2	2598-Goldenrod-2018 P2 Pre	Perfluorobutanesulfonic acid (PFBS)	375-73-5	0.28	0.95	0.99		ng/l	J	0.99 J	2
320-44239-1	2601 Kalispell-2018PFAS-P2Post	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.15	1.7	0.45	J B	ng/L	J B	0.45 J B	1
320-41851-1	2691Regal-2018PFAS-PostTreat	6:2 FTS	27619-97-2	1.8	18	7.5	J B	ng/L	J B	7.5 J B	1
320-41851-1	2691Regal-2018PFAS-PostTreat	Perfluorobutanoic acid (PFBA)	375-22-4	0.31	1.8	0.53	J B	ng/L	J B	0.53 J B	1
320-41851-1	2691Regal-2018PFAS-PostTreat	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.15	1.8	0.25	J B	ng/L	J B	0.25 J B	1
320-41851-1	2691Regal-2018PFAS-PreTreat	6:2 FTS	27619-97-2	1.8	18	18	B	ng/L	B	18 B	1
320-41851-1	2691Regal-2018PFAS-PreTreat	Perfluorobutanoic acid (PFBA)	375-22-4	0.32	1.8	3.1	B	ng/L	B	3.1 B	1
320-44463-2	2890 Glacier State-2018PFAS-P2 Post	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.15	1.7	0.24	J B	ng/L	J B	0.24 J B	1
320-44463-1	2936 Badger-2018PFAS-P2 Post	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.14	1.7	0.29	J B	ng/L	J B	0.29 J B	1
320-44239-5	2985 Badger-2018PFAS-P2Post	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.14	1.7	0.25	J B	ng/L	J B	0.25 J B	1

Table 1
Summary of Qualified Data
NPR PFAS Phase I / II
Data Quality Assessment

SDG	Sample ID	Analyte	CAS	DL	LOQ	Result	Original Flag	Units	QC Flag	Final Qualified Result	Note
320-44239-5	2985 Badger-2018PFAS-P2Pre	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.15	1.7	2.7	B	ng/L	B	2.7 B	1
320-44463-5	9999 Edward-2018 PFAS-P2	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.15	1.7	3.1	B	ng/L	B	3.1 B	1
320-45632-1	9999Stonecrest-2018PFAS-P2	Perfluorobutanesulfonic acid (PFBS)	375-73-5	0.19	1.9	0.20	J	ng/L	J	0.20 J	3
320-45632-1	9999Stonecrest-2018PFAS-P2	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.16	1.9	0.83	J B	ng/L	J B	0.83 J B	1
320-44461-1	MW-158A-15	Perfluorooctanesulfonic acid (PFOS)	1763-23-1	0.46	1.7	8.9	B	ng/L	B	8.9 B	1
320-44461-1	MW-184-45	Perfluorooctanesulfonic acid (PFOS)	1763-23-1	0.46	1.7	3.4	B	ng/L	B	3.4 B	1
320-44672-1	MW-189B-60	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.17	2	2.1	B	ng/L	B	2.1 B	1
320-44672-1	MW-193A-15	Perfluorooctanesulfonic acid (PFOS)	1763-23-1	0.55	2	7.5		ng/L	J	7.5 J	3
320-44672-1	MW-293A-15	Perfluorooctanesulfonic acid (PFOS)	1763-23-1	0.52	1.9	2.7		ng/L	J	2.7 J	3
320-44672-1	MW-293A-15	Perfluorotetradecanoic acid (PFTeA)	376-06-7	0.28	1.9	0.36	J B	ng/L	J B	0.36 J B	1
320-44672-1	MW-311-15	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.17	2	0.41	J B	ng/L	J B	0.41 J B	1
320-44672-1	MW-311-46	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.17	2	0.38	J B	ng/L	J B	0.38 J B	1
320-41470-1	MW-314-15	Perfluorooctanesulfonic acid (PFOS)	1763-23-1	0.45	1.7	1.4	J	ng/L	J B	1.4 J B	1
320-44672-1	MW-316-56	Perfluorotetradecanoic acid (PFTeA)	376-06-7	0.29	2	0.34	J B	ng/L	J B	0.34 J B	1
320-44461-1	MW-318-20	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.15	1.8	2.5	B	ng/L	B	2.5 B	1
320-44461-1	MW-318-20	Perfluorooctanesulfonic acid (PFOS)	1763-23-1	0.48	1.8	3.3	B	ng/L	B	3.3 B	1
320-44461-1	MW-327-15	Perfluorooctanesulfonic acid (PFOS)	1763-23-1	0.48	1.8	2.2	B	ng/L	B	2.2 B	1
320-44672-1	MW-328-151	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.17	2	0.33	J B	ng/L	J B	0.33 J B	1
320-41470-1	MW-332-150	Perfluorooctanesulfonic acid (PFOS)	1763-23-1	0.44	1.6	1.6		ng/L	B	1.6 B	1
320-41470-1	MW-346-65	Perfluorooctanesulfonic acid (PFOS)	1763-23-1	0.45	1.7	1.2	J	ng/L	J B	1.2 J B	1
320-44461-1	MW-357-115	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.16	1.8	0.79	J B	ng/L	J B	0.79 J B	1
320-44461-1	MW-357-115	Perfluorooctanesulfonic acid (PFOS)	1763-23-1	0.5	1.8	1.7	J B	ng/L	J B	1.7 J B	1
320-44461-1	MW-357-15	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.16	1.8	0.87	J B	ng/L	J B	0.87 J B	1
320-44461-1	MW-357-15	Perfluorooctanesulfonic acid (PFOS)	1763-23-1	0.49	1.8	1.4	J B	ng/L	J B	1.4 J B	1
320-44672-1	MW-357-150	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.18	2.1	0.32	J B	ng/L	J B	0.32 J B	1
320-44672-1	MW-357-65	Perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.17	2	0.57	J B	ng/L	J B	0.57 J B	1

Table 1
Summary of Qualified Data
NPR PFAS Phase I / II
Data Quality Assessment

Notes

1	Blank detection	ng/L	nanograms per liter
2	IDA recovery failure	SDG	sample delivery group
3	Field duplicate RPD failure	CAS	Chemical Abstract Service number
		DL	detection limit
		LOQ	limit of quantitation

Data Qualifiers

B	The result is considered estimated, potentially biased high, due to analyte detection in a blank sample.
J	The result is considered estimated, with no clear direction of bias; the analyte was either detected below the LOQ, or was affected by a QC anomaly

Note: all analyses performed using a modified EPA Method 537 with isotope dilution

APPENDIX D – ADEC CONTAMINATED GROUNDWATER ADVISORY

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Alaska Department of Environmental Conservation

Spill Prevention and Response Division

Contaminated Sites Program

Contaminated Groundwater Advisory
North Pole Piped Water Expansion

The Alaska Department of Environmental Conservation (ADEC) is providing this contaminated groundwater[1] advisory to property owners within the North Pole piped water expansion area. Some private water wells within this area draw groundwater that has been contaminated by sulfolane and/or per- and poly-fluoroalkyl substances (PFAS). This Advisory explains precautions to help residents avoid unintentional contact with or spreading of contamination.

Description of Contamination: Releases of sulfolane at the former North Pole Refinery contaminated the groundwater throughout much of the City of North Pole and beyond the city boundaries. The sulfolane contamination affects many residents, homeowners, and landowners and is expected to remain in the groundwater for many years. The area of groundwater carrying sulfolane is approximately 2 miles wide, 3.5 miles long and over 300 feet deep. The sulfolane plume is not static. It continues to gradually migrate towards the north-northwest, and contaminant concentrations in groundwater wells may change over time.

The State has recently determined that historical releases of PFAS (chemicals used in some fire-fighting foams) at the former North Pole Refinery have also contaminated some of the groundwater in the North Pole area. Groundwater sampling is ongoing, and the extent of PFAS pollution has not yet been delineated.

Water Use Advisory: ADEC advises eligible property owners to connect to the expanded water utility service.

- The 2017 settlement agreement between the State of Alaska, Flint Hills Resources, Alaska (FHRA), and the City of North Pole will extend the city's piped water system to include the area currently impacted by sulfolane along with areas expected to be impacted in the future.

- Connecting to water utility service will protect the owner and anyone else on the property from any health effects that could be caused by exposure to contaminated well water.

ADEC similarly advises against using untreated, contaminated well water after a property is eligible for connection to the water utility service.

- Ceasing use of untreated, contaminated well water reduces spreading the pollution and eliminates human exposure. The sulfolane plume is not static. Concentrations in wells can change over time, and the extent of PFAS pollution in the groundwater is still uncertain. Understanding of the toxicity of these chemicals is also still evolving, with long-term toxicity studies on sulfolane pending and new cleanup levels for PFAS recently proposed. To best prevent spreading these chemicals to places where people might be exposed to them, ADEC is seeking community assistance in ceasing spread of chemicals from untreated, contaminated groundwater use.

- To avoid spreading the contaminants and help the community minimize additional impacts, owners are advised to cease future use of their existing well and to not construct new wells unless concentrations of sulfolane and PFAS are below levels of concern. ADEC is available to help owners with this determination and will provide guidance at the December 5, 2018 Open House.

Monitoring: Groundwater samples are being collected periodically (generally annually) from some private water wells to track movement of the contamination. ADEC may request access to your water well by the State of Alaska, FHRA, Williams Alaska Petroleum, Inc., and/or agents acting on their behalf for purposes of collecting groundwater samples and monitoring the groundwater contamination. Monitoring parties will always notify you prior to the desired sample date and work with you to sample during mutually agreeable times.

For additional information, please contact ADEC at 907-451-2143.

[1] The term, groundwater, refers to water stored under the surface of the ground in the tiny pore spaces between rock, sand, soil, and gravel. The term, well water, refers to groundwater that is obtained through a supply well.