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Perfluorobutane Sulfonic Acid (PFBS) Chemistry, Production, Uses, and Environmental Fate in Michigan

Prepared for :
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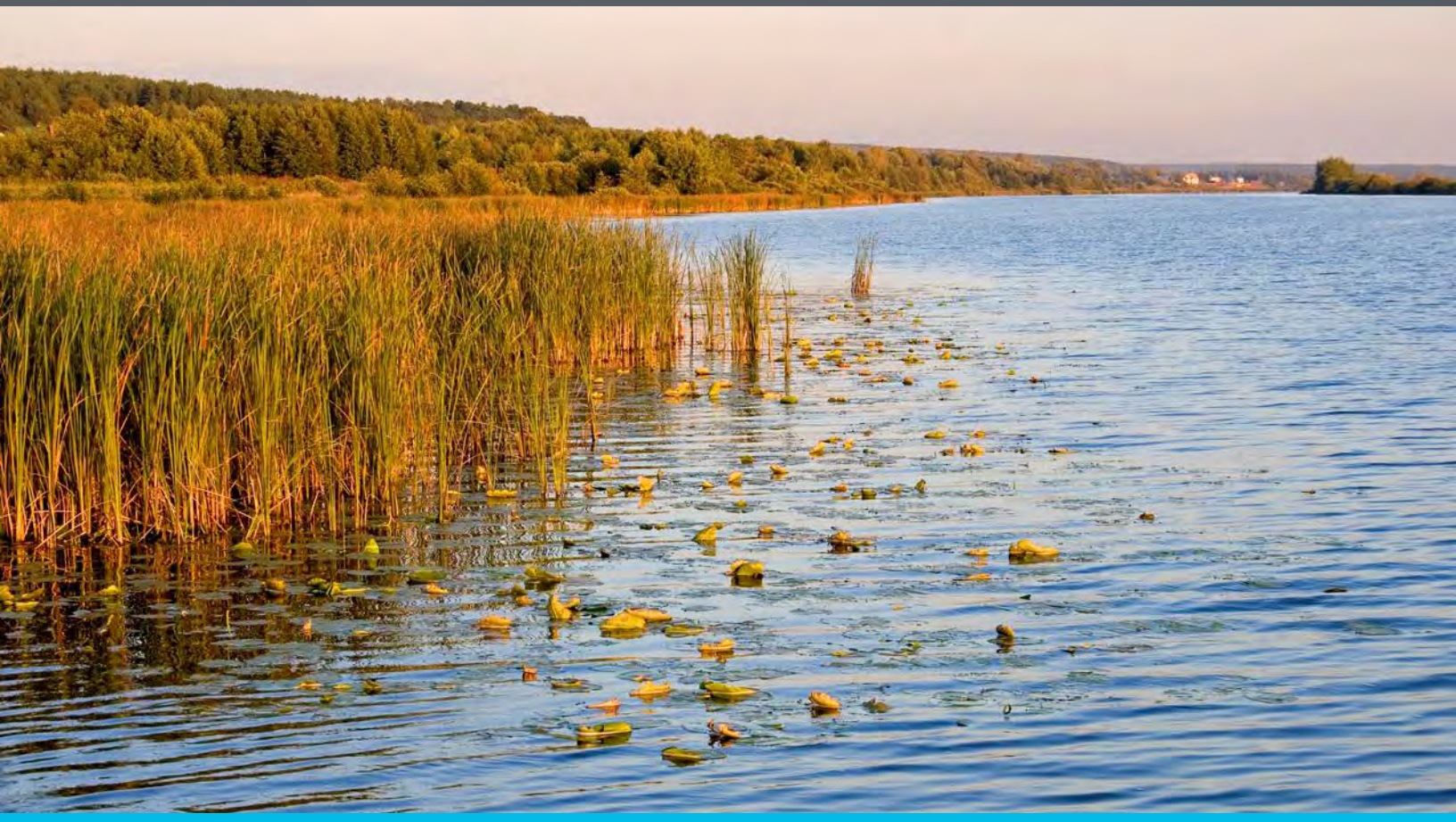

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List of Acronyms

AFFF	Aqueous Film Forming Foams
APFO	Ammonium Perfluorooctanoate
BAF	Bioaccumulation Factor
BCF	Bioconcentration Factor
BMF	Biomagnification Factor
CCD	Charge-Coupled Devices
C-F	Carbon and Fluorine Bond
ECF	Electrochemical Fluorination
EFSA	European Union Food and Safety Authority
ETFE	Ethylene Tetrafluoroethylene
EtFOSA	N-Ethyl Perfluorooctane Sulfonamide
EtFOSE	N-Ethyl Perfluorooctane Sulfonamidoethanol
EU	European Union
FEP	Perfluorinated Ethylene-Propylene Copolymers
FTI	Fluorotelomer Iodide
HNVs	Human Noncancer Values
K-EtFOSAA	Potassium N-Ethyl Perfluorooctane Sulfonamidoacetate
K-PFBS	Potassium PFBS
K-PFOS	Potassium Perfluorooctane Sulfonate
LHA	Lifetime Drinking Water Health Advisory
log K_{OW}	Octanol/Water Partition Coefficient
NaPFO	Sodium Perfluorooctanoate
NEt_4-PFOS	Tetraethylammonium Perfluorooctane Sulfonate
N-EtFOSAA	N-Ethylperfluoro-1-Octanesulfonamidoacetic Acid
ng/L or ppt	Nanograms Per Liter/Parts Per Trillion
NGI	Norwegian Environment Agency
N-MeFOSAA	N-Methylperfluoro-1-Octanesulfonamidoacetic Acid
PBTs	Persistent in the Environment, Bioaccumulative, Toxic
PFA	Perfluoroalkyl Polymers
PFAS	Per- and Polyfluoroalkyl Substances
PFBS	Perfluorobutane Sulfonic Acid
PFCAs	Perfluoroalkyl Carboxylic Acids
PFDA	Perfluorodecanoic Acid
PFDoDA	Perfluorododecanoic Acid
PFECHS	Perfluoroethylcyclohexanesulfonate
PFHpA	Perfluoroheptanoic Acid
PFHxA	Perfluorohexanoic Acid
PFHxS	Perfluorohexane Sulfonic Acid
PFMeCHS	Perfluoromethylcyclohexane Sulfonate
PFNA	Perfluorononanoic Acid
PFOA	Perfluorooctanoic Acid
PFOS	Perfluorooctane Sulfonic Acid

PFSAs	Perfluoroalkane Sulfonic Acids
PFTeDA	Perfluorotetradecanoic Acid
PFTrDA	Perfluorotridecanoic Acid
PFUnDA	Perfluoroundecanoic Acid
POCF	Perfluorooctanoyl Fluoride
POPs	Persistent Organic Pollutants
POSF	Perfluorooctane Sulfonyl Fluoride
PTFE	Polytetrafluoroethylene (Teflon)
PVDF	Polyvinylidene Fluoride
REACH	Registration, Evaluation, Authorization, and Restriction of Chemicals
SNUR	Significant New Use Rule
TMF	Trophic Magnification Factor
TSCA	Toxic Substances Control Act
UCMR	Unregulated Contaminant Monitoring Rule
USEPA	United States Environmental Protection Agency
vPvBs	Very Persistent, Very Bioaccumulative Chemicals

1. Introduction

Per- and polyfluoroalkyl substances (PFAS) are an emerging contaminant class of human-made chemicals that were first developed in the late 1930s. The term PFAS is attributed to a large class of chemicals composed of many families that have vastly different physical and chemical properties (Buck, 2011). A recent survey reported more than 4,700 PFAS had been identified (OECD, 2018). Due to their unique chemical properties, PFAS production increased as these chemicals were incorporated into components of inks, varnishes, waxes, firefighting foams, metal plating, and cleaning solutions, coating formulations, lubricants, water and oil repellents, paper, and textiles (Paul, 2009). Examples of industries using PFAS include automotive, aviation, aerospace and defense, biocides, cable and wiring, construction, electronics, energy, firefighting, food processing, household products, oil, and mining production, metal plating, medical articles, paper and packaging, semiconductors, textiles, leather goods, and apparel (OECD, 2013).

Many PFAS are highly persistent, bioaccumulative, and toxic and have been detected ubiquitously throughout the environment. Some PFAS undergo partial biotic or abiotic degradation to stable PFAS end-compounds that are highly persistent in the environment (Wang, 2017). As a result, these human-made chemicals are expected to be detected for decades in the environment. Varying concentrations of PFOS, PFOA, and other PFAS have been measured in surface waters in Michigan and in biota worldwide in areas remote from known or suspected sources, including in Polar Regions where contamination could occur only through environmental transport. Public water supplies (PWS) that use Michigan rivers, streams, lakes, or the Great Lakes could detect PFAS concentrations in the raw water due to this anthropogenic background concentration.

Widespread use of fluorinated chemistry at various manufacturing and industrial facilities in conjunction with these chemicals extreme resistance to degradation have resulted in the presence of PFAS in the environment. The Michigan Department of Environment, Great Lakes, and Energy's (EGLE) (formerly the Michigan Department of Environmental Quality or MDEQ) primary objective for this state-wide PFAS sampling was to proactively sample PWS, schools, daycares, and tribal locations that utilize groundwater and/or surface water as their sources for drinking water to verify these supplies are protective of the populations they serve.

The United States Environmental Protection Agency (USEPA) evaluated the potential presence of PFAS in drinking water during 2012 and 2015 under the 1996 amendment to the Safe Drinking Water Act (USEPA, 2016a, b). Once every five years, the USEPA issues a list of compounds to be monitored by public water supplies. Six (6) PFAS compounds, including PFOA and PFOS, were among the list of contaminates monitored during the third Unregulated Contaminate Monitoring Rule (UCMR 3). A full list of PFAS sampled during the UCMR3, and the reporting limits are presented in **Table 1** below. Two types of water supplies were monitored, large PWS serving more than 10,000 people and small PWS serving less than 10,000 people. A total of 4,064 large PWS and 800 small PWS were monitored during the UCMR3. However, the total number of small PWS in the United States (US) is about 144,165 supplies, and only about 0.5% (800) of these water supply supplies were included in the UCMR3 study. As a result, a large number of small PWS in the US, including Michigan, were not sampled during the UCMR3 sampling by USEPA.

Table 1. UCMR3 PFAS Analytes and Reporting Limit

PFAS Full Name	Acronym	Carbon Chain Length	Minimum Reporting Limit (ng/L)
Perfluorobutane sulfonic acid	PFBS	4	90
Perfluorohexane sulfonic acid	PFHxS	6	30
Perfluorooctane sulfonic acid	PFOS	8	40
Perfluoroheptanoic acid	PFHpA	7	10
Perfluorooctanoic acid	PFOA	8	20
Perfluorononanoic acid	PFNA	9	20

In Michigan, a total of 79 large and 13 small PWS were sampled by USEPA during the UCMR3 study. Two large PWS from Ann Arbor and Plainfield Township was identified to contain PFOS concentrations of 43 ng/L and 60 ng/L, respectively. In 2018 EGLE performed a Statewide PFAS Sampling of Drinking Water Supplies to evaluate the potential of PFAS impacts in drinking water supplies in Michigan. The results and findings of the sampling program are discussed in detail in **Section 1.1**.

During the 2018 Statewide PFAS Sampling Program, a total of 108 drinking water supplies had PFBS detections, out of which 36 locations only detected PFBS and no other PFAS. PFBS had the highest detection frequency of 5.4% out of the 14 PFAS, which were sampled during the 2018 Statewide PFAS Sampling Program.

Sections 2, 3, and **4** describe PFBS production, physicochemical properties, environmental fate and transport, and potential primary sources to the environment. It should be noted that there are knowledge gaps within these areas due to trade secrets and limited scientific evidence. This document does not attempt to be a definitive report on the PFBS, but to serve as an overview and identify potential sources to the detections in the public water supplies.

The objective of the report was to:

- Perform a review of PFBS production, physicochemical properties, environmental fate and transport, and potential primary sources to the environment that could be present in Michigan, and
- To evaluate the PFBS detections in the public water supplies to potentially identify the PFAS sources and whether it can be associated with any industry or particular consumer products.

1.1 Michigan PFAS Statewide Drinking Water Sampling

A total of 1,741 facilities, including both CWS and non-community water supplies (NCWS), were sampled during the EGLE 2018 Statewide PFAS Sampling Program. A total of 64 municipalities with intakes in one of the Great Lakes, connecting channels, or inland rivers, and 1,048 other facilities that rely on groundwater were sampled. The CWS facilities sampled consisted of municipalities, manufactured housing communities, apartment complexes, subdivisions, condominium developments, and others. A total of 460 schools and 152 daycares classified as NCWS, which have their own groundwater well(s), were also sampled. EGLE also included 17 federally recognized tribal entities as part of the 2018 Statewide PFAS Sampling Program.

The objective of the 2018 statewide PFAS sampling program was to evaluate and perform an initial statewide screening for PFAS in the drinking water supplies for approximately 75% of Michigan's population. The analysis was performed using the USEPA Method 537 Rev. 1.1 for 14 different PFAS, as presented in **Table 2**.

Table 2. USEPA Method 537 Rev. 1.1 PFAS Analyte List

PFAS Full Name	Acronym	Carbon Chain Length	CAS Number	Reporting Limit (ng/L)
Perfluorohexanoic acid	PFHxA	6	307-24-4	2
Perfluoroheptanoic acid	PFHpA	6	375-85-9	2
Perfluorooctanoic acid	PFOA	8	335-67-1	2
Perfluorononanoic acid	PFNA	9	375-95-1	2
Perfluorodecanoic acid	PFDA	10	335-76-2	2
Perfluoroundecanoic acid	PFUnDA	11	2058-94-8	4
Perfluorododecanoic acid	PFDoDA	12	307-55-1	4
Perfluorotridecanoic acid	PFTrDA	13	72629-94-8	4
Perfluorotetradecanoic acid	PFTeDA	14	376-06-7	4
Perfluorobutanesulfonic acid	PFBS	4	375-73-5	2
Perfluorohexanesulfonic acid	PFHxS	6	355-46-4	2
Perfluorooctanesulfonic acid	PFOS	8	1763-23-1	2
N-methylperfluoro-1-octanesulfonamidoacetic acid	N-MeFOSAA	8	2355-31-9	4
N-ethylperfluoro-1-octanesulfonamidoacetic acid	N-EtFOSAA	8	2991-50-6	4

A total of 2,286 individual entry point samples were collected from 1,741 individual PWS, schools, daycares, and tribal entities. A total of 89.9% of the PWS sampled were reported as non-detect for all of the 14 PFAS compounds analyzed with a reporting limit of 2 and 4 ng/L. A total of 6.6% of the PWS sampled were found to be in the low tier with a Total PFAS below ten (10) ng/L. A total of 3.6% of the PWS sampled were found to be in the medium tier with a Total PFAS above ten (10) ng/L and PFOA+PFOS concentration below 70 ng/L. A total of 0.1% of the PWS sampled were found to be in the high tier with PFOA+PFOS above 70 ng/L. The percentage of detection was calculated based on the 1,741 supplies sampled during this 2018 statewide PFAS sampling program. A summary of the PFAS result totals is presented in **Table 3**.

Table 3. Michigan 2018 PFAS Public Water Supplies Testing Results

Supply Type	Supplies Sampled	Non-Detect	<10ng/L Total PFAS	>10ng/L Total PFAS <70ng/L PFOA+PFOS	>70ng/L PFOA+PFOS
CWS & NCWS	1112	994	84	35	1
Schools	460	420	21	19	1
Tribal Entities	17	17	0	0	0
Daycares	152	134	10	8	0
Total Supplies	1741	1565	115	62	2
Approx. Population Served	7.7 million	5.8 million	1.4 million	490,000	3,500

1.2 PFAS Regulations

Worldwide chemical legislation has been used to ban or restrict the use of chemicals that are found to be harmful to humans or the environment. Chemicals are prohibited or restricted if they are found to be persistent in the environment, bioaccumulative, and toxic (PBTs) or persistent organic pollutants (POPs), which are compounds that have PBT properties that could also undergo long-range environmental transport. The POPs are regulated internationally by the United Nations Environment Programme's Stockholm Convention and the United Nations Economic Commission for Europe's Aarhus Protocol to the Convention on Long-range Transboundary Air Pollution. In the United States, under the Toxic Substances Control Act (TSCA), the USEPA can address PBT compounds under the New Chemical Substances program. In Europe, industrial chemicals are regulated through the Registration, Evaluation, Authorization, and Restriction of Chemicals (REACH). In addition to PBTs, REACH also has an additional classification of very persistent, very bioaccumulative chemicals (vPvBs). Chemicals that are classified as vPvB are subject to restrictions based on their environmental persistence and bioaccumulation potential, irrespective of their toxicity.

USEPA's final rule for Toxics Release Inventory considers chemicals to be persistent if they have half-lives of more than two months in water, soil, and sediment and two days in the air (US EPA, 1999). In the European Union (EU), chemicals with half-lives of greater than 40 days in water and greater than 120 days in sediment and soil are considered persistent (Cousins, 2016).

The bioaccumulation potential is a measurement of adsorption and concentration of a chemical in living organisms and is measured or estimated using parameters such as bioconcentration factor (BCF), bioaccumulation factor (BAF), octanol/water partition coefficient (log K_{OW}), and water solubility (Seow, 2013). The biomagnification factor (BMF) and trophic magnification factor (TMF) are also used to evaluate the potential for bioaccumulation in food chains. However, BMF and TMF have not been formally added to the legislation. The USEPA guideline under TSCA states that a substance that has a BCF or BAF below 1,000 is not considered bioaccumulative. If the BCF or BAF is between 1,000- 5,000, it is bioaccumulative and higher than 5,000 is considered very bioaccumulative (USEPA, 1999). In Europe, a chemical is identified as bioaccumulative if the BCF or BAF is above 2,000 and very bioaccumulative if the BCF or BAF is above 5,000.

In May 2000, the world's former leading producer of PFAS, 3M, announced to voluntarily phase out by 2002 its production chemistry based on perfluorooctane sulfonyl fluoride (POSF). The announcement for the switch in PFAS chemistry was in response to PFAS compounds, and particular perfluorooctane sulfonic acid (PFOS), being detected in various biota across the world, including remote parts as well as various environmental matrices. In 2006, the United States Environmental Protection Agency (USEPA) launched the voluntary PFOA Stewardship Program. This program invited eight major PFAS manufacturing companies (including 3M) to commit toward eliminating perfluorooctanoic acid (PFOA) and related chemicals from production emissions and product content by 2015 (USEPA, 2006). 3M met the program goals in 2008. In a 2002 technical data bulletin, 3M announced a new fluorosurfactant as an alternative to perfluorooctane sulfonic acid (PFOS). The new chemical, perfluorobutane sulfonic acid (PFBS), was a shorter chain PFAS and was believed to be less biologically accumulative than its longer chain counterpart PFOS.

Significant efforts have been made in many countries, including the United States, to significantly reduce the manufacturing and use of long-chain PFAS through both regulatory initiatives as well as voluntary agreements. The USEPA published under TSCA Significant New Use Rules (SNURs) and requested notification to USEPA before any future manufacturing or import of 183 PFASs (USEPA, 2007), including those that were voluntarily phased-out by 3M between 2000 and 2002. The SNUR allowed for the use of any of the 183 PFASs for limited, highly technical uses for which no alternatives were available and which were characterized by very low volume, low exposure, and low releases (USEPA, 2002, 2007). In 2015, the USEPA amended the SNUR again to include all long-chain PFCAs and PFSAs. PFOS was found to be persistent, bioaccumulative, and toxic to mammalian species. The amended USEPA SNUR from 2015 was also extended to include salts and precursors of these PFASs (USEPA, 2015). In 2008, the European Union Food and Safety Authority (EFSA) published a report on PFOS, PFOA, and their salts in

which PFOS was found to be bioaccumulative (kinetic BCFs of 1,000 to 4,000). In 2009, PFOS, along with its salts and precursors, as well as POSF, were listed under Annex A and B of the Stockholm Convention (Wang, 2017). In 2015, PFOA, its salts, and PFOA-related compounds had been proposed to be listed in Annexes A, B, and C under the Stockholm Convention on POPs (UNEP, 2015).

Today in the United States and many countries around the world, the main PFAS manufacturing is based on short-chain chemistry, such as PFBS. For specialized products and when small quantities are needed with no available replacements, long-chain PFAS are still being used. China has been the only county in the world that has produced more long-chain PFAS, including PFOS. In the United States, 3M has been the primary user of electrochemical fluorination (ECF) and PFBS-based chemistry for its PFAS market.

USEPA sets Maximum Contaminant Levels (MCLs) for drinking water quality. An MCL is the legal threshold limit on the amount of a substance that is allowed in PWS under the Safe Drinking Water Act (SDWA). In the absence of an MCL, the USEPA develops health advisories to provide information on contaminants that can cause human health effects and are known or anticipated to occur in drinking water. USEPA's health advisories are non-enforceable and non-regulatory and provide technical information to State agencies and other public health officials on health effects, analytical methodologies, and treatment technologies associated with drinking water contamination.

To provide consumers, including the most sensitive populations, with a margin of protection from a lifetime of exposure to PFOA and PFOS from drinking water, the USEPA, Office of Water, established a Lifetime Health Advisory (LHA) level of 70 ng/L in May 2016. When both PFOA and PFOS are found in drinking water, the combined concentrations of PFOA and PFOS should be compared with the 70 ng/L LHA. These new advisory levels replace the USEPA's January 2009 provisional health advisory levels for PFOA (400 ng/L) and PFOS (200 ng/L) and reflect the evolution of the science regarding exposure and toxicity of these chemicals.

EGLE promulgated ambient surface water quality (Human Noncancer Values (HNVs)) for PFOS and PFOA of 12 ng/L and 12,000 ng/L, respectively, for surface waters not used as a source of drinking water and 11 ng/L and 420 ng/L for surface water that is used for drinking water. In 2018, EGLE promulgated criterion for drinking water as 70 ng/L for the total concentration of PFOS and PFOA. However, at this time, there are no promulgated criteria for PFBS in Michigan. The Michigan Department of Health and Human Services (MDHHS) has developed a screening level for PFBS for drinking water of 1,000 ng/L and is in the process of developing an MCL. Other US states have developed PFBS criteria that have not been promulgated for groundwater or drinking water at levels between 2,000 ng/L up to 667,000 ng/L. The USEPA has a PFBS regional screening level of 400,000 ng/L for groundwater. A total of nineteen (19) individual US states and nine countries have also issued regulatory or advisory limits on various PFAS in drinking water and soil and are presented in **Appendix A Table 4-1** and **4-2** from the Interstate Technology Regulatory Council (ITRC) Regulations, Guidance, and Advisories for Per- and Polyfluoroalkyl Substances (PFAS) Fact Sheet (ITRC, 2018).

2. PFAS Manufacturing and Chemistry

PFAS are a complex group of fluorinated organic chemicals composed of several different families and are produced using two main manufacturing processes. Understanding PFAS chemistry related to PFBS and PFBS-related compounds is vital in determining the potential PFBS sources, environmental releases, and fate and transport. Each PFAS family is composed of PFAS compounds of various carbon chain lengths. Typically, a limited number of PFAS are manufactured as a raw ingredient, such as POSF, which is later used to produce other PFAS, which are incorporated into various intermediate and final products.

Two main manufacturing processes, electrochemical fluorination (ECF) and telomerization are used for the production of PFAS and will be briefly discussed in the following sections.

2.1 Electrochemical Fluorination

ECF was first used to mass-produce fluorosurfactants and fluorinated polymers by 3M in the late 1940s (Banks, Smart, and Tatlow 1994). By the late 1990s, 3M was producing many PFAS families using ECF; 95% of the production was based on POSF and POSF-related derivatives and 5% based on perfluorooctane carbonyl fluoride (POCF) which was used to make PFOA and PFOA salts (**Figure 1**). **Appendix B**, Figure 1 shows major POSF-related PFAS families manufactured by 3M in 1997 and the main product categories for which they were used. Historical and current major POCF-related PFAS families manufactured by 3M in the United States and the main product categories for which they were used depicted in Figure 2 from **Appendix B** In the United States, 3M produced ammonium and sodium salts of PFOA such as ammonium perfluorooctanoate (APFO) and sodium perfluorooctanoate (NaPFO), which aided in the polymerization of polytetrafluoroethylene (PTFE) known commercially under the tradename as Teflon, perfluorinated ethylene-propylene copolymers (FEP), perfluoroalkyl polymers (PFA), and polyvinylidene fluoride (PVDF) (Wang, 2014).

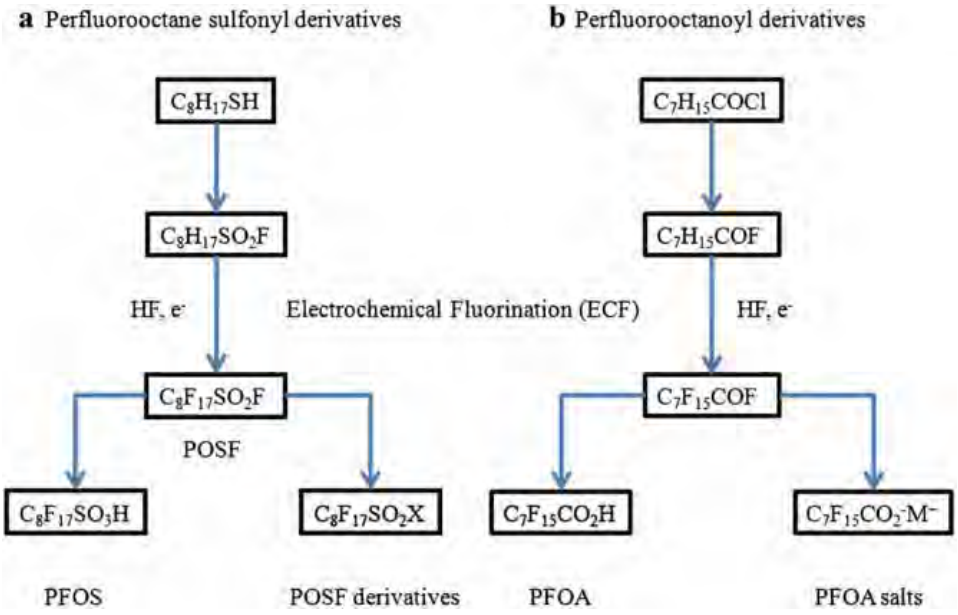

Figure 1. Synthesis Using ECF of a) PFOS and POSF Derivatives and b) PFOA and PFOA Salts (Buck, 2011)

2.2 Telomerization

In 1942, DuPont described a new process called telomerization. Fluorotelomer-based production began in the 1970s and has increased significantly in the early 2000s. Telomerization is similar to polymerization, where single molecules are combined to form larger molecules. However, in telomerization, single molecules (called telogens) are combined with another single-molecule (called a taxogen or chain transfer agent) to create a larger molecule (telomer), an example of the production of fluorotelomer iodide (FTI) and its derivatives are depicted in **Figure 2**. Many manufacturers have used this process to produce PFAS families that are different than those produced by ECF. The PFAS families produced using telomerization were different than those produced by 3M using the ECF process. Telomerization is unique to polymerization in that telomers have a lower molecular weight than polymer chains.

There are four main steps in telomerization: initiation, chain growth, chain transfer, and termination. The initiation step begins with a photochemical reaction (energy absorbed by light) involving a telogen and a catalyst, forming a free radical (reactive compound). In the second step, the free radical reacts with a taxogen. The radical and taxogen create a longer chain (i.e., chain growth). In the third step (chain transfer), the newly formed longer chain is then cleaved, forming a new shorter chain compound. Multiple rounds of chain growth and transfer can occur in telomerization. The final step is termination, where the end product is a nonradical compound.

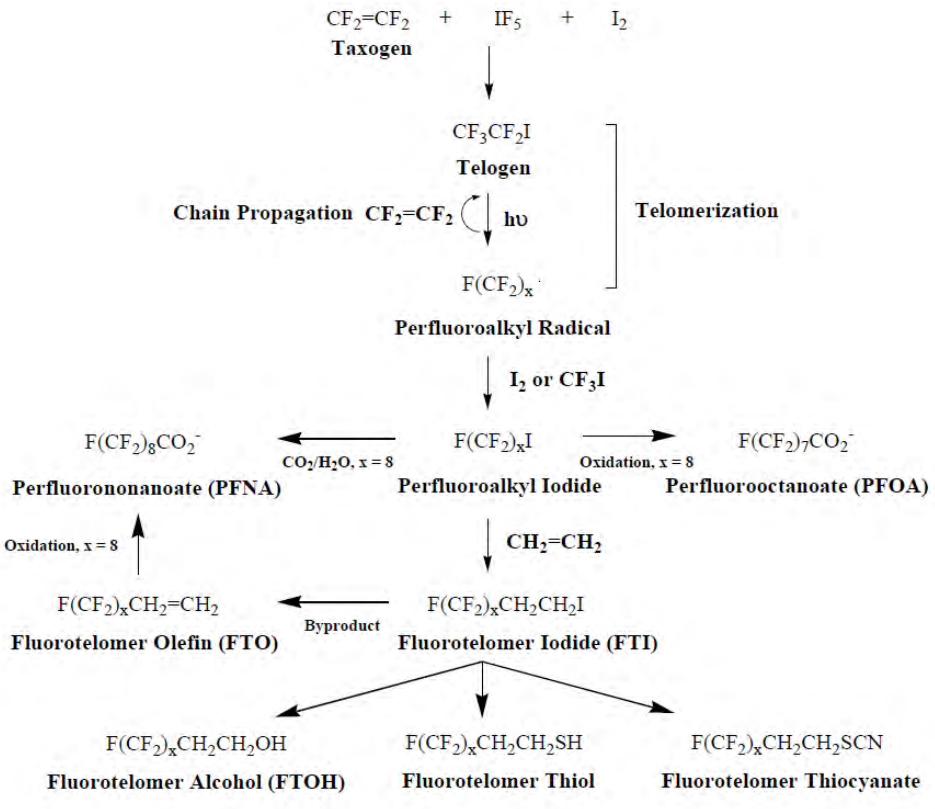

Figure 2. Telomerization Production of Fluorotelomer Iodide (FTI) and its Derivatives (Lee, 2013)

Approximately 80% of the telomerization manufacturing is directed towards the production of various polymeric materials for surface treatments for materials, and the remaining as surfactants using in food packaging, wetting agents, and in other consumer products.

2.3 Perfluorinated vs. Polyfluorinated Compounds

Many PFAS that are also surfactants have a two-part body structure consisting of a tail and ahead. The tail comprises two or more carbon (C) atoms attached to a functional group (head). Typically, the functionalized head consists of carboxylic or sulfonic acid. In perfluoroalkyl (also referred to as perfluorinated) compounds, the tail is made up of carbon atoms that are fully fluorinated and have all of the hydrogen atoms attached to carbon atoms being replaced by fluorine atoms. In polyfluoroalkyl (also referred to as polyfluorinated) compounds, at least one of the tail carbon atoms are bonded with an atom other than fluorine, typically hydrogen (H) or oxygen (O). An example chemical structure of both a perfluorinated and polyfluorinated substance is depicted in **Figure 3**.

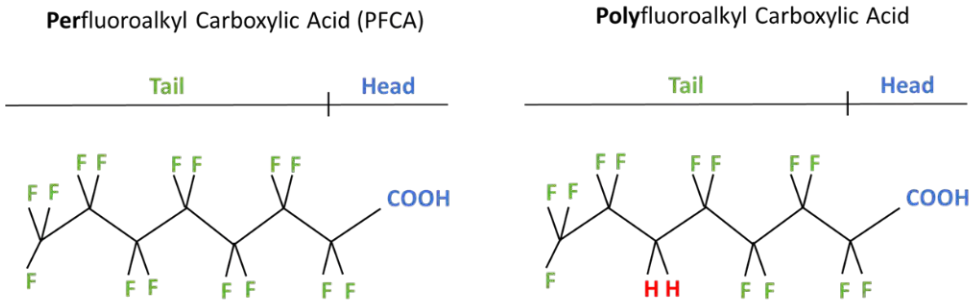

Figure 3. Examples of Perfluorinated and Polyfluorinated Substances

If a branched or odd carbon number telogen is used, the telomerization process could result in a mixture of the branched or odd-numbered carbon chain, and such telogens have been described in patents. However, to date, PFAS identified and produced using telomerization are found to have PFAS with only even-numbered and linear carbon tails (Buck, 2011; Lee, 2013).

2.4 Chain Length

PFAS compounds belonging to a particular family have the same functional heat, with the only difference being the fluorinated carbon-fluorine chain length. PFAS belonging to a family depends on the carbon chain length and can be considered either short- or long-chained. The carbon chain length of PFBS is formed with four (4) carbon atoms (C4), and PFOS is composed of 8 carbon atoms (C8) (**Figure 4**). The carbon chain length of various PFAS families has been found to significantly affect the chemical and physical properties of PFAS within the same family. PFBS is an example of a short-chain while PFAS and PFOS are considered a long-chain PFAS. Both PFBS and PFOS are part of the PFAS family of perfluoroalkane sulfonic acids (PFSAs). Typically, a PFAS with a fluorinated carbon chain length equal to or higher than eight carbons are considered to be long-chain, and PFAS compounds with less than eight carbons are considered to be short-chain PFAS.

Long-chain and short-chain PFAS are assumed to behave and have the overall properties described in **Table 4**. Please note that the physical/chemical properties described below are global observations based on studies performed on several PFAS families, and there could be exceptions. The ECF process results in the creation of various isomers, including linear, branched, and cyclic, and also results in the formation of different carbon chain length PFAS. For example, during the production of POSF, an eight-carbon chain (C8) compound, PFAS from the same families of higher and lower carbon chain lengths were also produced. The telomerization process results in high purity of the intended PFAS without the creation of unintended PFAS of various carbon chain lengths.

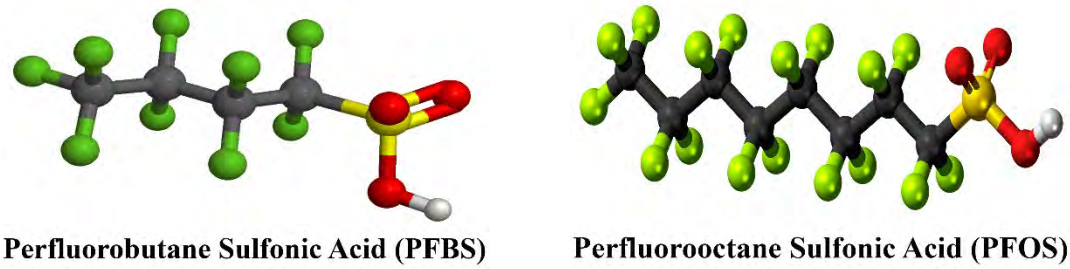

Figure 4. PFBS and PFOS Chemical Structures

Table 4. Short-Chain and Long-Chain Physical and Chemical Properties

Physical/Chemical Properties	Short-Chain	Long-Chain
Water Solubility	Higher	Lower
Bioaccumulation Potential in Biota	Lower	Higher
Accumulation Potential in Plants	Higher	Lower
Adsorption to Soil and Sediment	Lower	Higher
Overall Expected Toxicity	Lower	Higher

2.5 Linear, Branched, and Cyclic Isomers

The ECF process leads to carbon (C) chain rearrangement and breakage, resulting in a mixture of linear, branched, and cyclic isomers (Buck, 2011; OECD, 2018). The ratio of various isomers that are formed during the ECF process varies depending on how the process is controlled. Ratios of linear to branched isomers for PFOA and PFOS have been reported as being 70-80 percent linear, and 20-30 percent branched (Buck, 2011). This ratio of linear to branched isomers has been observed at locations where aqueous film-forming foam (AFFF) was released in the environment. However, 3M has reported ratios of 60-66 percent of branched isomers to 34-40 percent linear isomers for the production of POSF. There is not much information about cyclic isomers in the literature. The final branched and linear isomers could have either even- or odd-numbered carbon chain lengths (Concawe, 2016). One example of branched and linear PFOS isomers is presented in **Figure 5**. Technically there could be over 89 different branched PFOS isomers. However, less than six branched isomers have been typically identified in the environment (Giroday, 2014). Multiple studies identified between 20 to 30% branched isomers for PFOS, PFOA, and PFOS precursors (Benskin, 2010). In many studies, no branched isomers were identified for PFBS, and only in more recent studies were branched PFBS isomers identified in low concentrations compared to the linear isomer (Wang, 2015; Jin, 2015). As a result, PFBS linear isomers are most likely present in the environment. Branched isomers might be found in products produced more recently, after 2002.

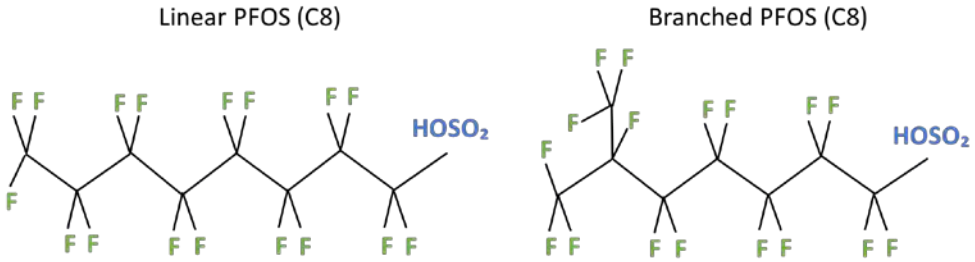

Figure 5. Linear and Branched PFOS Isomers

2.6 Precursors and Indirect PFAS Emissions

The carbon and fluorine bond (C-F) is one of the strongest bonds in organic chemistry, and compared to hydrocarbons, PFAS have enhanced chemical properties such as higher surface activity, better dielectric properties, higher thermal stability, and increased chemical resistance, and a physiological inertness (Brendel, 2018). However, many PFAS are polyfluorinated or polyfluoroalkyl for which not all of the carbons are fluorinated and are susceptible to degradation. A large family of side-chain fluorinated polymers, for example, has PFAS attached to a non-fluorinated polymer backbone that is also susceptible to degradation. All of the PFAS that could degrade abiotically and biotically in the environment to dead-end PFAS products are referred to as precursors. As a result, the emissions of PFAS in the environment could be direct and indirect as well. The degradation of precursors is considered indirect emissions of PFAS in the environment. Examples of various precursors and PFAS families to which they will degrade is presented in **Figure 6**. Many precursor PFAS families are known to degrade to perfluoroalkyl acids (PFAAs). Two of the most known PFAAs families are perfluoroalkyl carboxylic acids (PFCAs), which include PFOA, and perfluoroalkane sulfonic acids (PFSAs), which includes PFOS. Many of the precursors used in side-chain fluorinated polymers have also been found to degrade to PFAAs. Figure 3 from **Appendix B** also depicts the pathway of direct and indirect emissions of PFCAs from manufacturing to an end product use.

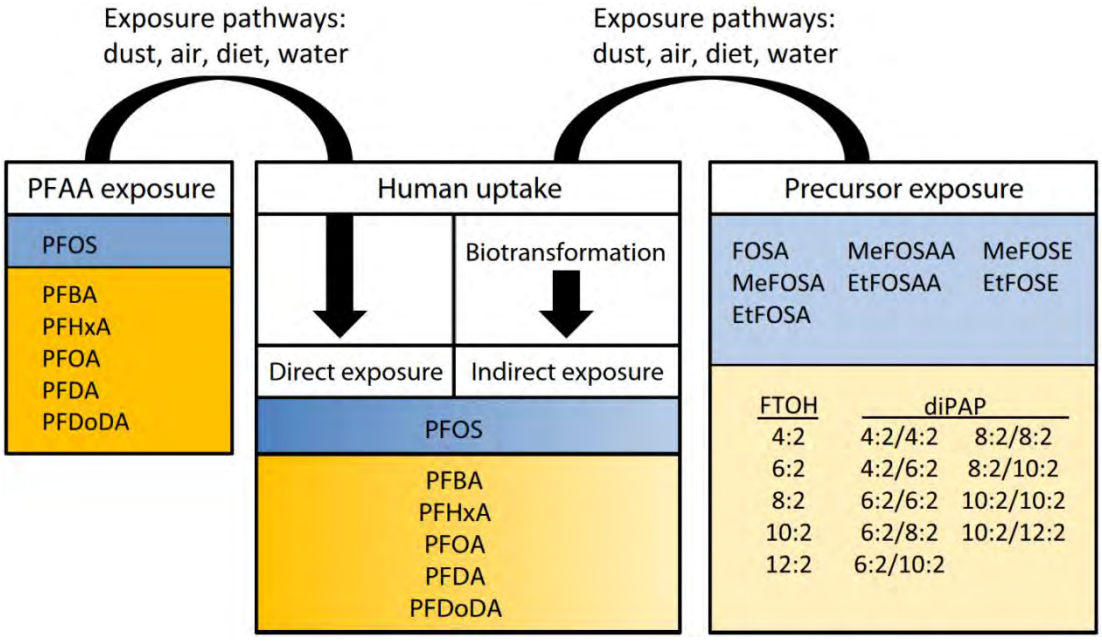

Figure 6. Schematic of direct and indirect (precursor) exposure pathways for PFOS and PFCAs (Gebbink, 2015)

3. PFBS Manufacturing and Use

PFBS manufacturing and use have changed significantly over time. Two primary time intervals regarding these changes are between 1949 through 2002 and from 2002 to the present day. PFBS has been produced since 1949 using the ECF process by various PFAS manufacturing companies during the production of POSF-based (mostly eight (8) carbon chain) products when PFBS (4 carbon chain) was manufactured as an impurity. As a result, before 2002, PFBS was produced only as a by-product and was present in consumer products as an impurity.

3M was the primary manufacturer of PFOS-based products and the first company to commercialize PFOS-based products. Additional manufactures from countries other than the US, especially China, have also produced PFOS-related compounds using ECF during 1949 thorough 2002. However, manufacturers from other countries are believed to have started the production of POSF-based compounds later. 3M was the primary producer of POSF-based products until 2002. Even in 2002, when other companies began producing, 3M was still manufacturing 80% of the total POSF global production. USEPA identified a total of 20 non-US companies that are manufacturing or supplying the global market with PFOS-related substances. A list of countries and manufactures of POSF-based compounds are presented in **Table 5** (OECD, 2002; DeSilva, 2008).

Table 5. Manufactures of POSF-based Products

Country	Manufacturer
USA	3M
Belgium	3M
Italy	Miteni S.p.A. EniChem Synthesis S.p.A.
Germany	Dyneon GmbH
Switzerland	Fluka Chemical Co, Ltd.
United Kingdom	BNFL Fluorochemicals Ltd. Fluorochem Ltd.
Russia	Scientific Industrial Association P & M Ltd.
Japan	Dianippon Ink & Chemicals, Inc. Midori Kaguka Co., Ltd. Tohkem Products Corporation Tokyo Kasei Kogyo Company, Ltd.
Brazil	Milenia Agro Ciencias S.A.
China	Changjiang Chemical Plant Indofine Chemical Company, Inc.

In 1949, 3M produced the first commercial-scale manufacturing pilot based on the ECF process. However, the earliest patents for POSF-based products filed by 3M were in 1956, and POSF-based products only started to be produced in the late 1950s or early 1960s (3M, 1999). Initial POSF-based product lines for surface treatment applications were developed in 1957 and marketed under the trade name of Scotchgard™, and paper and packaging applications in the 1960s marketed under the trade name of Scotchban™. Another commercialization of product lines as performance chemicals before 2002 were marketed under Fluorad™ and were made of low molecular weight compounds including PFOS, for the use as fire-fighting foams, mining and oil cationic surfactants, electroplating and etching bath surfactants, household additives, coating and coatings additives, carpet spot cleaners, and insecticide

raw materials. The primary product categories produced by 3M before 2002 are presented in Figure 4 from **Appendix B** (OECD, 2002).

In the US, 3M produced PFAS at Decatur, Alabama; Cottage Grove, Minnesota; and Cordova, Illinois. The manufacturing facility from Cottage Grove was minimal and was used as a pilot plant product only. The manufacturing facility from Decatur was the main production facility for 3M. It has been estimated the total metric tons (t), produced between 1957 through 2010, is between 66,000 and 101,000 t (Armitage, 2011; Paul, 2009). This information is presented in **Table 6**. PFBS is expected to have been present in many of the POSF-based products and raw materials produced between 1949 and 2002.

Table 6. Global POSF Production

Year	Number of Years	Global POSF Production (t)	POSF Production per Year
1957-1975	19	3,930	207
1976-1984	9	19,845	2,205
1985-1989	5	19,950	3,990
1990-1994	5	23,250	4,650
1995-2002	8	30,700	3,838
2003-2010	8	3,900	488

As long-chain PFAS became a more significant concern, global manufactures are transitioning to short-chain PFAS such as PFBS. 3M replaced its PFAS chemistry from POSF-based products in 2002 and started to produce PFBS-related products. Many other countries started to produce PFBS-based products using ECF as well. However, some countries, in particular China, have started to increase the production of POSF-related compounds. The PFBS manufacturing starts with unhalogenated butane sulfonyl fluoride that reacts with HF to form perfluorobutane sulfonyl fluoride (PBSF). PBSF can then be used to manufacture PFBS, its salts, and other PFBS related chemistry. **Figure 7** depicts the ECF reaction scheme.

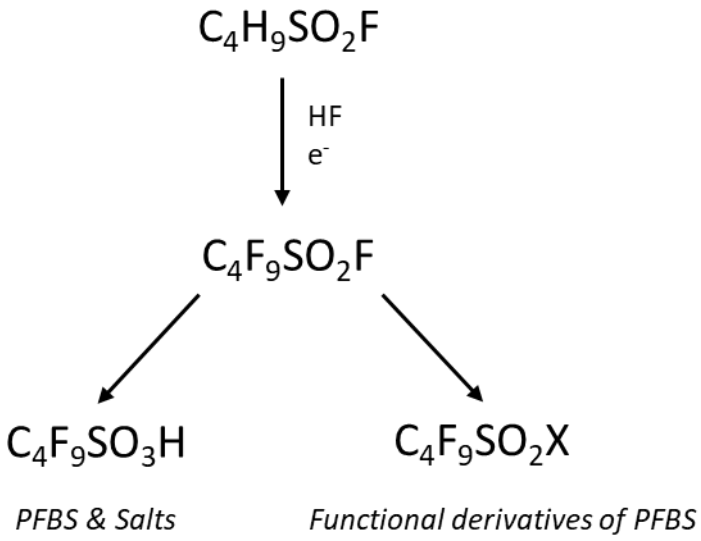

Figure 7. Formation PFBS and salts and functional derivative (NGI, 2017)

According to a recent market report for PFBS, the total global manufacture of PFBS increased from 23 t in 2011 to 27 t in 2015 (NGI, 2017). The global manufacture and consumption of PFBS for 2011 and 2015 is summarized in **Table 7**. The various uses of POSF-based products produced before 2002, where PFBS was presented as impurity and PFBS and PFBS-related products produced after 2002, are discussed in further detail in **Section 3.1** and **Section 3.2**, respectively.

Table 7. Global PFBS Manufacture and Consumption

	2011, t/year	2015, t/year
Production	**23.3**	**26.6**
Consumption		
-surfactants	16.9	19.2
-pharmaceutical industry	3.9	4.4
-insecticide	1.2	1.4
-other	1.4	1.6
Total Consumption	**23.4**	**26.6**

3.1 PFBS Manufacturing and Use Before 2002

A list of PFOS-based products produced by 3M before 2002 are discussed below in **Sections 3.1.1** through **3.1.13**.

3.1.1 Impregnation and Surface Protection

Side-chain fluorinated polymers are used extensively by the textile industry and by consumers for textiles such as carpet, apparel, and leather for the treatment of all-weather clothing, umbrellas, bags, sails, tents, parasols, sunshades, upholstery, leather, footwear, rugs, mats, and carpets to repel water, oil, and dirt (stains). The initial commercialization of product lines based on N-methyl perfluorooctane sulfonamidoethanol (MeFOSE) collectively was marketed under Scotchgard™ and began in the late 1950s.

The main PFOS derivatives were typically applied at 2–3% of the fiber weight for textiles and 15% for carpets. The PFOS derivatives used for textile and carpet surface treatment applications were the acrylate, methacrylate, adipate, and urethane polymers of N-ethyl perfluorooctane sulfonamidoethanol (EtFOSE). Before 2002 the most well-known soil and dirt repellents were:

1. Scotchgard™ (produced by 3M);
2. Capstone (produced by DuPont); and
3. Products produced by Daikin, Asahi Glass, Clariant, Rudolf Chemie, and others.

The main source of PFBS in the United States before 2002 were from products treated with PFAS produced by 3M. Many of the other PFAS producers from outside the United States used the telomerization process, which did not produce PFBS residuals within their products.

3.1.2 Impregnation of Packaging

PFAS were used in the paper industry to produce waterproof and greaseproof paper and cardboard. Product lines commercialization based on N-Ethyl perfluorooctane sulfonamidoethanol (EtFOSE) began in the late 1960s collectively marketed under Scotchban™, and primarily focused on packaging and paper products. In 1974 Scotchban™ started to be used in applications of food contact paper applications as well. The amount of PFAS used, based on the dry weight of the fibers, was between 1-1.5%. Polymeric PFAS layers can be applied on boards using the hot steel drum method. The surfactants could also be

applied through the wet end press, where the cellulosic fibers are mixed before entering the paper forming table or are applied at the size press and film press stage, which consists of impregnating the formed paper sheet with a surface treatment. The main suppliers of fluorochemicals in the paper industry, along with the brand names, are listed below in **Table 8**:

Table 8. Main PFAS Suppliers and Brand Names in the Paper Industry

PFAS Manufacturer	Brand Name
3M	Scotchban®
Bayer	Baysize S®
Ciba (BASF)	Lodyne®
Clariant	Cartafluor®
DuPont	Capstone®
Daikin	Unidyne®
Asahi	Asahigard®
Solvay	Solvera®
Rudolf Chemie	Ruco-guard®

PFOS derivatives were used in food contact applications such as plates, food containers, popcorn bags, pizza boxes, and wraps. PFOS derivatives used in non-food contact applications were folding cartons, containers, carbonless forms, and masking papers. Before 2002, the PFOS derivatives that were used most often were:

a) Mono-, di-, or triphosphate esters of N-ethyl perfluorooctane sulfonamidoethanol (EtFOSE) (such as SN-diPAPs alias SaM-PAPs).

b) N-Methyl perfluorooctane sulfonamidoethanol acrylate polymers.

A total of 32% of the total POSF-based PFAS used in the European Union was used for paper coating before 2002.

3.1.3 Cleaning Agents, Waxes and Polishes

PFOS derivatives have historically been used as surfactants to lower surface tension and improve wetting and rinse-off in a variety of industrial and household cleaning products such as automobile waxes, alkaline cleaners, denture cleaners, shampoos, floor polish, dishwashing liquids, car wash products, and carpet spot cleaners (UNEP, 2013). The PFOS derivative that was most often used in cleaning agents, floor polishes, and auto polishes is potassium N-ethyl perfluorooctane sulfonamidoacetate (K-EtFOSAA - CAS No. 2991-51-7), which is the potassium salt of N-Ethyl perfluorooctane sulfonamidoacetic acid (EtFOSAA). EtFOSAA is one of the PFAS included in the USEPA Method 537 Rev. 1.1 for the analysis of PFAS. The concentrations used in the final product were generally between 0.005% and 0.01%, and it has been estimated that the concentrations might have been ten times as high (UNEP, 2013).

3.1.4 Surface Coating, Paint, and Varnish

PFOS derivatives have been used in various coatings, paint, and varnish to reduce surface tension. Fluorinated surfactants have been used for water-based, solvent-based, and high-solids organic polymer coatings. The reduction in surface tension helped with the substrate wetting, leveling, dispersing, improved flow control, improved gloss and antistatic properties, reduction in foaming, open-time extension, oil repellency, and dirt pickup resistance. The PFOS derivatives have also been used as additives in dyes and ink, as pigment grinding aids or combat pigment flotation problems. The use in inkjet composition has helped with improved image quality on porous and non-porous media. The typical concentrations used were typically below 0.01% by wet weight. A survey of suppliers in the paint and

varnish industry has suggested that fluorosurfactants are, in general, more expensive than other alternative surfactants and are most likely used only when very low surface tension and an extremely smooth surface is desired.

3.1.5 Oil Production and Mining

PFOS derivatives were used as surfactants in the oil and mining industry to enhance oil and gas recovery in wells. The fluorinated surfactants can improve subsurface wetting, increase foam stability, and modify the surface properties of the reservoir formation by lowering the surface tension and foaming properties to well-stimulation additives (Buck, 2012). Fluorinated surfactants are also believed to have been used as evaporation inhibitors for gasoline, jet fuel, and hydrocarbon solvents (UNEP, 2013).

Fluorinated surfactants have also been used to enhance the recovery of metals from ores in copper and gold mines (UNEP, 2013) due to their ability to stabilize aqueous foams and remain stable under strongly acidic and basic conditions (Knepper, 2012). The fluorinated surfactants create stable foams for ore flotation that help separate metal salts from the soil and in the electroextraction of metals such as copper (Knepper, 2012). Tetraethylammonium perfluorooctane sulfonate (NEt_4-PFOS – CAS No. 56773-42-3) and PFOS potassium salt or potassium perfluorooctane sulfonate (K-PFOS– CAS No. 2795-39-3) were used in the mining industry (UNEP, 2013).

After 2002, PFOS is known to have been used only in China in older oil fields to recover oil trapped in small pores between rock particles. 3M has introduced PFBS as an alternative to PFOS, and US patents have identified other PFAS such as perfluoroalkyl-substituted amines, acids, amino acids, and thioether acids that could be used for oil recovery.

3.1.6 Photographic Industry

In the photographic industry, PFOS-related substances such as NEt_4-PFOS and perfluorooctyl sulfonamidopropyl quaternary ammonium iodide have been used in the manufacturing of film, paper, and printing plates. The PFOS-related compounds are used as surfactants, electrostatic charge control, friction control, dirt-repellent, and adhesion control agents. The use of PFOS-related compounds has decreased over time due to a lack of demand for some products in the photographic industry, such as color film from 20 tons in 2000 to 8 tons and 1 ton in 2004 and 2013, respectively. According to a 2006 survey, up to 20 tons of lithium PFOS salt and PFOS were used annually in the photographic industry as anti-reflective agents (UNEP, 2013). PFOS has also been used for medical and industrial X-ray films as well as in the movie industry.

3.1.7 Electronics Industry

Electrical and electronic equipment often requires complex products with hundreds of parts, which could lead to thousands of processes. Some of the processes are related to the semiconductor industry. PFOS-based chemicals are used in the manufacturing of digital cameras, cell phones, printers, scanners, satellite communication systems, and radar systems (UNEP, 2013). The PFOS-related compounds are used as process chemicals, and the final products are considered mostly PFOS-free as there are many washing steps during the manufacturing process. Intermediate transfer belts of color copiers and printers may contain up to 100 mg/L of PFOS (UNEP, 2013).

3.1.8 Semiconductor Industry

PFOS and PFOS-related compounds are required to be used by the semiconductor industry, especially in high-end lithography and formulations for photoresists. The PFOS is used in various processes; however, it is not expected to remain in the final semiconductor devices. Up to 500 steps that are used in the manufacturing processes from the semiconductor industry can be divided into four fundamental physical processes as Implant, Deposition, Etch, and Photolithography. Photolithography is the most important step out of the four processes and represents 150 of the total of 500 steps. Photolithography is also integral to the miniaturization of semiconductors.

PFOS is used in the etching solutions during the photoresists and photomasks, with additional small amounts of PFOS-based compounds being used during and following photolithography applications, which is used to achieve the accuracy and precision required to manufacture miniaturized high-performance semiconductor chips.

The use of PFOS in the semiconductor industry when compared to other uses is small. Before 2000, the estimated annual PFOS use was 470 kilograms, with emissions of 54 kilograms. In the European Union, by 2010, the total annual use for the semiconductor industry was 10 kilograms with emissions of less than 0.5 kilograms. The Japanese semiconductor industry has been using less than 5 kilograms of PFOS annually for the etching of high-frequency compound semiconductors and piezoelectric ceramic filters. Due to the very specialized use of PFOS, the PFBS presence as impurities and emissions into the environment from the semiconductor industry is not estimated to be significant.

3.1.9 Aviation Hydraulic Fluids

Potassium perfluorooctane sulfonate (K-PFOS) content of about 0.1% has been added in hydraulic oils for both military and civilian aircraft since the 1970s to prevent evaporation, fires, and corrosion. PFOS addition to hydraulic fluids inhibits corrosion of mechanical parts of the hydraulic systems such as servo valves. Annual PFOS consumption use globally has been estimated to be about 2 tons with the European Union, using about 730 Kg per year. Waste hydraulic fluids are treated to generate a new product.

Additional PFOS-based compounds have recently been associated with aviation hydraulic fluids such as perfluoroethylcyclohexanesulfonate (PFECHS) and perfluoromethylcyclohexane sulfonate (PFMeCHS), which are cyclic perfluorinated compounds which were sold by 3M as FC-98. 3M ceased the production of PFECHS by 2002 during their phase-out of their POSF-based chemistry. However, Boeing Co. requested in 2002 an exclusion from restrictions of FC-98, and similar PFAS compounds might still be used today in small amounts being manufactured in other countries such as China.

3.1.10 Insecticides and Pesticides

N-Ethyl perfluorooctane sulfonamide (EtFOSA - CAS No. 4151-50-2) is a registered chemical for use by farmers and grain merchants in several developing countries. EtFOSA is often referred to as sulfluramid and is used as both surfactant and the active substance in insecticide products against termites, cockroaches, and other insects. A survey in 2006 determined the use of sulfluramid in insecticides at concentrations of 0.01 to 0.1% at an annual volume of up to 17 tons.

Fluorosurfactants are also expected to have been used as “inert” surfactants in pesticide products to enhance the pesticide formulations. Two PFOS-related substances, K-EtFOSAA (CAS No. 2991-51-7) and perfluoroalkylsulfonyl quaternary ammonium iodide also known as Trimethyl-1-propanaminium iodide, fluorosurfactant FC-134, or FC-135 (CAS No. - 1652-63-7) have been approved in pesticide formulations in the United States in the past (UNEP, 2013). K-EtFOSAA is no longer permitted in the United States to be used in pesticides, and FC-134 was approved for non-food use only. Both PFAS are known to have been used for other uses, for example, as cleaning agents.

The US EPA canceled the registration of sulfluramid in May 2008. PFOS was no longer used to manufacture bait or insecticides for beetles and ants in the European Union by 2009; however, in China 95% of the baits for the control of leaf-cutting ants contained sulfluramid, and it was also used for pest control for cockroaches, white ants, and fire ants. In Brazil, it is estimated that sulfluramid prevents the damage of 14.5 of trees per hectare. Also, other agricultural products such as soybean and maize could benefit from the use of sulfluramid. A total of at least 14.5% of sulfluramid have been found to degrade directly to PFOS in the environment.

3.1.11 Medical Devices

A very small amount of PFOS (150 ng) is used in the color filter of charge-coupled devices (CCD) used in endoscopes. Today alternative PFOS-free CCD filters can be manufactured. However, the approximately 200,000 existing endoscopes that were produced in the past require their PFOS-containing filters to be

replaced. PFOS is also used as an effective dispersant when contrast agents are incorporated into a radio-opaque ethylene tetrafluoroethylene (ETFE) copolymer layer. It is believed that PFBS might have been used to phase out of PFOS in radio-opaque ETFE.

Medical fabrics, such as woven or nonwoven surgical drapes and gowns, have been treated with side-chain fluorinated polymers (such as fluorotelomer-based (meth) acrylate polymers and polyurethanes) to facilitate water, oil, and staining resistance (UNEP, 2013).

3.1.12 Metal plating

PFOS and PFOS-related compounds were used in numerous wet-chemical processes of surface finishing due to their properties of good chemical resistance and as a wetting agent. PFOS has been used in hard and bright chrome electrolytes, in chromic acid plastic etchants, in alkaline zinc and zinc alloy electrolytes, in precious metal plating (e.g., strongly acidic gold-palladium), rhodium baths, nickel plating, and aluminum anodizing. In electroplating, PFOS has been used due to its very high chemical stability to strong oxidizers, chromium (VI), and sulfuric acid/chromo-sulfuric acid. It is also able to decrease the surface tension of treatment baths, facilitate good wetting properties resulting in quality and uniformity of coatings, and reduce the amount of process solution carried over into subsequent tanks through more rapid drainage. The use of PFOS in chrome electroplating is also able to reduce the formation of chromium (VI) aerosols, which make it an important contributor for occupational safety. A list of various wetting agents that contain PFOS used in various plating processes is listed in **Table 9** below, along with the PFOS concentrations.

Table 9. Reported PFOS concentrations in various commercial wetting agents

Wetting Agent	PFOS Concentration (ng/L)
Fumetrol 140 by Atotech	43,000,000,000
Bayowet FT 248 by Lanxess	580,000,000,000
Proquel Z Fa.Kiesow	50,000,000,000
Silken Wet 302	45,000,000,000
Ankor SRK	69,000,000,000
NCR by Blasberg-Werra-Chemie	50,000,000,000

Alternative wetting agents (used to suppress fumes) that do not have PFOS have only been made available recently for some plating operations.

3.1.13 Fire- Fighting Foams

The U.S. Navy Research Laboratory (NRL), in collaboration with 3M, were pioneers in the development of firefighting agents. A patent was filed in 1963 and approved in 1966 for a new method of extinguishing liquid hydrocarbon fires using PFOS and PFOA type fluorosurfactants (Tuve and Jablonski, 1966). The first military-specific (Mil-Spec) AFFF, MIL-F-23905A, was published in 1965. This AFFF was referred to as “Light Water” and was only able to be used with freshwater. However, these original AFFFs were not used extensively due to their limitations to freshwater only. The development of new AFFF using both hydrocarbon fluorosurfactants and fluorosurfactants made it possible to be used with both fresh and seawater. The Department of Defense (DoD) published a new Mil-Spec in 1969 known as MIL-F-24385. AFFF started to be used more extensively after 1970.

AFFFs were manufactured with PFAS produced using both ECF and telomerization processes. The predominant AFFF agents that were sold globally until May 2000 were PFOS-based (Prevedouros, 2006). Based on a survey conducted in 2004, it was found that 75% of the military AFFF inventory was ECF-based products (Darwin, 2004). This was expected since 3M was the main supplier of AFFF to DoD from the 1970’s to 2000. Even though in 2002, 3M voluntarily removed their AFFF products from the manufacture, due to rising concern about PFOS/PFOA-based products, the 3M AFFF was able to be

purchased for all DoD facilities until 2009 (Place and Field, 2012). Due to its long shelf-life, 3M AFFF is still stockpiled at some DoD installations.

One of the main differences between AFFF produced by 3M compared to other manufactures is that the 3M AFFF contained PFSAs (PFOS family) and PFOS as an active ingredient. AFFF manufactured by 3M between 1989 and 2001, for example, had PFOS concentration between 6.7 g/L (6,700,000,000 ng/L) and 15 g/L (15,000,000,000 ng/L) and PFBS concentrations between 0.16 g/L (160,000,000 ng/L) and 0.38 g/L (380,000,000 ng/L) (Backe, 2013).

AFFFs are complex mixtures of various PFAS. To date, a total of 57 PFAS classes and over 240 individual PFAS have been identified in AFFF formulations or groundwater from AFFF impacted sites. Many of the PFAS identified in AFFF are precursors that could undergo partial degradation in the environment to PFAS, such as PFOA and PFOS. The PFAS families and concentrations present in AFFF formulations varied by brand and year.

Firefighting foams with PFOS are very effective for extinguishing liquid fuel fires at airports, oil refineries, and storage facilities. Common types of firefighting foam include:

- Aqueous film-forming foam (AFFF) developed in the 1960s and used for aviation, marine and shallow spill fires.
- Alcohol-resistant aqueous film-forming foam (AR-AFFF) used for polar solvent and hydrocarbon fuel fires.
- Fluoroprotein foam (FP) used for hydrocarbon storage tank protection and marine applications.
- Alcohol-resistant fluoroprotein foam (FPAR) used for polar solvent and hydrocarbon fuel fires.
- Film-forming fluoroprotein foams (FFFP) used for aviation and shallow spill fires.
- Alcohol-resistant film-forming fluoroprotein foam (AR-FFFP) used for polar solvent and hydrocarbon fuel fires.

The concentration of perfluorinated compounds in fire-fighting foams is about 0.1-5% (Bourgeois, 2014). The fluorinated surfactant used in AFFF forms an aqueous film covering the surface of the oil and is used for stopping fires at chemical plants, fuel storage facilities, airports, and underground parking facilities. In response to the USEPA's 2010/2015 voluntary PFOA Stewardship Program, most manufacturers have transitioned to the production of short-chain (C6) fluorotelomer based PFAS. As firefighting foams have a long shelf life (10-20 years or longer), PFOS and PFBS-containing fire-fighting foams may still be used on accidental oil fires.

3.2 PFBS Emissions Before 2002

In 2002, 3M introduced PFBS as a replacement for PFOS. In recent years, manufacturers have removed PFOS and another long-chain PFAS from their products in favor of shorter chained PFAS like PFBS. A list of various products in which PFBS and PFBS-based compounds were used is presented in **Section 3.2.1** through **Section 3.2.8**.

3.2.1 Surfactants for Inks, Paints, and Waxes

PFBS-related substances may be used in surfactants for use as wetting, leveling and flow agents in various applications, including architectural coatings, paints, inks, polymers, adhesives, waxes, polished, caulks, high solids coatings, water reducible coatings, radiation-curable coatings, and resins, as well as other industrial coatings. The substances provide low dynamic surface tension in aqueous formulations and low interfacial surface tension.

Identified substances used for these applications include fluroacrylate copolymer, N-methyl perflurorobutanesulfonamidethanol (MeFBSE), N-methylperfluroobutanesulfonamide (MeFBSA), N-methyl perflurorobutanesulfonamidoethyl acrylate, and 1-propanesulfonic acid salt.

3M Novec fluorosurfactants are examples of specific surfactant products containing these substances. It is a family of advanced wetting and leveling agents, used in a broad range of aqueous and solvent-borne coatings. These surfactants can be used for decorative paints. Only some of the 3m Novec™ products include PFBS. PFBS accounts for 90 percent of the active surfactant in NovecTM FC-4430 and FC-4432, but only 25 percent of NovecTM FC-4434 (NGI, 2017) (**Appendix C**). However, the final mixture (e.g., paints, solvents, etc.) contains 0.05 - 0.03 percent of the active surfactant.

Based on available information, it is estimated that the total content of PFBS in surfactants for paints, adhesives, waxes, etc. is on the order of 1-3 t/year. This relatively small quantity indicates that the use of these surfactants in mixtures is not widespread.

3.2.2 Flame Retardants for Polycarbonate

Potassium perfluorobutane sulfonate (K-PFBS) is used in flame retardants for polycarbonate (mainly in electrical and electronic equipment) and primarily used for Class C (electrical) fires. 3M produces a flame-retardant additive that is composed of 95-99 percent K-PFBS (FR-2025). Korea has demonstrated that this additive can still be an effective flame retardant in concentrations as low as 0.6-0.08 weight percent.

The following commercial flame retardant mixtures are known to contain K-PFBS:

- RM65 from the Italian company Miteni SpA.
- 3M FR-2025 Flame Retardant Additive.
- EFTOP EF-42 Potassium nonafluoro butanesulfonate, from Mitsubishi Materials Electronic Chemicals Company.
- BAYOWET C4 from Lanxess.

The global manufacture of K-PFBS in 2015 was reported at 46 tons, with 32 tons being used by China. It is estimated that currently, the majority of K-PFBS in flame retardants is 2-20 t/year.

3.2.3 Oil, Water, and Stain Repellent Fabric Protectants

Various side-chain fluorinated polymers are used as agents for oil, water, and stain repellent protection of fabrics, carpets, and leather. Many of these agents are based on polymers prepared based on fluorine chemistry without the Sulphur group. 3M is the only supplier of these products based on PFBS chemistry, with the most well-known product being Scotchgard™. Scotchgard™ products were initially based on PFOS-related compounds but were replaced by PFBS related compounds in 2003. PFBS may also be used during the manufacturing of synthetic fibers as polymer melt additives. The primary substances used in Scotchgard ™ are fluorochemical acrylate polymer, fluorochemical urethane, perfluorobutanesulfonamide, and polyoxyalkylene.

The following Scotchgard™ products contain PFBS chemistries.

Consumer products:

- Scotchgard™ Fabric Protector;
- Scotchgard™ Suede and Nubuck Protector; and
- Scotchgard™ Protector for Rugs & Carpet.

Non-consumer products:

- Scotchgard ™ Protective Material PM-97, PM-93, and PM-95.

Industrial products:

- 3M Protective Material for Fabric PM-4950;
- 3M Protective Material PM-1690;
- 3M Protective Chemical PM-490;
- 3M Protective Material PM 4700, PM-4701 and PM-4800;
- 3M Repellent Polymer Melt Additive PM-870.

Based on available information, the amount of PFBS used for fabric protectants in the EEA marker is 20-40 t/year.

3.2.4 Repellent Agents for Porous Hard Surfaces

PFBS-based substances and polymers are used to impart functional oil and water repellency when applied to porous hard surfaces such as concrete, grout, unglazed tile, granite, clay, slate, limestone, marble, and terracotta. The repellent agents can be used either as penetrating sealers or as additives in various coating and sealer formulations. Identified substances for this application include PFBS-related polymers, such as fluoroacrylate modified urethane and fluorochemical acrylate polymer, and MeFBSE.

The following PFBS –containing repellent products for porous hard surfaces have been identified:

- 3M Stain Resistant Additive SRC-220;
- 3M Stain Resistant Additive and Sealer PM-1680;
- 3M Protective Material PM-803, and
- SILRES® BS 38 from Wacker Chemie.

Based on available information, the total tonnage of PFBS containing products used as repellent agents for porous hard surfaces on the EEA market is likely in the range of 5-10 t/year.

3.2.5 Metal Plating

One PFBS-related substance, tetraethylammonium perfluorobutane sulfonate, is registered for industrial use for metal, specifically chromium, plating. Historically, salts of PFOS have been used as wetting agents and mist suppressing agents in decorative plating and non-decorative hard plating. Recent technology developments using chromium-III instead of chromium VI has made PFOS related substances use in chrome plating obsolete. Chromium III, however, cannot be used for hard chrome plating.

The only known mixture containing tetraethylammonium perfluorobutane sulfonate is Bayowet FT 248 liquid, used as a spray mist inhibitor for chromium galvanic industry. Quantities of Tetraethylammonium perfluorobutane sulfonate used in the EEA are estimated at 1-10 t/year.

3.2.6 Surfactants and Solder Paste for Electronics

Some PFBS-related substances are included in surfactants and solder paste used in the electronic industry. The substances used for these applications include 1-Propanesulfonic acid, 3[hexyl[(nonafluoro-butyl)-sukfonyl]amino]-2-hydroxy-, monoammonium salt, ammonium perfluorobutanesulfonamideoethanolate, fluroacrylate copolymer, N-Methyl perfluorobutanesulfonamidoethyl acrylate.

The following surfactants and soldering flux mixtures have been identified:

- 3M Novec™ 4300 Electronic Surfactant;
- 3M Novec™ 4200 Electronic Surfactant;
- ECOFREC 200, and
- LOCTITE LF 318M solder paste.

Based on limited available information, the total consumption of PFBS-containing products for these uses is likely minimal and in the range of 0.1-1 t/year.

3.2.7 Pesticides

NGI, 2017, indicated pesticides as the second most commonly used commercial or industrial area for PFBS use. Twenty-eight percent (28%) of PFBS world consumption consists of pesticide use (NGI 2017). So, 2007 indicated a significant analytical measurement of PFBS in two Chinese rivers downstream of agricultural fields where pesticides contained PFBS was used. The authors measured total perfluorinated compounds in several locations of the Pear and Yangtze Rivers, including highly industrial and rural areas. A range of 22.9-26.1 percent PFBS was measured. This indicates PFBS travels longer distances than its longer chain counterparts, and the use of PFBS-based pesticides are used in rural areas.

3.2.8 Other Minor Applications

Some minor applications of PFBS-related substances have been identified; however, there is not enough information about the consumptions of PFBS-related substances in these applications to justify more detailed descriptions. These minor applications include:

- Curatives in fluoroelastomer formulations;
- Manufacture of synthetic leather;
- Acid catalysts;
- Anti-static additive for plastics, and
- Laboratory agents.

Consumptions of PFBS for these applications is limited compared to the uses described in the above sections.

After 2002, 3M under the brand name Novec® used various C4 perfluorinated compounds such as ethyl nonafluorobutyl ether (CAS No. 163702-07-6) and methyl nonafluoroisobutyl ether (CAS no. 163702-08-7) for commercial and industrial cleaning products.

3.3 Actual PFBS Levels in Products

During the application of mixtures with PFBS-related substances, the substances may be transformed and built into two and three-dimensional polymer structures, where the parent substances are only present in trace amounts. This prospect means that the substances identified by analysis of the final coated articles are not necessarily the same as the substances applied. This issue complicates significantly a quantification of the amounts of the substances traded using final articles and the potential for releases of the compounds.

Table 10, derived from NGI 2017, describes the measured levels of PFBS in various mixtures and articles.

Table 10. Measured levels of PFBS in various mixtures and articles

Consumer Product	PFBS Concentration	Consumer Product	PFBS Concentration
Firefighting foam	253,700 µg/L	Plastics (DVD cover)	0.384 µg/kg
Waterproofing agent	38.65 µg/L	Building materials (wooden board)	0.201 µg/kg
Shoe Leather	1.36 µg/m^2	Insulation material	0.086 – 3.87 µg/kg
Furniture Leather	308 µg/m^2	Water resistant paint	0.536 µg/kg
Non-stick ware	2.84 µg/kg	Car interior material	0.068 – 2.18 µg/kg
Children's snowsuit	0.01 µg/m^2	Baking ware	0.019 – 0.029 µg/m^2
Textile (outdoor wear)	<0.05 – 1.01 µg/m^2	Footwear	0.623 – 19.7 µg/m^2
Textile (tablecloth)	<0.01 – 0.02 µg/m^2	Waterproof clothing	0.192 – 2.10 µg/m^2
Swimsuit	0.05 µg/m^2	Footwear	0.29 – 195 µg/m^2
Food contact material	0.069 µg/m^2	Backpack	3.18 – 9.42 µg/m^2
Textiles (curtains, bed cover, teddy bear coir)	0.159 - 6.14 µg/kg	Outdoor pants	5.04 – 51.4 µg/m^2
Carpet	0.348 – 0.966 µg/kg	Outdoor jackets	0.11 - 673 µg/m^2
Electronics (keyboard, coffee maker, vacuum cleaner)	0.028 – 11.4 µg/kg	Gloves	2.0 µg/kg

4. Physiochemical Properties of PFBS

PFBS can be present as a colorless liquid ($C_4F_9SO_3H$) or a crystalline salt ($C_4F_9SO_3^-X^+$). Liquid PFBS is heavy and colorless, with a very high boiling point and low surface tension. It is readily soluble, dissociates in water, and is a strong acid. PFBS salts are crystalline, non-volatile solids, highly soluble in water with high melting points. The salts are direct precursors of PFBS. The most important salt is potassium perfluorobutane sulfonate (PFBS-K), which is used as a flame retardant. Because of their relatively high water solubility, PFBS salts can be transported over long distances as anions in the environment. **Table 11** (NGI, 2018), depicts varying properties of PFBS-K salt and PFBS.

Table 11. Physical and chemical properties of PFBS-K salt and PFBS

Property	PFBS-K Salt	PFBS
Physical State at 20°C and 101.2 kPa	White powder	Liquid
Melting/Freezing point	>280°C	-21°C
Boiling Point	Decomposes before boiling	198°C
Vapor Pressure	<1.22E-05 Pa at 20°C ±1°C	7 Pa at 20°C (REACH, 2018) 2.8 Pa (Wang, 2011)
Density	2.248 g/cm3 at 20°C	1.824 g/cm3 at 20°C
Water Solubility	5.46 g/mL at 22.5-24°C	Fully miscible at 20°C
Partitioning Coefficient soil/water	<2	2.2
Dissociation constant	-3.94	--
Partition coefficient n-octanol/water (log Kow/pH dependent D_{ow} value)	-1.8 at 23°C	3.9 (neutral form) -4.0 - 0.0 (pH4) -7.0 - -3.0 (pH7) -8.0 - -4.0 (pH8)
Partition coefficient air/water (log Kaw/ pH dependent D_{ow} value)	-2.59 (pH<<0)	--
Partition coefficient air/water (Log Kaw/pH dependent D_{aw} value)	6.49	--

4.1 Adsorption/Desorption

For organic ions like PFBS, conceptualizing sorption/desorption to the soil is more complex than neutral organic molecules. For ionic substances like PFBS, non-ionic sorption interactions, and ionic interactions between the substance and soil must be considered. Soils generally exhibit a wide variation in their anion exchange capacity, and therefore their tendency to retain molecules like PFBS.

Generally, PFBS adsorption to the soil is low; therefore, it is considered highly mobile in the aquatic environment and can be readily transported in water. The concentration of PFBS in water per liter (L) is expected to be very closely equal to soil or sediment for kg (NGI, 2018).

4.2 Volatilization

PFBS-K salts do not volatilize, but neutral PFBS does volatilize in relatively low amounts (ca 2.8-7 Pa). PFBS fumes would be present in a room containing neutral PFBS and poor ventilation. PFBS does not readily volatilize from water, because at neutral pH, essential all PFBS is ionic and would be exclusively in the water.

Because PFBS volatilization from water is negligible, its presence in the air would be largely due to emissions of the PFBS or its salts into the air. When PFBS is in the atmosphere, it is expected to readily partition with surface water and water droplets and undergo removal from the atmosphere via wet-deposition.

4.3 Environmental Fate of PFBS

PFAS has two structural parts, a hydrophobic fluorinated tail, and a hydrophilic non-fluorinated head. These two competing parts of PFAS play an essential role in their environmental fate and transport. The hydrophobic tail has an affinity to sorb to organic carbon within the soil. This process retards the transport of PFAS through soils and groundwater. Typically, sorption increases with increasing carbon tail (chain) length. This is not only seen within the environment but also in biological attenuation. 3M's main reason for replacing PFOS and PFOS-based chemistry with PFBS-based chemistry is due to this overarching trend. In a 2013 OECD report, the half-life of PFBS within a human is 26 days, whereas PFOS has a half-life of 1,500 days.

The reduced attenuation of PFBS due to its shorter carbon chain length may be a reason for finding PFBS concentrations in environmental samples with no known sources. PFBS can be transported via ground or surface water longer distances than its longer carbon chain counterparts. Longer chain PFAS can degrade within the environment into shorter chain PFAS (TRC 2017). This can contribute to an increase of shorter chain PFAS, such as PFBS downstream of a source.

4.4 Monitoring Data

Numerous studies are reporting PFBS concentrations in the environment; a compilation of this data is presented in NGI 2018. The PFBS concentrations were present for air, rain, surface water, marine water, drinking water, groundwater, soil, sediment, wastewater treatment plants, landfills, marine biota, freshwater biota, terrestrial biota, terrestrial plants, and humans. An in-depth analysis of the results of the NGI 2018 study is outside the scope of this report; however, graphs depicting the results of this study are included in **Appendix D**.

5. PFBS Detection in Michigan

A total of 2,286 individual entry point samples were collected from 1,741 individual CWS, schools, daycares, and tribal entities during the 2018 Statewide PFAS Sampling Program (**Figure 8**). PFBS had the highest detection frequency of 5.4% out of the 14 sampled PFAS, with a total of 36 locations where PFBS was the only PFAS detected. A list of 11 industrial users and facilities have been identified by EGLE as potential users or sources of PFAS in the environment (**Figure 9**) and were used together with the regional geology to develop a sampling schedule based on prioritization (**Figure 10**). The prioritization was not based on information on actual use and potential releases of PFAS but based on the probability that PFAS might have been at these locations. Before sampling, there was no information available to indicate that a particular drinking water supply could be impacted by PFAS. **Figure 11** presents the locations where PFAS has been detected during the 2018 Statewide PFAS Sampling Program. The majority of PFAS detections were located in counties and areas with a higher degree of industrialization that could have been potential PFAS sources. Based on these sampling results it was observed that fire stations and historic landfills were not correlated very well with PFAS detections as some of the counties (e.g., Huron, Tuscola, Sanilac, Lapeer, St. Clair, Oscoda, Cheboygan) did not have any PFAS detections even though they all had fire stations and historic landfills throughout the counties. However, this does not mean that PFAS is not present in the environment in these counties. **Figure 12** presents the locations where other PFAS with no PFBS were detected and a heat map for the locations where PFBS was detected. There was no trend observed between the locations where only PFBS or other PFAS were detected, indicating that no particular potential PFAS source can be attributed to the PFBS detections. The counties and areas where PFAS were detected with or without PFBS were similar to those where PFBS only was detected. The total PFBS percentage as a heat map is presented in **Figure 13**, from which we can see that a good number of PFAS detections were 100% PFBS.

The objective of the evaluation was to attempt to identify the potential sources of PFBS. The potential of common sources of PFBS in 14 drinking water supplies from 12 Michigan Counties with a Total PFAS of at least ten (10) ng/L and PFBS percentage above 50% were further evaluated (**Figure 14**) and presented in **Sections 5.1** through **5.12**. A figure with the land use, city or village boundary, 11 potential PFAS sources, and well logs for the drinking water supplies sampled in close proximity to the supplies that were selected for further evaluation are presented in **Appendix E**. There could be other PFAS sources that have not been identified and further evaluation, and environmental investigations might be necessary to determine the PFAS sources that have been impacting these drinking water supplies. However, as a screening tool, the current evaluation will evaluate the 11 potential PFAS source categories identified by EGLE.

5.1 Allegan County

City of Otsego

Wellogic boring logs describe the lithology as a thick sequence of sand and gravel to a depth of approximately 110ft below ground surface. A clay is observed below the sand. The Otsego City wells are set in gravel and sand zones at depths ranging from 80ft to 120ft below ground surface (bgs). Local water wells are screened within the sand and gravel at shallower depths ranging from 35ft to 60ft below ground surface. The regional geology is described as glacial outwash sand and gravel and postglacial alluvium. Groundwater flow is to the north towards the Kalamazoo River. The highly conductive sand and gravel will produce narrow contaminant plumes if present and PFAS detections within the deeper city well screens suggest a spatially moderately distant potential source area.

The City of Otsego Well 3 water sample detected 7ppt PFBS out of 11ppt PFAS total (64% PFBS), and the nearby City of Otsego Wells 4 and 5 were non-detect for all PFAS (**Appendix E - Allegan County**). In comparison, the City of Plainwell Well 5, to the southeast of Otsego, detected 19ppt PFBS out of 54ppt PFAS total (35% PFBS), an increase in PFBS concentration, but a decrease in the percent of PFBS. The City of Otsego has three relatively deep wells that are drilled to 80-120ft bgs, consistent with the geologic

findings above. From the EGLE Wellogic Water Well and Pump Records, the only listed screen depth is Well 2 from 95-120ft bgs. The City of Plainwell Well 5 is screened from 72-102ft bgs, a similar depth to the Otsego wells. The City of Plainwell Well 5 is approximately 8,500 feet southeast (side gradient) of the City of Otsego Well 3. Groundwater flow is expected to move north based on water elevations and topography. The EGLE Wellogic Water Well and Pump Records for the City of Plainwell Well 5 notes possible thin clay layers 25-28ft bgs and 57-62ft bgs; however, they are not likely to be continuous or act as confining layers to contamination. Due to the deep screen depths of all the City of Otsego wells and City of Plainwell Well 5, the PFBS source is likely distant; however, no obvious sources are located hydraulically upgradient of the well fields. The Orangeville Township Fire Department, located approximately 4,200 east of the City of Plainwell Well 5 may be a potential source of PFBS; however, it is hydraulically side gradient of Well 5 and is not likely the source of PFBS detected in the well. There may be other unidentified potential industrial waste sources of PFBS in the vicinity of the City of Otsego and City of Plainwell. The wells located at both locations are situated within city boundaries, and other PFAS sources could exist from possible industrialized areas.

5.2 Calhoun County

Athens Day Care / Kids Time Day Care Center

Wellogic boring logs describe the lithology as interbedded clay, sand, and gravel with well screens set in the sand and gravel zones at depths between 35ft and 45ft below ground surface. The clay layers likely produce localized semi-confining conditions. The regional geology is coarse textured glacial till. Groundwater flow is to the west towards Pine Creek. The highly conductive gravel and sand will produce narrow contaminant plumes if present and PFAS detections within the relatively shallow well screen depth below potential confining layers suggest a moderately close potential source area. However, the extent of the confining layer both at the source and well screen locations will affect the PFAS distribution.

The Athens Day Care Center (previously known as Kids Time Day Care Center) well detected 13ppt PFBS out of 18ppt PFAS total (72% PFBS) (**Appendix E – Calhoun County**). In comparison, the combined water sample from two wells at the nearby Birchwood Estates, located approximately 1,800 feet north, were non-detect for all PFAS. The Athens Day Care well screen is set at 35-40ft bgs, which is consistent with the geologic findings above. The wells are both set roughly at the same depths at approximately 35-43ft bgs, still consistent with the geologic findings above. Groundwater flow is expected to move west towards Pine Creek based on water elevations and topography. Based on this observation, the Birchwood Estates wells are hydraulically side gradient to the Athens Day Care Center well. On the EGLE Wellogic Water Well and Pump Record for the Athens Day Care Center, the formation description of the lithology notes clay lithology from approximately 0-33ft bgs, which may be acting as a confining layer for contaminates to travel through the gravel and sand below. The shallow well screens within the confined, highly conductive, sandy gravel may provide a narrow contaminant plume for PFBS, which could explain the detection of PFBS at Athens Day Care but not at Birchwood Estates. The source of PFBS is unlikely to be from industrialization due to the surrounding rural area. No obvious sources are located hydraulically upgradient of the Athens Day Care Center well.

Calhoun Interim School

Wellogic boring logs describe the lithology as interbedded clay, sand, and gravel underlain by Marshall Sandstone at depths ranging from 55ft and 93ft below ground surface. The clay layers likely produce localized confining conditions. The regional geology includes end moraines of coarse textured glacial till and glacial outwash sand and gravel and postglacial alluvium. Water wells in the area are set within the bedrock Marshall Sandstone. Groundwater flow is to the southwest towards the Kalamazoo River. The relatively low conductive Marshall Sandstone would produce moderately wide contaminant plumes, if present, and PFAS detections within the deep well screen depth below the clay confining layers suggest a distant potential source area. However, the extent of the confining layer both at the source and well screen locations will affect the PFAS distribution.

The Calhoun Interim School District Well detected 9ppt PFBS out of 17ppt PFAS total (53% PFBS). This well is relatively isolated from other surrounding drinking water wells; however, the four combined City of

Marshall drinking water wells two miles south of the school were sampled and were non-detect for all PFAS. The Calhoun Interim School District well screen is set deep into the Marshall Sandstone bedrock. The EGLE Wellogic Water Well and Pump Record does not provide a screen depth, but the well is drilled to 200ft bgs, which would be set within the Marshall Sandstone that ranges from 93-200ft bgs, which is consistent with the geologic findings above (**Appendix E – Calhoun County**). The EGLE Wellogic Water Well and Pump Records for all four City of Marshall wells also do not provide screen depths, but rather note they are all bedrock wells drilled to approximately 100ft bgs. The Wellogic records for both the Calhoun School District Well and City of Marshall wells show significant sand and gravel and interbedded clay layers until the Marshall Sandstone bedrock within the 50-100ft bgs range. The relatively low conductive Marshall Sandstone would produce moderately wide contaminate plumes from a distant potential source area. Groundwater flow is expected to move southwest towards the Kalamazoo River, which would provide little evidence for any industrial source of PFBS for the Calhoun Interim School District well. No obvious sources are located hydraulically upgradient of the Calhoun Interim School District well. No agricultural fields where land applied biosolids were identified hydraulically upgradient of the Calhoun Interim School. However, the site is located close to the City of Marshall, and potential PFAS contamination from industry is possible.

5.3 Charlevoix County

Walloon Lake Water System

Wellogic boring logs describe the lithology as varying amounts of clay, sand, and gravel to a depth of approximately 160 feet below ground surface with limestone underlying the unconsolidated deposits. Well screens are set within the shallow sand and gravel deposits, if present (depths of approximately 31-65ft below ground surface), or within the limestone bedrock at depths below 165ft below ground surface. The regional geology is coarse-textured glacial till; however, glacial outwash sand and gravel with post-glacial alluvium are present along the Bear River. Regional groundwater flow is expected to be generally to the north towards Lake Michigan; however, the wellhead protection area shown on the Wellogic website depicts a southerly groundwater flow towards the Walloon Lake Water System pumping wells. The highly conductive, shallow gravel and sand will produce narrow contaminant plumes if present, and the relatively shallow well screen depth with no significant confining layer suggests a relatively spatially close potential source area. PFBS concentrations detected in the bedrock wells suggest a more distant source.

The Walloon Lake Water System (WLWS) Well TP102 detected 14ppt PFBS out of 19ppt PFAS total (74% PFBS). In comparison, the nearby Walloon Lake Water System (WLWS) Well TP101 detected 0ppt PFBS out of 2ppt PFAS total, approximately 1,000 feet north (**Appendix E – Charlevoix County**). The WLWS TP102 well screen is shallow and set at 31-59ft bgs, which is consistent with the geologic findings above. The WLWS TP101 well screen is set deep in the limestone bedrock below 168ft bgs, still consistent with the geologic findings above. Local groundwater flow is to the south towards the Walloon Lake Water System pumping wells. On the EGLE Wellogic Water Well and Pump Records for both the WLWS wells, the formation description of the lithology notes significant sand and gravel and interbedded clay layers until the limestone bedrock at 168ft bgs. The difference in screen depth between WLWS TP102 and WLWS TP101 likely explains the sharp contrast of the PFBS detections in WLWS TP102 and not in WLWS TP101. The source of PFBS is likely shallow and from a close potential source area, consistent with the geologic findings above. The nearest potential source of PFBS in the Melrose Township Fire Department that is located approximately 1,500 feet directly east of the WLWS TP102. However, there is not enough evidence at this time to indicate that the Melrose Township Fire Department is the actual PFAS source.

5.4 Ionia County

Eight Cap Ionia County Outreach School

Wellogic boring logs describe the lithology as interbedded clay and sand with well screens set in the sand zones at depths between 33ft and 67ft below ground surface. The clay layers likely produce localized

semi-confining conditions. The regional geology is end moraines with medium textured till. The regional groundwater flow is generally expected to be to the west towards the Flat River; however, the wellhead protection area shown on the Wellogic website indicates a local groundwater flow to the north. The conductive sand will produce relatively narrow contaminant plumes if present and PFAS detections within the relatively shallow well screen depth below potential confining layers suggest a moderately close potential source area. However, the extent of the confining layer both at the source and well screen locations will affect the PFAS distribution.

The Eight Cap Ionia County Outreach School well detected 200ppt PFBS out of 203ppt PFAS total (99% PFBS). In comparison, two wells at Long Lake Mobile Home Park approximately 2.5 miles north of the school both detected 4ppt PFBS out of 15ppt PFAS total (27% PFBS). The Eight Cap Ionia County Outreach School well screen is not listed on the EGLE Wellogic Water Well and Pump Record (Appendix D); however, the well depth drilled is listed at 80ft bgs. The wells at Long Lake Mobile Home Park are screened at 33-43ft bgs (Well 1) and 52-57ft bgs (Well 2), consistent with the geologic findings above. The local groundwater flow is to the north based on the wellhead protection area. On the EGLE Wellogic Water Well and Pump Records for the Long Lake Mobile Home Park wells, the formation description of the lithology notes the well screen for Well 1 within a significant coarse sand interval confined by clay layers (20-30ft bgs and 43-82ft bgs), and the screen for Well 2 within a significant sand interval below a clay layer (10-30ft bgs) (**Appendix E – Ionia County**). The shallow screen depths of the Long Lake Mobile Home Park wells with low PFBS detections are likely sourced from a distant PFBS contamination source. The Eight Cap Ionia County Outreach School PFBS impact is potentially a nearby source of contamination, consistent with the geologic findings above. The nearest potential source of contamination is the Orleans Township fire department, located approximately 2,000 feet directly south (hydraulically upgradient) of the school. There is likely minimal influence from industrial contamination due to the rural location. However, there is not enough evidence at this time to indicate that the Orleans Township fire department is the actual PFAS source, or if AFFF was ever used by the fire department.

5.5 Kent County

Spring Valley Mobile Home Park

Wellogic boring logs describe the lithology as interbedded clay, sand, and gravel with well screens set in the sand and gravel zones at depths between 46ft and 66ft below ground surface. The clay layers likely produce localized semi-confining conditions. The regional geology is glacial outwash sand and gravel with post-glacial alluvium. Groundwater flow is generally to the south/southwest towards the Grand River. The highly conductive gravel and sand will produce narrow contaminant plumes if present and PFAS detections within the relatively shallow well screen depth below potential confining layers suggest a moderately close potential source area. However, the extent of the confining layer both at the source and well screen locations will affect the PFAS distribution.

The Spring Valley Mobile Home Park water samples detected 9ppt PFBS out of 43ppt PFAS total (Well 3) (21% PFBS) and 7ppt PFBS out of 12ppt PFAS (Well 2) (58% PFBS) (**Appendix E – Kent County**). In comparison, 2 wells (Well 3 and 4) at the Woodland Estates approximately 2,500 feet north of the Spring Valley MHP combined as one sample detected 4ppt PFBS out of 6ppt PFAS total (67% PFBS). The Spring Valley MHP well screens are listed on the EGLE Wellogic Water Well and Pump Records (Appendix E1) as 51-57ft bgs (Well 3) and 58-66ft bgs (Well 4), both consistent with the geologic findings above. Both well screens of Wells 3 and 4 at the Woodland Estates are listed on the EGLE Wellogic Water Well and Pump Records. Well 3 at Woodland Estates is screened relatively shallow at 65-75 ft bgs, and Well 4 at Woodland Estates is deeper at 98-118ft bgs. Both sites' lithology consists of interbedded clay, sand, and gravel with groundwater flow generally expected to move south/southwest towards the Grand River. PFBS impact detected in the relatively shallow well screens suggests a potential moderately close source of contamination. No obvious sources are located hydraulically upgradient of the Spring Valley Mobile Home Park or Woodland Estate wells. The well is located close to the City of Rockford, which has a fire station and also used to have a tannery where Scotchgard™ was used. There is not enough evidence at this time to indicate that the fire department might have responded to a fire in the area where AFFF could have been used, or if AFFF was ever used by the fire

department. The tannery has disposed of sludge and other waste from its production in various places between the areas. Other potential sources of PFBS contamination may include disposal of industrial waste at unidentified locations in the area from the tannery or possible other industrial users.

Whispering Pines Estates

Wellogic boring logs describe the lithology as generally sand and gravel with well screens set at depths between 26 and 38ft below ground surface. The regional geology is glacial outwash sand and gravel with post-glacial alluvium. Groundwater flow is generally to the east/northeast towards the Rouge River. The highly conductive gravel and sand will produce narrow contaminant plumes if present, and the relatively shallow well screen depth with no significant confining layer suggests a relatively spatially close potential source area.

The Whispering Pines Estates combined water sample from Wells 1, and 2 detected 49ppt PFBS out of 64ppt PFAS total (77% PFBS) (**Appendix E – Kent County**). In comparison, three wells at Parkwood Green Mobile Home Park approximately 2,000 feet east of Whispering Pines detected 0-2ppt PFBS out of 0-5ppt PFAS total. The Whispering Pines well screens are listed on the EGLE Wellogic Water Well and Pump Records as 33-38ft bgs (Well 1) and 32-37ft bgs (Well 2), both consistent with the geologic findings above. The EGLE Wellogic Water Well and Pump Records do not provide any information regarding screen depth or lithology details for Wells 1 and 2 at Parkwood Green; however, the well depth and lithology is described for Well 3 at Parkwood Green (Appendix E2). Well 3 is screened at 26-32ft bgs, with sand and gravel throughout except for a 1 ft clay layer at 14-15ft bgs. The shallow screen depths of both the Whispering Pines wells and Well 3 at Parkwood Green show contradicting PFBS detections, providing little correlation between depth of the screen and PFBS contamination at this site. The two shallow screened wells at Whispering Pines may potentially be influenced by a close source of contamination, consistent with the geologic findings above. No obvious sources are located hydraulically upgradient of the Whispering Pines Estates or the Parkwood Green Mobile Home Park wells. The well is located close to the Village of Sparta, and other industrial users might have existed in the past that could have disposed of industrial wastes in the area.

5.6 Mason County

Heritage Hills Mobile Home Park

Wellogic boring logs describe the lithology as generally clay with sand and gravel to a maximum depth of 90ft below ground surface. Medium to coarse sand and gravel is reported below the clay. The thick clay sequence likely produces confining conditions with the well screens set below the clay at depths ranging from 93 to 104ft below ground surface. The regional geology is described as end moraines of fine-textured till. Regional groundwater flow is expected to be to the west towards Lake Michigan; however, the wellhead protection area for the Heritage Hills Mobile Home Park Wells 1 and 2 indicates local groundwater flow to the east. The conductive sand and gravel below the clay will produce fairly narrow contaminant plumes if present, and the deep well screen depth below the confining layer suggests a spatially distant potential source area.

The combined water sample from Heritage Hills Mobile Home Park Wells 1 and 2, detected 9ppt PFBS out of 13ppt PFAS total (69% PFBS) (**Appendix E – Mason County**). Unfortunately, these two wells are relatively isolated from other surrounding drinking water wells for comparisons. From the EGLE Wellogic Water Well and Pump Records, Well 1 is screened from 93-103ft bgs, and Well 2 is screened from 94-103ft bgs. Additionally, from these records, it is noted that the lithology in this area contains significant shallow clay roughly 0-50ft bgs, which would act as a significant confining layer over the coarser grained sediment beneath the clay. No obvious sources are located hydraulically upgradient of the Heritage Hills Mobile Home Park wells.

5.7 Newaygo County

Village of Hesperia

Wellogic boring logs describe the lithology as generally sand and gravel with occasional clay layers up to 25 feet thick. These clay layers may produce localized semi-confining conditions. The well screens are set at depths ranging from 110 to 160ft below ground surface. The regional geology is glacial outwash sand and gravel with post-glacial alluvium. Groundwater flow is expected to be to the north towards the Muskegon River. The conductive gravel and sand will likely produce narrow contaminant plumes if present and the deep well screen depth below the potential confining layer suggests a spatially distant potential source area.

The Village of Hesperia combined water samples from Wells 1, and 2 detected 15ppt PFBS out of 15ppt PFAS total (100% PFBS) (**Appendix E – Newaygo County**). In comparison, Well 3 for the Village of Hesperia, approximately 2,200 feet south of the combined Wells 1 and 2, detected 2ppt PFBS out of 29ppt PFAS (7% PFBS). Additionally, a water sample from three combined wells at Evergreen Mobile Home Park, approximately 4,000 feet northeast of the Village of Hesperia, was non-detect for all PFAS. From the EGLE Wellogic Water Well and Pump Records, the Village of Hesperia Wells 1 and 2 are both screened from 110-135ft bgs, consistent with the geologic findings above predicting deep well screens. Wells 1, 2, and 3 at Evergreen MHP are all screened at roughly 145-160ft bgs. Wellogic records for Well 3 of the Village of Hesperia do not provide the screen depth; however, it does list the well was drilled to 125ft bgs. All comparison wells are similar to the depths of Wells 1 and 2 of the Village of Hesperia. Wellogic records show clay layers within the 25-35ft bgs and 50-75ft bgs, likely resulting in a confining environment. All of the well screens are set below this potentially confining clay within a conductive sand formation, which would likely expose all of the wells to the same potential PFBS source. Groundwater flow is generally expected to flow north towards the Muskegon River. As PFAS contaminated plumes move through the subsurface, PFBS is typically one of the compounds that mobilize the furthest, which could explain the increase of PFBS detected from the Village of Hesperia Well 3 to the more northern Village of Hesperia Wells 1 and 2. The Evergreen Mobile Home Park wells are located east of the Village of Hesperia wells, which may locate them outside of the PFBS plume of contamination. No obvious sources are located hydraulically upgradient of the Heritage Hills Mobile Home Park wells; however, both wells which had detectable PFAS were located within the Village of Hesperia. There might be other industrial users within the Village of Hesperia that could have disposed of industrial wastes in the area. There is also a fire department in the area, but there is not enough evidence at this time to indicate that the fire department is the actual PFAS source or if AFFF was ever used by the fire department.

5.8 Oakland County

Heritage Apartments

Wellogic boring logs describe the lithology as interbedded clay, sand, and gravel with well screens set in the sand and gravel zones at depths between 46ft and 80ft below ground surface or in deeper sand and gravel zones at a depth of approximately 200ft below ground surface. The clay layers likely produce localized semi-confining conditions. The regional geology is described as glacial outwash sand and gravel with postglacial alluvium. Groundwater flow is to the northwest; however, local surface water bodies could locally influence the groundwater flow direction. The highly conductive gravel and sand will produce narrow contaminant plumes if present and PFAS detections within the well screen depths below potential confining layers suggest a distant potential source area. However, the extent of the confining layer both at the source and well screen locations will affect the PFAS distribution.

The Heritage Apartments water sample detected 21ppt PFBS out of 36ppt PFAS total (58% PFBS) (**Appendix E – Oakland County**). In comparison, the nearby Lakeside Apartments were non-detect for all PFAS. The Heritage Apartments have two wells that combine for a blended water sample. From the EGLE Wellogic Water Well and Pump Records, only the Heritage Apartments Well 2 well screen is noted at 46-51ft bgs, which is consistent with the geologic findings above. There are two wells at Lakeside Apartments that also combine for a blended water sample. The well screens are set slightly below the Heritage Well 2 screen, at 56-60ft bgs and 52-62ft bgs, still consistent with the geologic findings above.

The Heritage and Lakeside wells are approximately 300 feet apart, so they are likely within the same exposure pathway for contaminants originating from the southeast. It was noted above that groundwater flow may be influenced by local surface water bodies; therefore, the neighboring Wolverine Lake may influence the groundwater flow. The EGLE Wellogic Water Well and Pump Records for both of the wells at Heritage Apartments and Lakeside Apartments note possible clay layers within 27-40ft bgs. All of the well screens are set below this potential clay, which would likely expose all of the wells to the same potential PFBS source. A potential source of PFBS contamination is the Commerce Township Fire Department Station #3 that is approximately 4,000 feet southeast and hydraulically upgradient of both apartment complexes. However, there is not enough evidence at this time to indicate that the fire department is the actual PFAS source, or if AFFF was ever used by the fire department. The well is also located close to the boundaries of couple Cities and Village of Wolverine Lake. The City of Wixom Wastewater Treatment Plant was identified as a PFAS source in the areas; however, it is situated downgradient. The agricultural fields where biosolids were land applied from the City of Wixom WWTP are not situated in close proximity and upgradient of the Heritage Apartments wells. There might be other industrial users from the various Cities and Villages of Wolverine Lake that could have disposed of industrial wastes in the area.

5.9 Osceola County

City of Evart

Wellogic boring logs describe the lithology as generally sand and gravel with occasional clay layers up to 7 feet thick. These clay layers may produce localized semi-confining conditions. The well screens are set at depths ranging from 24 to 60ft below the ground surface. The regional geology is glacial outwash sand and gravel with post-glacial alluvium. Groundwater flow is expected to be to the south/southeast towards the Muskegon River; however, localized, shallow groundwater flow may be towards Twin Creek. The highly conductive gravel and sand would produce narrow contaminant plumes, if present, and the relatively shallow well screen depth if no significant confining layer is present, suggests a relatively spatially close potential source area. If a confining layer is present, the potential source area could be more spatially distant.

The City of Evart Well 4 detected 20ppt PFBS out of 20ppt PFAS total (100% PFBS) (**Appendix E – Osceola County**). In comparison, four other wells for the City of Evart detected 4ppt PFBS or less out of 4ppt or less PFAS total: Well 1: 4ppt PFBS out of 4ppt PFAS (100% PFBS), Well 6: 0ppt PFBS out of 2ppt PFAS, and Wells 2 & 3: both were non-detect for all PFAS. The City of Evart Well 4 well screen is set at 40-60ft bgs, which is consistent with the geologic findings above. The comparable other four city wells do not have screen depths listed on their EGLE Wellogic Water Well and Pump Records; however, the wells were drilled to similar depths within 45-60ft bgs. The well locations are within a 700-foot radius and are at similar elevations of approximately 1,000 feet above sea level, so they are likely within the same exposure pathway of contaminates coming out of the north/northwest. Within the city wells, there is a trend of increasing PFBS from the northwest to southeast, which is similar to the path of groundwater movement, suggesting a source to the north/northwest. The shallow well screens within highly conductive sand and gravel may provide a narrow path for the contaminant plume of PFBS. As PFAS contaminated plumes move through the subsurface, PFBS is typically one of the compounds that move the furthest, which could explain the increase of PFBS detected within the city wells that are further to the southeast or downgradient (Well 4). No obvious sources are located hydraulically upgradient of the City of Evart wells; however, potential sources of PFBS contamination include unidentified industrial sources within the City of Evart. There is also a fire department present in the City of Evart that does not appear to be upgradient, and there is not enough evidence at this time to indicate that the fire department is the actual PFAS source by responding to possible fires in areas located upgradient of Well 4, or if AFFF was ever used by the fire department.

5.10 Ottawa County

Crockery Mobile Home Park

Wellogic boring logs describe the lithology as sand to a depth of approximately 45ft below ground surface. A blue clay is observed below the sand. Wells to the east and southeast of the Crockery Mobile Home Park encounter the blue clay at a much shallower depth (approximately 16ft below ground surface) with a significant thickness of clay of greater than 100ft in some areas. The thick clay sequence likely produces confining conditions. Where the clay is deeper (e.g., the Crockery Mobile Home Park), well screens are set within the shallow sand at depth intervals between 25ft and 45ft below ground surface. At locations where the clay is deeper, well screens are set in gravel and sand below the clay. The regional geology is described as lacustrine sand and gravel with dune sand. Groundwater flow is to the southeast towards the Grand River; however, shallow groundwater flow could be locally influenced by creeks in the area. The moderately conductive shallow sand will produce fairly narrow contaminant plumes if present and PFAS detections within the shallow well screens suggest a spatially local potential source area.

The combined water sample from Crockery Mobile Home Park Wells 2, 3, and 4, detected 13ppt PFBS out of 13ppt PFAS total (100% PFBS) (**Appendix E – Ottawa County**). In comparison, Well 1 at Crockery MHP approximately 700 feet south detected 3ppt PFBS out of 3ppt PFAS total (100% PFBS). On average, all wells at Crockery MHP are located at similar elevations around 630ft above sea level. From the EGLE Wellogic Water Well and Pump Records, Wells 2, 3, and 4 at Crockery MHP have screen depths that average around 33-42ft bgs. In comparison, Well 1 from Crockery MHP is drilled to only 30ft bgs, without noting the screen depth on the Wellogic records. It is inferred that the screen depth is less than 30ftbgs, which is shallower than the other Crockery MHP wells. From the Crockery Well 3 Wellogic records, a clay layer is noted from 41-43ft bgs, which may act as a confining layer. The difference in screen depths, along with the possible clay confining layer, may explain the contrasting PFBS values. The deeper well screens of Wells 2, 3, and 4 within highly conductive sand and gravel possibly under a confining clay layer may provide a narrow contaminant plume for PFBS, resulting in higher detection values. No obvious local sources are located hydraulically upgradient of the Crockery MHP wells; however, potential sources of PFBS contamination include septic systems in the area. Also, potential distant sources of PFBS are historic landfills approximately 11,000 feet northwest and southwest of Crockery MHP wells. The large distance to the landfills could explain the detection of only PFBS in the samples. There is also a WWTP located downgradient of Crockery Mobile Home Park wells and at this time has not been identified to be a source of PFAS, nor were there any agricultural fields where biosolids were applied.

5.11 Roscommon County

Roscommon C.O.O.R. School

Wellogic boring logs describe the lithology as generally sand and gravel with occasional, thin clay layers. The well screens are set within sand and gravel at depths between 103 and 234 ft below ground surface. The regional geology is ice contact and glacial outwash sand and gravel with post-glacial alluvium. Groundwater flow is expected to be to the northeast based on surface water elevations. The highly conductive gravel and sand will produce narrow contaminant plumes if present, and the relatively deep well screen depths with no significant confining layer suggests a relatively spatially distant potential source area(s).

The combined water sample from Wells 1, 2, and 3 at the Roscommon C.O.O.R School detected 17ppt PFBS out of 17ppt PFAS total (100% PFBS) (**Appendix E – Roscommon County**). In comparison, all wells at the Roscommon Elementary, Middle, and High school, approximately two miles to the east, were non-detect for all PFAS. From the EGLE Wellogic Water Well and Pump Records, the Roscommon C.O.O.R. School has three deep wells that are screened from the 225-280ft bgs range, consistent with the geologic findings above. The Roscommon Elementary, Middle, and High School well screens are listed within the 100-190ft bgs range; however, they are also approximately 100ft lower in elevation compared to the Roscommon C.O.O.R. School which likely puts all the wells within a similar layer of highly conductive coarse sand and gravel. Due to the deep well screen depths of all the Roscommon

C.O.O.R., Elementary, Middle, and High School wells, the PFBS source is likely distant. Groundwater flow is expected to move northeast based on water elevations and topography, which likely puts the Roscommon C.O.O.R. School in a different pathway for PFBS than the Roscommon Elementary, Middle, and High Schools. This would help explain the detection of PFBS in the Roscommon C.O.O.R. School and the lack of any PFBS detection in the Roscommon Elementary, Middle, and High Schools wells. No obvious local sources are located hydraulically upgradient of the Roscommon C.O.O.R. School wells.

5.12 Washtenaw County

Emerson Elementary School

Wellogic boring logs describe the lithology as interbedded clay, sand, and gravel with well screens set in the sand and gravel zones at depths between 144 ft and 171 ft below ground surface. The clay layers likely produce localized semi-confining conditions. The regional geology is medium-textured glacial till. Groundwater flow is expected to be to the northwest based on surface water elevations and topography. The highly conductive gravel and sand will produce narrow contaminant plumes if present and PFAS detections within the deep well screen depth below potential confining layers suggest a distant potential source area.

The Emerson Elementary School well detected 15ppt PFBS out of 15ppt PFAS total (100% PFBS) (**Appendix E – Washtenaw County**). In comparison, the neighboring Emerson Middle School were non-detect for all PFAS. The Elementary school well is set at 151-171ft bgs, which is consistent with the geologic findings above. The Middle School well is set slightly above the Elementary well, at 141-152ft bgs, still consistent with the geologic findings above. The wells are approximately 400 feet apart, so they are likely within the same exposure pathway of contaminants originating from the southeast. On the EGLE Wellogic Water Well and Pump Record for the Emerson Elementary School, the formation description of the lithology notes a gray clay layer detected from 141-148ft bgs. This clay layer may be a confining layer between the two well screens, possibly explaining the sharp contrast of the Emerson Elementary well detecting 15ppt PFBS, and the adjacent Middle School well detecting no PFBS. No obvious local sources are located hydraulically upgradient of the Emerson Elementary well. However, the school is located in close proximity to the City of Ann Arbor. There could be other industrial locations with the City of Ann Arbor boundaries or upgradient areas where industrial wastes might have been disposed of in the past.

6. Conclusion

PFBS could have been present as an impurity in many commercial products since the late 1950s through 2002. Since 2002 there has been an increase in the manufacturing of PFBS-based products as a substitute for more toxic long-chain PFAS, such as PFOS.

The current evaluation of the potential PFBS sources in the drinking water supplies from the 14 locations evaluated across 12 Michigan Counties, was done by comparing these results to 11 potential PFAS source types. As presented in **Section 3**, there could be many other consumer products and industries beyond the 11 potential source types evaluated that used PFAS in the past and remain a possible source of PFBS today. Disposal of waste from various industries could have also resulted in PFAS impact. All of the locations evaluated in this report are expected to have septic tanks, and the sludge from the septic tanks could be impacted with PFBS.

Based upon PFBS physiochemical properties, PFBS is expected to travel faster and further than other PFAS released from a particular source. PFBS is not expected to adsorb significantly to soil and will generally remain in the aqueous phase. PFBS releases in the environment could come from many different sources and are expected to travel greater distances than another longer chain PFAS. As a result, PFBS detections, especially at low concentrations, would be a difficult indicator in identifying a potential (localized) PFAS source.

There were no facilities or consumer products that could be identified as the PFBS source during this screening evaluation. Additional work would need to be conducted, including records search and environmental investigations, to better evaluate the actual PFBS sources at these locations.

7. Works Cited

3M Company. 1999. “Fluorochemical Use, Distribution and Release Overview.” Available on USEPA Administrative Record AR-226-0550.

3M Company. 2000. “Initial Assessment: Perfluorooctane Sulfonic Acid and its Salts: October 2, 2000.” Available on USEPA Administrative Record AR-226.

Armitage, J. M., I. T. Cousins, R. C. Buck, K. Prevedouros, M. H. Russell, M. MacLeod, and S. H. Korzeniowski. 2006. “Modeling Global-Scale Fate and Transport of Perfluorooctanoate Emitted from Direct Sources.” *Environmental Science and Technology* 40: (22) 6969-6975.

Backe, W. J., T. C. Day, and J. A. Field. 2013. “Zwitterionic, cationic, and anionic fluorinated chemicals in aqueous film forming foam formulations and groundwater from U.S. military bases by nonaqueous large-volume injection HPLC-MS/MS.” *Environmental Science and Technology* 47: 5226-5234.

Banks, R. E., B. E. Smart, and J. C. Tatlow. 1994. Organofluorine Chemistry: Principles and Commercial Applications. New York, N. Y.: Spring Science + Business Media.

Buck, R. C., J. Franklin, U. Berger, J. M. Conder, I. T. Cousins, P. de Voogt, A. A. Jensen, K. Kannan, S. A. Mabury, and S. P. van Leeuwenet. 2011. “Perfluoroalkyl and Polyfluoroalkyl Substances in the Environment: Terminology, Classification, and Origins.” Integrated Environmental Assessment and Management 7: 513-541. Open access http://dx.doi.org/10.1002/ieam.258

Benskin, J., L. W. Y. Yeung, N. Yamashita, S. Taniyasu, P. K. S. Lam, and J. W. Martin. 2010. “Perfluorinated Acid Isomer Profiling in Water and Quantitative Assessment of Manufacturing Source.” *Environmental Science Technology*, 44, 9049-9054.

Bourgeois, A. L. L. 2014. “Biodegradability of Fluorinated Fire Fighting Foams.” (Master of Science of Environmental Engineering Thesis)” Worcester Polytechnic Institute.

Brendel, S., E. Fetter, C. Staude, L. Vierke, and A. Biegel-Engler. 2018. “Short-chain perfluoroalkyl acids: environmental concerns and a regulatory strategy under REACH.” *Environmental Sciences Europe*, 30:9

Concawe (Conservation of Clean Air and Water in Europe). 2016. Environmental Fate and Effects of Poly- and Perfluoroalkyl Substances (PFAS). Report No. 8/16. Auderghem, Belgium.

Cousins, I. T., R. Vestergren, Z. Wang, M. Scheringer, and M. S. McLachlan. 2016. “The precautionary principle and chemicals management: The example of perfluoroalkyl acids in groundwater.” *Environment International* 94: 331-340.

Darwin, R. L. 2011. “Estimated Inventory of PFOS-based Aqueous Film Forming Foam (AFFF).” Prepared for the Fire Fighting Foam Coalition, Inc., Arlington, VA.

De Silva, A. O. 2008. “Perfluorocarboxylate Isomer Analysis as a Tool for Source Elucidation (Doctoral Thesis)”. Department of Chemistry, University of Toronto.

Gebbink, W.A., U. Berger, and I. T. Cousins. 2015. “Estimating human exposure to PFOS isomers and PFCA homologues: the relative importance of direct and indirect (precursor) exposure.” *Environment International* 74: 160-9.

Giroday, T., M. M. Montero-Campillo and N. Mora-Diez. 2014. “Thermodynamic stability of PFOS: MO6-2X and B3LYP comparison.” *Computational and Theoretical Chemistry* 1046, 81-92.

Interstate Technology Regulatory Council (ITRC). 2018. “Regulations, Guidance, and Advisories for Per- and Polyfluoroalkyl Substances (PFAS).”

Jin, H., Y. Zhang, L. Zhu, and J. W. Martin. 2015. “Isomer Profiles of Perfluoroalkyl Substances in Water and Soil Surrounding a Chinese Fluorochemical Manufacturing Park.” *Environmental Science & Technology*, 49, 4946-4954.

Knepper T.P. and F.T. Lange. 2012. “Polyfluorinated Chemicals and Transformation Products.” The Handbook of Environmental Chemistry. Springer Heidelberg Dordrecht London New York.

Lee, H. 2013. “Environmental Chemistry of Commercial Fluorinated Surfactants: Transport, Fate, and Source of Perfluoroalkyl Acid Contamination in the Environment (Doctoral Thesis)”. Department of Chemistry, University of Toronto.

NGI (Norwegian Geotechnical Institute). 2017. “Sources of Perfluorobutane Sulfonic Acid (PFBS) in the Environment.” Norwegian Environmental Agency. COWI Investigation of Sources to PFBS in the Environment.

NGI (Norwegian Geotechnical Institute). 2018. “PFBS in the Environment: Monitoring and Physical-Chemical Data Related to the Environmental Distribution of Perfluorobutanesulfonic Acid.” Norwegian Environmental Agency Report M-1122. NGI DOC.NO. 20180533-01-R.

OECD (Organisation for Economic Co-operation and Development). 2002. “Hazard Assessment of Perfluorooctane Sulfonate (PFOS) and its Salts.” ENV/JM/RD(2002)17/FINAL.

OECD (Organisation for Economic Co-operation and Development). 2013. “Synthesis paper on per- and polyfluorinated chemicals (PFCs).” Paris: OECD.

OECD (Organisation for Economic Co-operation and Development). 2018. “Toward a new comprehensive global of per- and polyfluoroalkyl substances (PFASs): Summary report on updating the OECD 2007 List of per- and polyfluoroalkyl substances (PFASs).” Paris: OECD.

Paul, A.G., K. C. Jones, and A. J. Sweetman. 2009. “Perfluoroalkyl contaminants in the Canadian Arctic: evidence of atmospheric transport and local contamination.” *Environmental Science and Technology* 43: 386-392.

Place, J. B. and J. A. Field. 2012. “Identification of Novel Fluorochemicals in Aqueous Film-Forming Foams Used by the US Military.” *Environmental Science & Technology* 46: 7120-7127.

Posner, S. 2012. “Perfluorinated Compounds: Occurrence and Uses in Products.” The Handbook of Environmental Chemistry 17. Polyfluorinated Chemicals and Transformation Products. 25-54.

Prevedouros K., I. T. Cousins, R. C. Buck, and S. H. Korzeniowski. 2006. “Sources, Fate and Transport of Perfluorocarboxylates.” *Environmental Science and Technology* 40 (1): 32-44.

Seow, J. 2013. “Fire Fighting Foams with Perfluorochemicals – Environmental Review.” Department of Environment and Conservation Western Australia. Manager Pollution Response Unit.

So, M. K., Y. Miyake, W. Y. Yeung, Y. M. Ho, S. Taniyasu, P. Rostkowski, N. Yamashita, B. S. Zhou, X. J. Shi, J. X. Wang, J. P. Giesy, H. Yu, and P. K. S. Lam. 2007. “Perfluorinated compounds in the Pearl River and Yangtze River of China.” *Chemosphere*, 68, 2085-2095.

Tuve, R. L., and E. J. Jablonski. 1966. “Method of Extinguishing Liquid Hydrocarbon Fires.” United States Patent Office. Ser. No. 306,665, 9 Claims (Cl. 252-3).

UNEP. 2013. “Guidance on alternatives to Perfluorooctane sulfonic acid, its salts, Perfluorooctane sulfonyl fluoride and their related chemicals.” 14-18 October 2013. Organized by the Persistent Organic Pollutants Review Committee. Organized by UNEP and the Persistent Organic Pollutants Review Committee.

UNEP. 2015. “Proposal to list pentadecafluorooctanic acid (CAS No: 335-67-1, PFOA, perfluorooctanic acid) its salts and PFOA-related compounds in Annexes A, B, and/or C to the Stockholm Convention on

Persistent Organic Pollutants.“ 19-23 October 2015. Organized by UNEP and the Persistent Organic Pollutants Review Committee.

United States Environmental Protection Agency (USEPA).1999. “Category for Persistent, Bioaccumulative, and Toxic New Chemical Substances.” Federal Register. Vol. 64. No. 213. Washington, D.C.: EPA, November 4, 1999.

United States Environmental Protection Agency (USEPA). 2002. “Perfluoroalkyl Sulfonates; Significant New Use Rule.” Federal Register. Vol. 67. No. 236. Washington, D.C.: December 9, 2002.

United States Environmental Protection Agency (USEPA). 2006a. “2010/2015 PFOA Stewardship Program.” EPA-HQ-2003-0012-1071.
http://www.epa.gov/opptintr/pfoa/pubs/pfoastewardship.htm.

United States Environmental Protection Agency (USEPA). 2007. “Perfluoroalkyl Sulfonates; Significant New Use Rule.” 72 Federal Register 57222. Washington D.C. October 9.

United States Environmental Protection Agency (USEPA). 2009c. “Provisional Health Advisories for Perfluorooctanoic Acid (PFOA) and Perfluorooctane Sulfonate (PFOS).”
https://www.epa.gov/sites/production/files/2015-09/documents/pfoa-pfos-provisional.pdf

United States Environmental Protection Agency (USEPA). 2015b. “Long-Chain Perfluoroalkyl Carboxylate and Perfluoroalkyl Sulfonate Chemical Substances; Significant New Use Rule.” 80 Federal Register 2885. Washington D.C.: EPA, January 21.

United States Environmental Protection Agency (USEPA). 2016a. “Drinking Water Health Advisory for Perfluorooctanoic Acid (PFOA).” Office of Water (4304T). Health and Ecological Criteria Division, Washington, DC 20460. EPA Document Number: 822-R-16-005.

United States Environmental Protection Agency (USEPA). 2016b. “Drinking Water Health Advisory for Perfluorooctane Sulfonate (PFOS).” Office of Water (4304T). Health and Ecological Criteria Division, Washington, DC 20460. EPA Document Number: 822-R-16-004.

Wang, Z., I. T. Cousins, M. Scheringer, R. C. Buck, and K. Hungerbuhler. 2014a. “Global emission inventories for C4-C14 perfluoroalkyl carboxylic acid (PFCA) homologues from 1951 to 2030, part I: production and emissions from quantifiable sources.” *Environmental International* (70) (2014) 62-75.

Wang, Z., I. T. Cousins, M. Scheringer, R. C. Buck, and K. Hungerbuhler. 2014b. “Global emission inventories for C4-C14 perfluoroalkyl carboxylic acid (PFCA) homologues from 1951 to 2030, part II: the remaining pieces of the puzzle.” *Environmental International* (69) (2014) 166-176.

Wang, Z., J. C. DeWitt, C. P. Higgins, and I. T. Cousins. 2017a. “A Never-Ending Story of Per- and Poly-Fluoroalkyl Substances (PFASs)?” *Environmental Science and Technology* 51: 2508-2518.

Wang, Z., J. M. Boucher, M. Scheringer, I.T. Cousins. 2017b. “Toward a Comprehensive Global Emission Inventory of C4-C10 Perfluoroalkanesulfonic Acids (PFSAs) and Related Precursors: Focus on the Life Cycle of C8-Based Products and Ongoing Industrial Transition.” *Environmental Science and Technology* 51: 4482-4493.

Figures

Upper Peninsula

Keweenaw
Houghton
Ontonagon
Baraga
Gogebic
Marquette
Alger
Luce
Chippewa
Iron
Schoolcraft
Mackinac
Dickinson
Delta
Menominee

Lower Peninsula

Legend

Sample Locations

- Public Water System
- School
- Daycare
- Tribal Water Supply

Emmet
Cheboygan
Presque Isle
Charlevoix
Otsego
Montmorency
Alpena
Antrim
Leelanau
Grand Traverse
Benzie
Kalkaska
Crawford
Oscoda
Alcona
Manistee
Wexford
Missaukee
Roscommon
Ogemaw
Iosco
Arenac
Mason
Lake
Osceola
Clare
Gladwin
Huron
Oceana
Newaygo
Mecosta
Isabella
Midland
Bay
Tuscola
Sanilac
Saginaw
Montcalm
Gratiot
Muskegon
Lapeer
Genesee
St. Clair
Kent
Ionia
Clinton
Shiawassee
Ottawa
Macomb
Oakland
Allegan
Barry
Eaton
Ingham
Livingston
Washtenaw
Wayne
Van Buren
Kalamazoo
Calhoun
Jackson
Monroe
Berrien
Cass
St. Joseph
Branch
Hillsdale
Lenawee

EGLE	
Drawn: JS 6/28/2019	
Approved: 6/28/2019	
Project #: 60560354	

0 25 50 100 Miles

N

FIGURE 8

2018 PFAS SAMPLING OF DRINKING WATER SYSTEMS IN MICHIGAN

Source: ESRI USA Topo Maps

G:\GrandRapids\DCS\GIS\ArcMap_GeoDB_Projects\ENV\GIS_Data\GIS\MDEQ CWS\MXD\CWS_overview_Sample_Locations_2.mxd

Upper Peninsula

Keweenaw
Houghton
Ontonagon
Baraga
Gogebic
Marquette
Iron
Dickinson
Menominee
Alger
Schoolcraft
Luce
Mackinac
Chippewa
Delta

Lower Peninsula

Legend

- Active Landfills
- Superfund Sites
- Electroplaters
- Plating and Polishing Sites
- Airports
- Petroleum Terminals
- Petroleum Bulk Stations
- Paints & Allied Products
- Military Sites
- Fire Stations
- Historic Landfills

Emmet
Cheboygan
Presque Isle
Charlevoix
Antrim
Otsego
Montmorency
Alpena
Leelanau
Grand Traverse
Benzie
Kalkaska
Crawford
Oscoda
Alcona
Manistee
Wexford
Missaukee
Roscommon
Ogemaw
Iosco
Arenac
Mason
Lake
Osceola
Clare
Gladwin
Huron
Oceana
Newaygo
Mecosta
Isabella
Midland
Bay
Tuscola
Sanilac
Saginaw
Montcalm
Gratiot
Muskegon
Lapeer
St. Clair
Genesee
Kent
Ottawa
Ionia
Clinton
Shiawassee
Macomb
Oakland
Allegan
Barry
Eaton
Ingham
Livingston
Van Buren
Kalamazoo
Calhoun
Jackson
Washtenaw
Wayne
Berrien
Cass
St. Joseph
Branch
Hillsdale
Lenawee
Monroe

EGLE	
Drawn: JS 3/4/2019	
Approved: 3/4/2019	
Project #: 60560354	

0 25 50 100 Miles

N

FIGURE 9

PFAS POTENTIAL SOURCES

Source: ESRI USA Topo Maps

G:\GrandRapids\DCS\GIS\ArcMap_GeoDB_Projects\ENV\GIS_Data\GIS\MDEQ CWS\MXD\PFBS_Evaluation\Figure3_Potential_PFAS_Sources.mxd

Upper Peninsula

Keweenaw
Houghton
Ontonagon
Baraga
Gogebic
Marquette
Iron
Dickinson
Menominee
Alger
Luce
Chippewa
Schoolcraft
Mackinac
Delta

Lower Peninsula

Legend

PFAS Sampling Prioritization

- Low
- Medium
- High
- Very High

PFAS Sampling Prioritization Determined using a Combination of Potential PFAS Sources, Geologic Sensitivity, Population, and Statewide PFAS Sampling Results

Emmet
Cheboygan
Presque Isle
Charlevoix
Antrim
Otsego
Montmorency
Alpena
Leelanau
Benzie
Grand Traverse
Kalkaska
Crawford
Oscoda
Alcona
Manistee
Wexford
Missaukee
Roscommon
Ogemaw
Iosco
Mason
Lake
Osceola
Clare
Gladwin
Arenac
Huron
Oceana
Newaygo
Mecosta
Isabella
Midland
Bay
Tuscola
Sanilac
Muskegon
Montcalm
Gratiot
Saginaw
Lapeer
Kent
Ionia
Clinton
Shiawassee
Genesee
St. Clair
Ottawa
Allegan
Barry
Eaton
Ingham
Livingston
Oakland
Macomb
Van Buren
Kalamazoo
Calhoun
Jackson
Washtenaw
Wayne
Berrien
Cass
St. Joseph
Branch
Hillsdale
Lenawee
Monroe

CANADA
UNITED STATES
MICHIGAN

EGLE

Drawn: JS 6/7/2019
Approved: 6/7/2019
Project #: 60560354

0 25 50 100 Miles

N

FIGURE 10

2018 PUBLIC WATER SUPPLY
PFAS SAMPLING PRIORITIZATION

Source: ESRI USA Topo Maps

G:\GrandRapids\DCS\GIS\ArcMap_GeoDB_Projects\ENV\GIS_Data\GIS\MDEQ CWS\MXD\PFBS_Evaluation\Figure2_PFAS_Detection_Probability_2.mxd

Upper Peninsula

Keweenaw
Houghton
Ontonagon
Baraga
Gogebic
Marquette
Iron
Dickinson
Menominee
Alger
Schoolcraft
Delta
Luce
Mackinac
Chippewa

Lower Peninsula

Legend

- PFAS Detection (Groundwater)
- PFAS Detection (Surface Water)
- PFAS Non-Detect

PFAS Sampling Prioritization

- Low
- Medium
- High
- Very High

PFAS Priority Rank Determined using a Combination of Potential PFAS Sources, Geologic Sensitivity, Population, and Statewide PFAS Sampling Results

Emmet
Cheboygan
Presque Isle
Charlevoix
Antrim
Otsego
Montmorency
Alpena
Leelanau
Benzie
Grand Traverse
Kalkaska
Crawford
Oscoda
Alcona
Manistee
Wexford
Missaukee
Roscommon
Ogemaw
Iosco
Mason
Lake
Osceola
Clare
Gladwin
Arenac
Huron
Oceana
Newaygo
Mecosta
Isabella
Midland
Bay
Tuscola
Sanilac
Muskegon
Montcalm
Gratiot
Saginaw
Lapeer
Genesee
St. Clair
Kent
Ottawa
Ionia
Clinton
Shiawassee
Macomb
Oakland
Allegan
Barry
Eaton
Ingham
Livingston
Washtenaw
Wayne
Van Buren
Kalamazoo
Calhoun
Jackson
Berrien
Cass
St. Joseph
Branch
Hillsdale
Lenawee
Monroe

EGLE	
Drawn: JS 7/17/2019	
Approved: 7/17/2019	
Project #:	

0 25 50 100 Miles

N

FIGURE 11

PFAS DETECTIONS IN MICHIGAN DRINKING WATER SYSTEMS

Source: ESRI USA Topo Maps

G:\GrandRapids\DCS\GIS\ArcMap_GeoDB_Projects\ENV\GIS_Data\GIS\MDEQ CWS\MXD\PFBS_Evaluation\Figure5_PFAS_Priority_Zones_PFAS_Detects_2.mxd

Upper Peninsula

Keweenaw
Houghton
Ontonagon
Baraga
Gogebic
Marquette
Alger
Luce
Chippewa
Iron
Schoolcraft
Mackinac
Dickinson
Delta
Menominee

Lower Peninsula

Legend

- PFAS Non-Detect
- PFAS Detected Without PFBS

PFBS Detects (ppt)

- >0 - 5
- >5 - 10
- >10 - 20
- >20 - 40
- >40

Emmet
Cheboygan
Presque Isle
Charlevoix
Antrim
Otsego
Montmorency
Alpena
Leelanau
Grand Traverse
Benzie
Kalkaska
Crawford
Oscoda
Alcona
Manistee
Wexford
Missaukee
Roscommon
Ogemaw
Iosco
Arenac
Mason
Lake
Osceola
Clare
Gladwin
Huron
Oceana
Newaygo
Mecosta
Isabella
Midland
Bay
Tuscola
Sanilac
Muskegon
Montcalm
Gratiot
Saginaw
Kent
Ionia
Clinton
Shiawassee
Genesee
Lapeer
St. Clair
Ottawa
Macomb
Oakland
Allegan
Barry
Eaton
Ingham
Livingston
Washtenaw
Wayne
Van Buren
Kalamazoo
Calhoun
Jackson
Berrien
Cass
St. Joseph
Branch
Hillsdale
Lenawee
Monroe

EGLE

Drawn: JS 3/4/2019
Approved: 3/4/2019
Project #: 60560354

0 25 50 100 Miles

N

FIGURE 12

PFBS HEATMAP IN MICHIGAN DRINKING WATER SYSTEMS

Source: ESRI USA Topo Maps

G:\GrandRapids\DCS\GIS\ArcMap_GeoDB_Projects\ENV\GIS_Data\GIS\MDEQ CWS\MXD\PFBS_Evaluation\Figure7_PFBS_Heatmap.mxd

Upper Peninsula

Keweenaw
Houghton
Ontonagon
Baraga
Gogebic
Marquette
Alger
Luce
Chippewa
Iron
Schoolcraft
Mackinac
Dickinson
Delta
Menominee

Lower Peninsula

Legend

- PFAS Non-Detect

PFBS / Total PFAS (%)

- 0% (PFBS Non-Detect)
- >0% - 25%
- >25% - 50%
- >50% - 75%
- >75% - 99%
- 100%

Emmet
Cheboygan
Presque Isle
Charlevoix
Antrim
Otsego
Montmorency
Alpena
Leelanau
Grand Traverse
Benzie
Kalkaska
Crawford
Oscoda
Alcona
Manistee
Wexford
Missaukee
Roscommon
Ogemaw
Iosco
Arenac
Mason
Lake
Osceola
Clare
Gladwin
Huron
Oceana
Newaygo
Mecosta
Isabella
Midland
Bay
Tuscola
Sanilac
Muskegon
Montcalm
Gratiot
Saginaw
Kent
Genesee
Lapeer
St. Clair
Ottawa
Ionia
Clinton
Shiawassee
Macomb
Oakland
Allegan
Barry
Eaton
Ingham
Livingston
Washtenaw
Wayne
Van Buren
Kalamazoo
Calhoun
Jackson
Berrien
Cass
St. Joseph
Branch
Hillsdale
Lenawee
Monroe

EGLE

Drawn: JS 3/4/2019
Approved: 3/4/2019
Project #: 60560354

0 25 50 100 Miles

N

FIGURE 13

PFBS PERCENTAGE HEATMAP IN MICHIGAN DRINKING WATER SYSTEMS

Source: ESRI USA Topo Maps

G:\GrandRapids\DCS\GIS\ArcMap_GeoDB_Projects\ENV\GIS_Data\GIS\MDEQ CWS\MXD\PFBS_Evaluation\Figure8_PFBS_Percentage_Heatmap.mxd

Upper Peninsula

Keweenaw
Houghton
Ontonagon
Baraga
Gogebic
Marquette
Alger
Luce
Chippewa
Iron
Schoolcraft
Mackinac
Dickinson
Delta
Menominee

Lower Peninsula

Legend

- PFAS Non-Detect
- PFAS Detect; PFBS < 50% of Total PFAS

PFBS > 50% of Total PFAS

Total PFAS (ppt)

- >0 - 10
- >10 - 50
- >50 - 100
- >100 - 200
- >200

Emmet
Cheboygan
Presque Isle
Charlevoix
Antrim
Otsego
Montmorency
Alpena
Leelanau
Benzie
Grand Traverse
Kalkaska
Crawford
Oscoda
Alcona
Manistee
Wexford
Missaukee
Roscommon
Ogemaw
Iosco
Mason
Lake
Osceola
Clare
Gladwin
Arenac
Huron
Oceana
Newaygo
Mecosta
Isabella
Midland
Bay
Tuscola
Sanilac
Muskegon
Montcalm
Gratiot
Saginaw
Kent
Ionia
Clinton
Shiawassee
Genesee
Lapeer
St. Clair
Ottawa
Macomb
Oakland
Allegan
Barry
Eaton
Ingham
Livingston
Washtenaw
Wayne
Van Buren
Kalamazoo
Calhoun
Jackson
Berrien
Cass
St. Joseph
Branch
Hillsdale
Lenawee
Monroe

EGLE

Drawn:	JS	3/4/2019
Approved:		3/4/2019
Project #:	60560354	

0 25 50 100 Miles

N

FIGURE 14

TOTAL PFAS HEATMAP WITH PFBS > 50% IN MICHIGAN DRINKING WATER SYSTEMS

Source: ESRI USA Topo Maps

G:\GrandRapids\DCS\GIS\ArcMap_GeoDB_Projects\ENV\GIS_Data\GIS\MDEQ CWS\MXD\PFBS_Evaluation\Figure9_PFBS_50_TotalPFAS_Heatmap.mxd

Appendix A

August 2019

Table 4-1. Standards and guidance values for PFAS in groundwater, drinking water, and surface water/effluent (wastewater).

This Table 4.1 belongs with the ITRC PFAS Regulations, Guidance and Advisories Fact Sheet. The values included here reflect values we are aware of as of August 31, 2019. These values are changing rapidly. The ITRC intends to update this table periodically as new information is gathered. The fact sheet user is encouraged to visit the ITRC PFAS web page (http://pfas-1.itrcweb.org) to access the current version of this file. Please see ITRC Disclaimer http://pfas-1.itrcweb.org/about-itrc/#disclaimer

								PFAS Analyte Concentration (µg/L) and CAS RN														
Location	Agency / Dept	Year First Listed	Standard / Guidance	Type	Promulgated Rule (Y/N/O)	Footnote	PFOA	PFOS	PFNA	PFBA	PFBS	PFHxS	PFHxA	PFPeA	PFHpA	PFOSA	PFDA	PFDS, PFUnA, PFDoA, PFTrDA, PFTeDA	6:2 FTS	8:2 FTS	Gen-X
							335-67-1	1763-23-1	375-95-1	375-22-4	375-73-5	355-46-4	307-24-4	2706-90-3	375-85-9	754-91-6	335-76-2	2058-94-8, 307-55-1, 72629-94-8, 376-06-7	39108-34-4	39108-34-4	3252-13-6
U.S. Environmental Protection Agency																					
USEPA	Office of Water	2016	HA	DW	N	a	0.070	0.070													
	Regions	2014	RSL	GW	N	b					400										
	Regions	2018	RSL Calculation	GW	N	c	0.400	0.400													
U.S. States																					
Alaska (AK)	DEC	2016	CL	GW	Y		0.400	0.400													
	DEC	2018	Action Level	DW/GW/SW	N	a	0.070	0.070													
California (CA)	SWRCB	2018	NL	DW	N		0.014	0.013													
Colorado (CO)	DPHE	2018	GQS	GW	Y	d	0.070	0.070													
Connecticut (CT)	DPH	2016	AL	DW/GW	N	e	0.070	0.070	0.070			0.070			0.070						
Delaware (DE)	DNREC	2016	RL	GW	N	a	0.070	0.070													
	DNREC	2016	SL	GW	N	a	0.070	0.070			38										
Iowa (IA)	DNR	2016	Statewide Standards	Protected GW	Y	a	0.070	0.070													
	DNR	2016		Non-protected GW	Y			1													
Maine (ME)	DEP	2018	RAG	GW	N		0.400	0.400			400										
Massachusetts (MA)	DEP	2018	Guidance Values	DW	O	e	0.070	0.070	0.070		2	0.070			0.070						
Michigan (MI)	DEQ	2015	HNV	SW	Y		0.420	0.011													
	DEQ	2018	GCC	DW/GW	Y	a	0.070	0.070													
	DHHS	2019	Screening Levels	DW	N		0.009	0.008	0.009		1	0.084									
Minnesota (MN)	MDH	2017/2019	short-term HBV	DW/GW	O/N	f	0.035	0.015		7	3	0.047									
	MDH	2017/2019	subchronic HBV	DW/GW	O/N	f	0.035	0.015		7	3	0.047									
	MDH	2017/2019	chronic HBV	DW/GW	O/N	f	0.035	0.015		7	2	0.047									
Montana (MT)	DEQ	2019	Water Quality Standard	GW	Y	a	0.070	0.070													
Nevada (NV)	DEP	2015	BCL	DW	N		0.667	0.667			667										
New Hampshire (NH)	DES	2016	AGQS	GW	Y	a	0.070	0.070													
New Jersey (NJ)	DEP	2018	GWQS	GW	Y				0.013												
	DEP	2018	MCL	DW	Y				0.013												
	DWQI	2017	MCL	DW	O		0.014														
	DWQI	2018	MCL	DW	O			0.013													
	DEP	2019	ISGWQC	GW	Y		0.01	0.01													
North Carolina (NC)	DEQ	2006	IMAC	GW	Y		2														
	DHHS	2017	Health Goal	DW	N																0.140
Oregon (OR)	DEQ	2011	IL	SW	Y		24	300	1						300	0.200					
Pennsylvania (PA)	DEP	2016	MSC	GW	N	a	0.070	0.070													
Rhode Island	DEM	2017	Groundwater Quality Standard	DW/GW	Y	a	0.070	0.070													
Texas (TX)	CEQ	2016	Tier 1 PCL	GW	Y		0.290	0.560	0.290	71	34	0.093	0.093	0.093	0.560	0.290	0.370	0.290			
Vermont (VT)	DEC/DOH	2018	HA	DW/GW	Y	e	0.020	0.020	0.020			0.020			0.020						
	DEC	2016	PAL	GW	Y		0.010	0.010	0.010			0.010			0.010						

August 2019

Table 4-1. Standards and guidance values for PFAS in groundwater, drinking water, and surface water/effluent (wastewater).

This Table 4.1 belongs with the ITRC PFAS Regulations, Guidance and Advisories Fact Sheet. The values included here reflect values we are aware of as of August 31, 2019. These values are changing rapidly. The ITRC intends to update this table periodically as new information is gathered. The fact sheet user is encouraged to visit the ITRC PFAS web page (http://pfas-1.itrcweb.org) to access the current version of this file. Please see ITRC Disclaimer http://pfas-1.itrcweb.org/about-itrc/#disclaimer

							PFAS Analyte Concentration (µg/L) and CAS RN														
Location	Agency / Dept	Year First Listed	Standard / Guidance	Type	Promulgated Rule (Y/N/O)	Footnote	PFOA	PFOS	PFNA	PFBA	PFBS	PFHxS	PFHxA	PFPeA	PFHpA	PFOSA	PFDA	PFDS, PFUnA, PFDoA, PFTrDA, PFTeDA	6:2 FTS		Gen-X
International																					
Australia	DOH	2017	health-based	DW		g	0.560	0.070				0.070									
		2017	health-based	RW		g	5.6	0.700				0.700									
British Columbia, Canada		2018	water standard	DW/GW			0.200	0.300			80										
Canada	HC	2016	DWSV	DW			0.200	0.600	0.020	30	15	0.600	0.200	0.200	0.200						
	HC	2019	DWSV	DW															0.200	0.200	
	HC	2018	MAC	DW	Y		0.200	0.600													
Denmark	EPA	2015	health-based	DW/GW		h	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100		0.100		
Germany	GMH	2006	health-based	DW			0.300	0.300													
			administrative	DW		i	0.100	0.100													
		2018	GFS	GW			0.100	0.100	0.060	10	6	0.100	6								
Italy		2017	health-based	DW			0.500			7	3		1	3							
		2017	screening value	FW		j	0.100			7	3		1	3							
Netherlands	EPA	2011	health-based	DW				0.530													
		2011	administrative	DW				0.0053													
Norway		2014	EQS	SW			9.1	0.00065													
		2014	EQS	CW			9.1	0.00013													
Sweden		2014	health-based	DW				0.090													
		2014	administrative	DW		k	0.090	0.090			0.090	0.090	0.090	0.090	0.090						
UK	DWI	2009	health-based	DW			10	0.300													
		2009	admin. Level 1	DW			0.300	0.300													
		2009	admin. Level 2	DW			10	1													
		2009	admin. Level 3	DW			90	9													

Notes:

The following states use the EPA Health Advisories: Alabama (AL), Arizona (Az), Colorado (CO), Indiana (IN), Kansas (KS), Maine (ME), Missouri (MO), Nebraska (NE), West Virginia (WV), and Wyoming (WY).

Promulgated (Yes/No/Other)- Values are considered promulgated Rule if they have been finalized into law or if the table of values is referenced in supporting law. Values are not considered promulgated when they are not finalized into law but are considered final guidance. Values identified as "other" include those that are proposed, considered draft, or recommended but not yet finalized.

Year First Listed is the year the value became effective. References are provided for the most recent publication of the values.

a Applies to the individual results for PFOA and PFOS, as well as the sum of PFOA + PFOS.

b Regional Screening Level (RSL) as presented in the USEPA Regional Screening Level (RSL) Summary Table (TR=1E-06, HQ=1) November 2014 through May 2018.

c As of June 2018, calculated by the USEPA RSL calculator using USEPA OW RfDs, HQ of 1, and residential exposure assumptions. Note: RSL users screening sites with multiple contaminants should consult the USEPA (2018) RSL User's Guide and USEPA (1989) Risk Assessment Guidance.

d The 2018 Colorado Site-specific Groundwater Quality Standard was adopted to provide a cleanup goal for the contaminated aquifer in El Paso County only.

e Applies to the individual results for PFOA, PFOS, PFHpA, PFNA, and PFHxS as well as the sum of concentrations of these 5 PFAS.

f HRLs for PFOA (0.035 µg/L) and PFBA (7 µg/L) published in 2018 are promulgated. The MN values for PFOS, PFBS, and PFHxS are not promulgated HBVs.

g The Australian Government Department of Health values for PFOS/PFHxS are combined value when both are present.

h Applies to the individual results for PFOA, PFOS, PFNA, PFBA, PFBS, PFHxS, PFHxA, PFPeA, PFHpA, PFOSA, PFDA, AND 6:2 FTS as well as the sum of concentrations of these 12 PFAS.

i The GMH administrative guidance value of 0.1 µg/L is a composite precautionary value for both PFOA and PFOS for long term exposure in drinking water.

j Annual Average - Environmental Quality Standards. PFOA AA-EQS based on secondary poisoning of wildlife.

k Administrative value is for the sum of seven PFAS found in drinking water: PFOS, PFOA, PFHxS, PFBS, PFHpA, PFHxA, and PFPeA. PFOS is considered to be the most toxic. Water can still be used at up to 0.09 µg/L.

August 2019

Table 4-1. Standards and guidance values for PFAS in groundwater, drinking water, and surface water/effluent (wastewater).

This Table 4.1 belongs with the ITRC PFAS Regulations, Guidance and Advisories Fact Sheet. The values included here reflect values we are aware of as of August 31, 2019. These values are changing rapidly. The ITRC intends to update this table periodically as new information is gathered. The fact sheet user is encouraged to visit the ITRC PFAS web page (http://pfas-1.itrcweb.org) to access the current version of this file. Please see ITRC Disclaimer http://pfas-1.itrcweb.org/about-itrc/#disclaimer

Regulatory Agency
CDC= Center for Disease Control & Prevention
CEQ = Commission on Environmental Quality
DEC = Dept. of Environmental Conservation
DEM = Dept. of Environmental Management
DEP = Dept. of Environmental Protection
DEQ = Dept. of Environmental Quality
DES = Dept. of Environmental Services
DHHR = Dept. of Health and Human Resources
DHHS = Dept. of Health and Human Services
DNR = Dept. of Natural Resources
DNREC = Dept. of Natural Resources and Environmental Control
DOH = Dept. of Health
DPH = Division or Department of Public Health
DPHE = Department of Public Health and Environment
DWI = Drinking Water Inspectorate
DWQI = NJ Drinking Water Quality Institute
DWSV = Drinking Water Screening Value
EPA = Environmental Protection Agency
GMH = German Ministry of Health
MDH = Minnesota Department of Health
OEHS = Office of Environmental Health Services
SWRCB = California State Water Resources Control Board

Standard or Guidance
AGQS = ambient groundwater quality standard
AL = private well action level
BCL = basic comparison level
CL = groundwater cleanup level
CW = Coastal Water
DWSV = Drinking Water Screening Value
ES = environmental standard
EQS = environmental quality standard
GCC = Generic Cleanup Criteria
GFS = significance thresholds
GQS = Site-Specific Groundwater Quality Standard
GTLC = groundwater cleanup target levels
GWQS = Groundwater Water Quality Standard
HA = lifetime health advisory
HNV = human noncancer value for surface drinking water
HBV = health-based value
HRL = health risk limit
IL = initiation level
IMAC = interim maximum allowable standard
ISGWQS = Interim Specific Ground Water Quality Standard
MAC = maximum acceptable concentration
MCL = maximum contaminant level
MEG = maximum exposure guideline
MSC = medium-specific concentration
NL = Notification Level
PAL = preventive action level
PCL = protective concentration level
PGWES = primary groundwater enforcement standard

Per- and polyfluoroalkly substances
PFAS = per- and polyfluoroalkyl substances
PFOA = perfluorooctanoic acid (C8)
PFOS = perfluorooctane sulfonic acid (C8)
PFNA = perfluorononanoic acid (C9)
PFBA = perfluorobutyric acid (C4)
PFBS = perfluorobutane sulfonic acid (C4)
PFPeA = perfluoropentanoic acid (C5)
PFHxS = perfluorohexane sulfonic acid (C6)
PFHxA = perfluorohexanoic acid (C6)
PFHpA = perrfluoroheptanoic acid (C7)
PFOSA = perfluorooctane sulfonamide (C8)
PFDA = perfluorodecanoic acid (C10)
PFDS = perfluorodecane sulfonate (10)
PFUnA = perfluoroundecanoic acid (C11)
PFDoA = perfluorododecanoic acid (C12)
PFTrDA = perfluorotridecanoic acid (C13)
PFTeDA = perfluorotetradecanoic acid (C14)
6:2 FTS = 6:2 Fluorotelomer sulfonate
8:2 FTS = 8:2 Fluorotelomer sulfonate

Type of Medium
DW = drinking water
FW = fresh water
GW = groundwater
RW = recreational water
SW = surface water and/or effluent

August 2019

Table 4-1. References for Standards and guidance values for PFAS in groundwater, drinking water, and surface water/effluent (wastewater).

References: United States Environmental Protection Agency (USEPA)

USEPA	United States Environmental Protection Agency (USEPA). 1989. Risk Assessment Guidance for Superfund (RAGS), Volume 1, Human Health Evaluation Manual (Part A). Interim Final. EPA/540/1-89/002. December.
	United States Environmental Protection Agency (USEPA). 2016. *Drinking Water Health Advisory for Perfluorooctanoic Acid (PFOA)* . Office of Water (4304T). Health and Ecological Criteria Division, Washington, DC 20460. EPA Document Number: 822-R-16-005. May 2016.
	United States Environmental Protection Agency (USEPA). 2016. *Drinking Water Health Advisory for Perfluorooctane Sulfonate (PFOS)* . Office of Water (4304T). Health and Ecological Criteria Division, Washington, DC 20460. EPA Document Number: 822-R-16-004. May 2016.
	United States Environmental Protection Agency (USEPA). 2018. Regional Screening Levels (RSLs), RSL User's Guide, and RSL Calculator. May.

References: U.S. States

AL	Alabama Department of Environmental Management (ADEM). ADEM Announces EPA National Health Advisory. May 19, 2016.
AK	Alaska Department of Environmental Conservation (AKDEC). 2017. 18 AAC 75. Oil and Other Hazardous Substances Pollution Control. As amended through July 1, 2017.
	Alaska Department of Environmental Conservation (AKDEC). 2018. Technical Memorandum, Action Levels for PFAS in Water and Guidance on Sampling Groundwater and Drinking Water. August 20.
	Alaska Department of Environmental Conservation (AKDEC). 2019. Technical Memorandum, Action Levels for PFAS in Water and Guidance on Sampling Groundwater and Drinking Water. April 9.
AZ	Liberty Utilities. 2017. Notice to Our Communities: Avondale, Goodyear, Litchfield Park, and Maricopa County. Notice in response to EPA Drinking Water Health Advisories for PFOS and PFOA.
CA	California State Water Resources Control Board. (SWRCB). 2018. Division of Drinking Water (DDW). Drinking Water Notification Levels and Response Levels: An Overview. July 13.
CT	Connecticut Department of Public Health (CTDPH). 2016. Drinking Water Action Level for Perfluorinated Alkyl Substances (PFAS). December.
CO	Colorado Department of Public Health and the Environment (CDPHE). PFCs Health Advisory, 2018.
	Colorado Department of Public Health and the Environment (CDPHE). Site-specific Groundwater Standard PFOA/PFOS in El Paso County. Adopted by the Water Quality Control Commission on April 9, 2018. The groundwater quality standard becomes effective on June 30, 2018.
DE - RL	Delaware Department of Natural Resources and Environmental Control (DNREC). 2016. *Guidance for Notification Requirements. January 2013. Reporting Level Table. Updated July 2016.* Division of Waste and Hazardous Substances. Site Investigation & Restoration Section. July 2016.
DE - SL	Delaware Department of Natural Resources and Environmental Control (DNREC). 2016. Screening Level Table. Division of Waste and Hazardous Substances. Site Investigation & Restoration Section. January 1, 2013. Last Updated July 2016.
IA	Iowa Department of Natural Resources (IDNR). 2016. Statewide standards for contaminants in soil and groundwater. Cumulative Risk Calculator.
MA	Massachusetts Department of Environmental Protection (MassDEP). 2018. Office of Research and Standards Final Recommendations for Interim Toxicity and Drinking Water Guidance Values for Perfluorinated Alkyl Substances Included in the Unregulated Chemical Monitoring Rule 3. June 8.
ME -DW	Maine Center for Disease Control and Prevention (Me CDC). 2017. Summary of the 2016 Updates to the Maximum Exposure Guidelines. Published January 10, 2017.
ME -GW	Maine Department of Environmental Protection (DEP). 2018. Maine Remedial Action Guidelines (RAGs) for Sites Contaminated with Hazardous Substances. October 19 (p. 58).
ME-GW SLs	Maine Center for Disease Control and Prevention (CDC). 2016. Interdepartmental Memo from MeCDC to DEP regarding Human Health Risk-Based Screening Levels for Perfluoroalkyl Compounds. August 17. Contact Maine CDC for Copy of this Reference.
ME-SW/RW	Maine Center for Disease Control and Prevention (CDC). 2016. Interdepartmental Memo from MeCDC to DEP regarding Human Health Risk-Based Screening Levels for Perfluoroalkyl Compounds. August 17. Contact Maine CDC for Copy of this Reference.
MI-SW	Michigan Department of Environmental Quality (DEQ). 2016. Rule 57 Water Quality Values. Surface Water Assessment Section. October 21, 2016.
MI-GW	Michigan Department of Environmental Quality (DEQ). 2018. Remediation and Redevelopment Division. Environmental Contamination Response Activity Rules. Table 1. Groundwater: Residential and Nonresidential, Part 201 Generic Cleanup Criteria and Screening Levels. Effective January 10, 2018.
MI-GW	Michigan Department of Health and Human Services (DHHS). 2019. Public Health Drinking Water Screening Levels for PFAS. February 22, 2019. Adopted April 4, 2019.
MN	Minnesota Department of Health (MDH). 2019. Human Health-Based Water Guidance Table.
MT	Montana Department of Environmental Quality (DEQ). 2019. Circular DEQ-7, Montana Numeric Water Quality Standards. June.
NV	Nevada Division of Environmental Protection (DEP). -2017. Basic Comparison Levels, July 2017.
NH	New Hampshire Code of Administrative Rules. Chapter Env-Or 600- Contaminated Site Management (1/10/17)
NJ -GW: PFNA	State of New Jersey Department of Environmental Protection. 2016. Ground Water Quality Standards N.J.A.C. 7:9C: Interim Ground Water Quality Criteria Table. Last Updated August 12, 2016.
NJ -GW: PFOA/PFOS	State of New Jersey Department of Environmental Protection. 2019. Ground Water Quality Standards N.J.A.C. 7:9C: Interim Ground Water Quality Criteria Table. Last Updated March 13, 2019.
	Table of Interim Specific Ground Water Quality Criteria (ISGWQC), Interim PQLs (IPQLs), and Interim Specific Ground Water Quality Standards (ISGWQS) for Constituents in Class II-A Ground Water
NJ -DW	State of New Jersey Department of Environmental Protection. Memorandum to Barker Hamill, Assistant Director for Water Supply Operations, from Gloria Post, Ph.D. DABT, Research Scientist, Risk Analysis Section, DSRT. Subject: Guidance for PFOA in Drinking Water at Pennsgrove Water Supply Company.
	New Jersey Drinking Water Quality Institute (NJDWQI) 2017. Maximum Contaminant Level Recommendation for Perfluorooctanoic Acid in Drinking Water, Basis and Background. March 15, 2017
	New Jersey Drinking Water Quality Institute (NJDWQI) 2018. Maximum Contaminant Level Recommendation for Perfluorooctane Sulfonate in Drinking Water. June 8.
	New Jersey Drinking Water Quality Institute (NJDWQI) 2018. Maximum Contaminant Level Recommendation for Perfluorononanoic Acid in Drinking Water. July 1, 2015. Adopted September 6, 2018.
NC-GW	North Carolina Department of Environmental Quality (NCDEQ) 2013. Appendix #1: Interim maximum allowable concentrations (IMACs). May 22, 2013.
NC-DW	North Carolina Department of Health and Human Services (NC DHHS). 2017. GenX Health Information.
OR	Oregon Department of Environmental Quality (DEQ). Division 045. Regulations Pertaining to NPDES and WPCF Permits. Initiation Level Rule 340-045-0100.
PA	Pennsylvania Department of Environmental Protection (DEP). 2016. PFOA & PFOS Drinking Water Health Advisories in Pennsylvania.
RI	Rhode Island Department of Environmental Management (RIDEM). 2017. Determination of a Groundwater Quality Standard for: Perfluorooctanoic Acid (PFOA) and Perfluorooctane Sulfonate (PFOS). October 18.
TX	Texas Commission on Environmental Quality (TCEQ). 2018. Texas Risk Reduction Program (TRRP). Protective Concentration Levels (PCLs). April.
VT	Vermont Department of Health (DOH). 2018. Fact Sheet. Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS) in Drinking Water. July 9.
	Vermont Department of Health (DOH). 2018. Memorandum regarding Drinking Water Health Advisory for Five PFAS (per-and polyfluorinated alkyl substances). July 10.
	Vermont Agency of Natural Resources, Department of Environmental Conservation. 2018. Chapter 12 of the Environmental Protection Rules: Groundwater Protection Rule and Strategy. Adopted July 11, 2018.
	Vermont Agency of Natural Resources, Department of Environmental Conservation. 2019. Chapter 12 of the Environmental Protection Rules: Groundwater Protection Rule and Strategy. Adopted January 8, 2018.
WV	West Virginia Department of Health and Human Resources. 2016. Perfluorinated compounds drinking water health advisory. Bureau of Public Health.

References: International

Australia	Australian Government Department of Health. Health Based Guidance Values for PFAS. For Use in Site Investigations in Australia.
British Columbia	British Columbia Office of Legislative Counsel, Ministry of Attorney General, Victoria, British Columbia. Environmental Management Act. Contaminated Sites Regulation. B.C. Rg. 375/96. July 24, 2018.
Canada	Health Canada. 2016. Health Canada's Drinking Water Screening Values for Perfluoroalkylated Substances (PFAS). February 2016. Updated July 2018.
	Health Canada. 2018. Guidelines for Canadian Drinking Water Quality, Guideline Technical Document. Perfluorooctane Acid (PFOA). December 2018.
	Health Canada. 2018. Guidelines for Canadian Drinking Water Quality, Guideline Technical Document. Perfluorooctane Sulfonate (PFOS). December 2018.
	Health Canada. 2019. Summary Table: Health Canada Draft Guidelines, Screening Values and Toxicological Reference Values (TRVs) for Perfluoroalkyl Substances (PFAS). February, 2019.
	Health Canada. 2019. Water Talk - Drinking Water and Perfluoroalkyl Substances (PFAS). April, 2019.
Denmark	Danish Ministry of the Environment. 2015. Perfluoroalkylated substances: PFOA, PFOS and PFOSA. Evaluation of health hazards and proposal of a health based quality criterion for drinking water, soil and ground water. Environmental project No. 1665, 2015.
Germany	German Ministry of Health at the Federal Environment Agency. Assessment of PFOA in the drinking water of the German Hochsauerlandkreis. Statement by the Drinking Water commission (Trinkwasserkommission) of the German Ministry of Health at the Federal Environment Agency. June 21, 2006/revised July 13, 2006.
	von der Trenck et al. 2018. Significance thresholds for the assessment of contaminated groundwater: perfluorinated and polyfluorinated chemicals. Environ Sci Eur (2018) 30:19.
Italy	Valsecchi, S., Et al. Deriving environmental quality standards for perfluorooctanoic acid (PFOA) and related short chain perfluorinated alkyl acids. Journal of Hazardous Materials. Volume 323, Part A, 5 February 2017, Pages 84-98.
Netherlands	Rijksinstituut voor Volksgezondheid en Milieu. Verkenning doelstelling voor herstel verontreiniging met PFOS. Versie mei 2011.
Norway	NIVA og NGI. 2014. Kvalitetssikring av miljokvalitetsstandarder. September.
Sweden	Concawe. 2016. Environmental fate and effects of poly- and perfluoroalkyl substances (PFAS). Report no. 8/16.
UK	United Kingdom Drinking Water Inspectorate (DWI). Guardians of drinking water quality. 2009. Guidance on the Water Supply (Water Quality) Regulations 2000 specific to PFOS (perfluorooctane sulphonate) and PFOA (perfluorooctanoic acid) concentrations in drinking water. October 2009.

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Table 4-2. Residential soil standards and guidance values for PFAS.

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		Soil Screening Levels for Groundwater Protection (mg/kg)								Human Health Soil Screening Level (mg/kg)																			
		U.S.	U.S States							U.S.	U.S. States																		
	Agency	USEPA	Alaska	Maine	Michigan		North Carolina	Texas	Texas	USEPA	Alaska	Delaware	Iowa	Maine	Michigan	Minnesota	Nevada	New Hampshire	North Carolina	Texas	Texas	Australia			Western Australia	British Columbia, Canada	Canada	Denmark	Norway
	Department	Regions	DEC	DEP	DEQ		DEQ	CEQ	CEQ	Regions	DEC	DNREC	DNR	DEP	DEQ	PCA	DEP	DES - EHP	DEQ	CEQ	CEQ	HEPA/ DoEE	HEPA/ DoEE	HEPA/ DoEE	DER		HC		
	Year	2018	2017	2018	2016		2018	2017	2017	2018	2017	2016	2016	2018	2016	2016	2017	2017	2018	2017	2017	2018	2018	2018	2017	2018	2019	2015	2018
	Standard	RSL[a]	CL	RAG	GSIPC		PSRG	PCL	PCL	RSL[a]	CL[d]			RAG	GCC	SRV	BCL	DCRB	PSRG	PCL	PCL				ISL		SSV		
PFAS	CAS RN				Drinking Surface Water[b]	Non-drinking Surface Water[c]		0.5 acre source	30 acre source											0.5 acre source	30 acre source	Residential with garden/ accessible soil	Residential with minimal opportunities for soil access	Public open space			Agricultural/ Residential Parkland Land Use		
PFNA	375-95-1	--	--	--	--	--	--	0.003	0.0015	--	--	--	--	--	--	--	--	--	--	0.8	0.7	--	--	--	--	--	0.08	0.4	
PFOA	335-67-1	0.000172	0.0017	0.0095	0.35	10	0.017	0.003	0.0015	1.26	1.3	16	1.2	1.7	6	0.33	1.56	0.5	--	0.6	0.5	0.1	20	10	40	--	0.7	0.4	0.013
PFOS	1763-23-1	0.000378	0.003	0.021	0.00022	0.00024	--	0.05	0.025	1.26	1.3	6	1.8	1.7	3.2	1.7	1.56	0.5	--	1.5	1.5	0.009	2	1	4	1	2.1	0.4	0.0023
PFBA	375-22-4	--	--	--	--	--	--	0.2	0.098	--	--	--	--	--	--	63		--	--	180	160	--	--	--	--	--	114	0.4	
PFBS	375-73-5	0.13	--	7.1	--	--	0.91	0.11	0.053	1300	--	--	--	1,700	--	30	125	--	250	86	80	--	--	--	--	300	61	0.4	
PFPeA	2706-90-3	--	--	--	--	--	--	0.00032	0.00016	--	--	--	--	--	--	--	--	--	--	0.3	0.3	--	--	--	--	--	0.8	0.4	
PFHxS	355-46-4	--	--	--	--	--	--	0.002	0.001	--	--	--	--	--	--	--	--	--	--	0.3	0.2	0.009	2	1	4	--	2.3	0.4	
PFHxA	307-24-4	--	--	--	--	--	--	0.00048	0.00024	--	--	--	--	--	--	--	--	--	--	0.3	0.3	--	--	--	--	--	0.8	0.4	
PFHpA	375-85-9	--	--	--	--	--	--	0.0046	0.0023	--	--	--	--	--	--	--	--	--	--	1.5	1.5	--	--	--	--	--	0.8	0.4	
PFOSA	754-91-6	--	--	--	--	--	--	0.92	0.46	--	--	--	--	--	--	--	--	--	--	0.058	0.03	--	--	--	--	--	--	0.4	
PFDA	335-76-2	--	--	--	--	--	--	0.022	0.011	--	--	--	--	--	--	--	--	--	--	0.99	0.98	--	--	--	--	--	--	0.4	
PFDS	335-77-3	--	--	--	--	--	--	0.04	0.02	--	--	--	--	--	--	--	--	--	--	0.8	0.8	--	--	--	--	--	--	--	
PFUnA	2058-94-8	--	--	--	--	--	--	0.018	0.0092	--	--	--	--	--	--	--	--	--	--	0.8	0.8	--	--	--	--	--	--	--	
PFDoA	307-55-1	--	--	--	--	--	--	0.034	0.017	--	--	--	--	--	--	--	--	--	--	0.8	0.8	--	--	--	--	--	--	--	
PFTrDA	72629-94-8	--	--	--	--	--	--	0.061	0.03	--	--	--	--	--	--	--	--	--	--	0.6	0.6	--	--	--	--	--	--	--	
PFTeDA	376-06-7	--	--	--	--	--	--	0.11	0.056	--	--	--	--	--	--	--	--	--	--	0.5	0.5	--	--	--	--	--	--	--	
6:2 FTS	27619-97-2	--	--	--	--	--	--			--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.8	0.4	
8:2 FTS	39108-34-4	--	--	--	--	--	--			--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.8	0.4	

Notes:

a. Regional Screening Levels (RSL) for PFBS as presented in the USEPA Regional Screening Level (RSL) Summary Table (TR=1E-06, HQ=1) November 2014 through May 2018. As of June 2018, values for PFOA and PFOS calculated by the EPA RSL calculator using EPA OW RfDs, HQ of 1, and residential exposure assumptions. Note: RSL users screening sites with multiple contaminants should consult the USEPA (2018) RSL User's Guide and USEPA (1989) Risk Assessment Guidance.

b. Michigan soil GSIPCs for non-drinking surface water are developed to be protective of surface water that is NOT used as drinking water; these soil GSIPCs consider incidental ingestion of surface water and ingestion of fish that inhabit the water.

c. Michigan soil GSIPCs for drinking surface water are developed to be protective of surface water that is used as a drinking water source.

d. Alaska proposed cleanup levels for Human Health - most stringent value is from the "Over 40 Inch Zone".

c. Interim screening level for contaminated sites

d. The recommended approach to summing PFOA and PFOS is: $PFOS/SSV_{PFOS} + PFOA/SSV_{PFOA} \leq 1$

e. Applies to the individual results for PFOA, PFOS, PFNA, PFBA, PFBS, PFHxS, PFHxA, PFPeA, PFHpA, PFOSA, PFDA, AND 6:2 FTS as well as the sum of concentrations of these 12 PFAS.

Regulatory Agency
CEQ = Commission on Environmental Quality
DEC = Department of Environmental Conservation
DENR = Department of Environment and Natural Resources
DEP = Department of Environmental Protection
DES-EHP = Department of Environmental Services-Environmental Health Program
DEQ = Department of Environmental Quality
DER = Department of Environment Regulation
DoEE = Department of Environment and Energy
DNREC = Department of Natural Resources and Environmental Control
HC = Health Canada
HEPA = Heads of EPAs Australia and New Zealand
PCA = Pollution Control Agency
USEPA = United States Environmental Protection Agency

Standard
BCL= Basic Comparison Levels
CL = Cleanup Level
DCRB = Direct Contact Risk-Based concentration
GCC = Generic Cleanup Criteria
GSIPC = Groundwater Surface Water (GSI) Protection Criteria (GSIPC)
PCL = Protective Concentration Level
PSRG = Preliminary Soil Remediation Goal
RAG = Remedial Action Goal
RSL = Regional Screening Level
SL = Screening Level
SRV = Soil Reference Value
SSV = Soil Screening Value

Per- and polyfluoroalkyl substances
PFAS = per- and polyfluoroalkyl substances
PFOA = perfluorooctanoic acid (C8)
PFOS = perfluorooctane sulfonic acid (C8)
PFNA = perfluorononanoic acid (C9)
PFBA = perfluorobutyric acid (C4)
PFBS = perfluorobutane sulfonic acid (C4)
PFPeA = perfluoropentanoic acid (C5)
PFHxS = perfluorohexane sulfonic acid (C6)
PFHxA = perfluorohexanoic acid (C6)
PFHpA = perrfluoroheptanoic acid (C7)
PFOSA = perfluorooctane sulfonamide (C8)
PFDA = perfluorodecanoic acid (C10)
PFDS = perfluorodecane sulfonate (10)
PFUnA = perfluoroundecanoic acid (C11)
PFDoA = perfluorododecanoic acid (C12)
PFTrDA = perfluorotridecanoic acid (C13)
PFTeDA = perfluorotetradecanoic acid (C14)
6:2 FTS = 6:2 Fluorotelomer sulfonate
8:2 FTS = 8:2 Fluorotelomer sulfonate

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Table 4-2. Residential soil standards and guidance values for PFAS.

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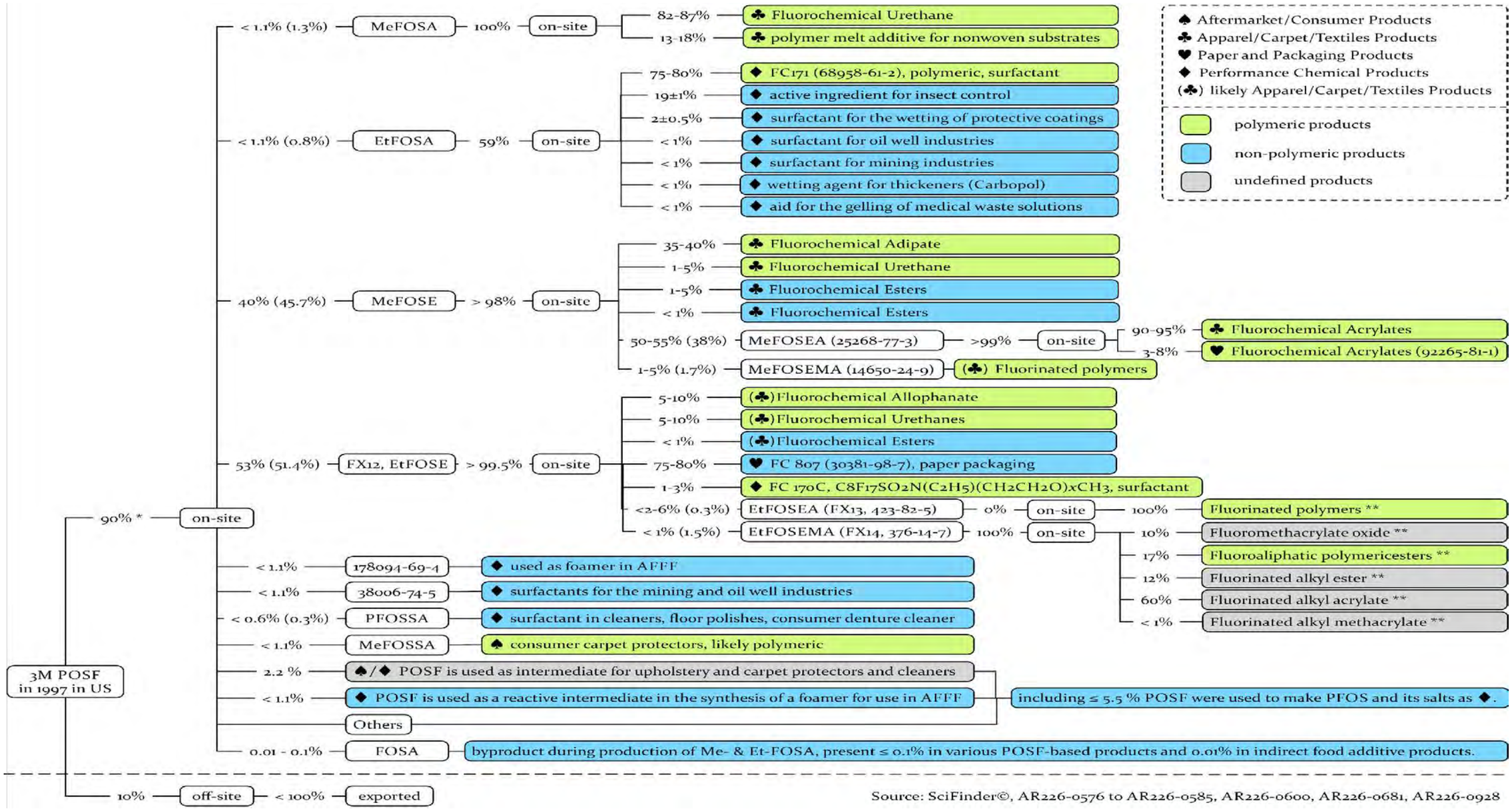
References: U.S. States

USEPA	United States Environmental Protection Agency (USEPA). 1989. Risk Assessment Guidance for Superfund (RAGS), Volume 1, Human Health Evaluation Manual (Part A). Interim Final. EPA/540/1-89/002. December.
	United States Environmental Protection Agency (USEPA). 2018. Regional Screening Levels (RSLs), RSL User's Guide, and RSL Calculator. May.
AK	Alaska Department of Environmental Conservation (ADEC). 2017. 18 AAC 75, Oil and Other Hazardous Substances Pollution Control. As amended through March 23, 2017. (p. 79)
DE	Delaware Department of Natural Resources and Environmental Control (DNREC). 2018. Screening Level Table. Division of Waste and Hazardous Substances. Site Investigation & Restoration Section. HSCA Reporting Level Table. Effective February 2018.
IA	Iowa Department of Natural Resources (IDNR). 2016. Land Recycling Program. Statewide standards for contaminants in soil and groundwater.
ME - RAGs	Maine Department of Environmental Protection (DEP). 2018. Maine Remedial Action Guidelines (RAGs) for Sites Contaminated with Hazardous Substances. October 19 (p. 47).
ME - SL	Maine Center for Disease Control and Prevention (CDC). 2016. Interdepartmental Memo from Maine CDC to DEP regarding Human Health Risk-Based Screening Levels for Perfluoroalkyl Compounds. August 17. Contact Maine CDC for Copy of this Reference.
MI	Michigan Department of Environmental Quality (DEQ). 2018. Remediation and Redevelopment Division. Cleanup Criteria Requirements for Response Activity (Formerly the Part 201 Generic Cleanup Criteria and Screening Levels). June 25.
MN	Minnesota Pollution Control Agency (PCA) Risk-Based Site Evaluation Guidance, Draft Soil Reference Value (SRV) Technical Support Document and SRV Spreadsheets as of September 2016.
NC	North Carolina Department of Environmental Quality (DEQ). 2018. Preliminary Soil Remediation Goals (PSRG) Table. February 2018.
NH	New Hampshire Department of Environmental Services-Environmental Health Program. Direct Contact Risk-Based Soil Concentration. Perfluorooctanoic Acid. CAS #335-67-1. June 17, 2016
	New Hampshire Department of Environmental Services-Environmental Health Program. Direct Contact Risk-Based Soil Concentration. Perfluorooctane Sulfonate. CAS #1763-23-1 . June 28, 2016
TX	Texas Commission on Environmental Quality (TCEQ). 2016. Texas Risk Reduction Program (TRRP) Tier 1 Protective Concentration Levels (PCLs).

References: International

Australia	Heads of EPAs Australia and New Zealand (HEPA) and the Australian Government Department of the Environment (DoEE). 2018. PFAS National Environmental Management Plan (NEMP). January.
W. Australia	Government of Western Australia Department of Environment Regulation (DER). 2017. *Interim Guideline on the Assessment and Management of Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS). Contaminated Sites Guidelines*. January.
British Colum	British Columbia Office of Legislative Counsel, Ministry of Attorney General, Victoria, British Columbia. Environmental Management Act. Contaminated Sites Regulation. B.C. Rg. 375/96. July 24, 2018..
Canada	Updates to Health Canada Soil Screening Values for Perfluoroalkylated Substances (PFAS). Health Canada. May 2019.
Denmark	Danish Ministry of the Environment. 2015. Perfluoroalkylated substances: PFOA, PFOS and PFOSA. Evaluation of health hazards and proposal of a health based quality criterion for drinking water, soil and ground water. Environmental project No. 1665, 2015.

Appendix B



Source: SciFinder©, AR226-0576 to AR226-0585, AR226-0600, AR226-0681, AR226-0928

* The percentages in this figure represent the relative yields of each product from its parent compound. The numbers in brackets are derived from the AR226-0600, while the others are taken from AR226-0576 to AR226-0681. It is unknown in which form or end products the chemicals were distributed off-site. In order to simplify the calculations, it is assumed that both on-site and off-site chemicals share the same use pattern as described in this figure.
** These chemicals are used as intermediates to produce surfactants, textile treating resins or paper sizings. The exact end use of each species is not yet determined.

Figure 1. Substance flow of POSF-based products manufactured by 3M in 1997 in the US (Wang, 2014)

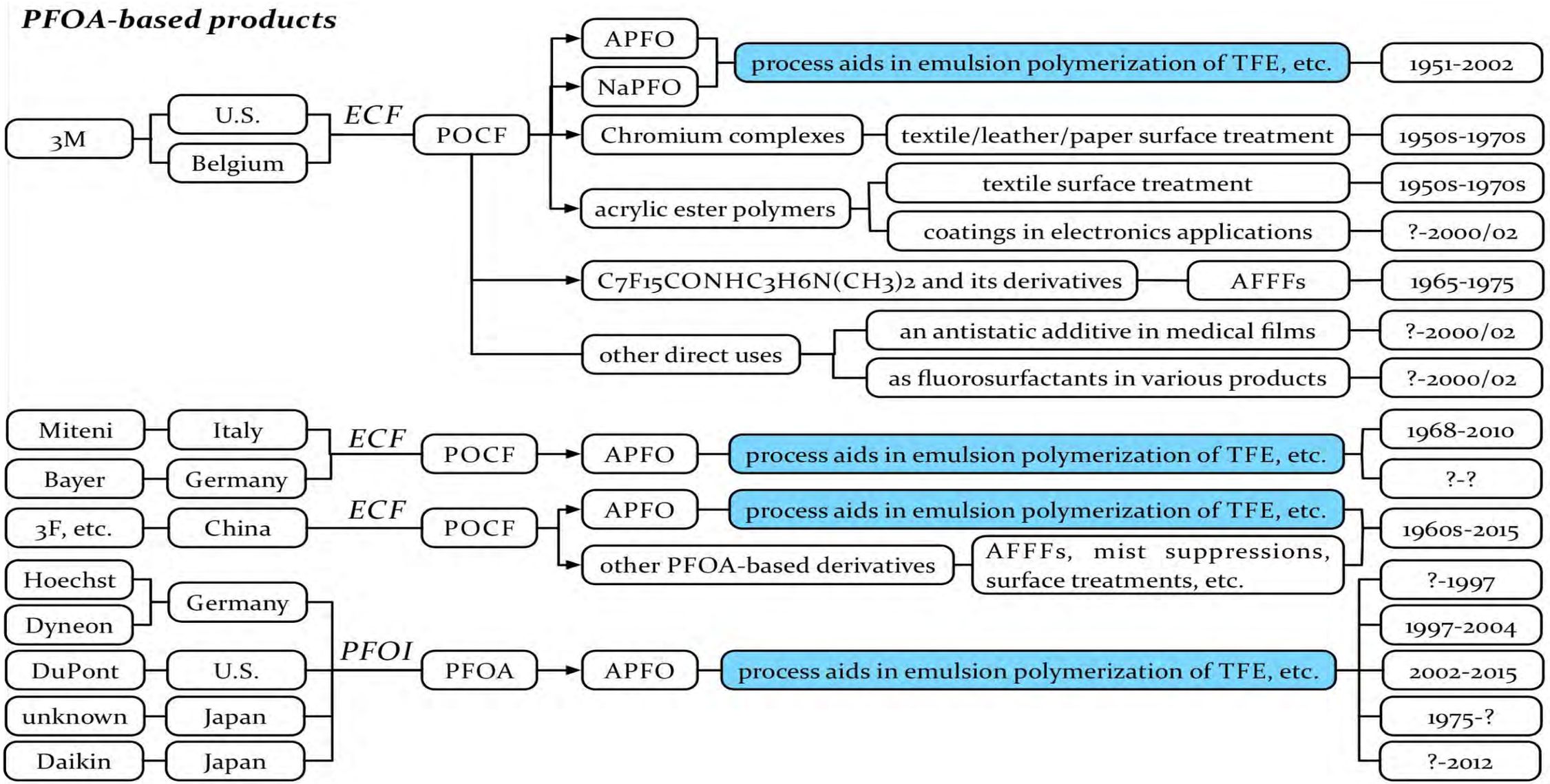
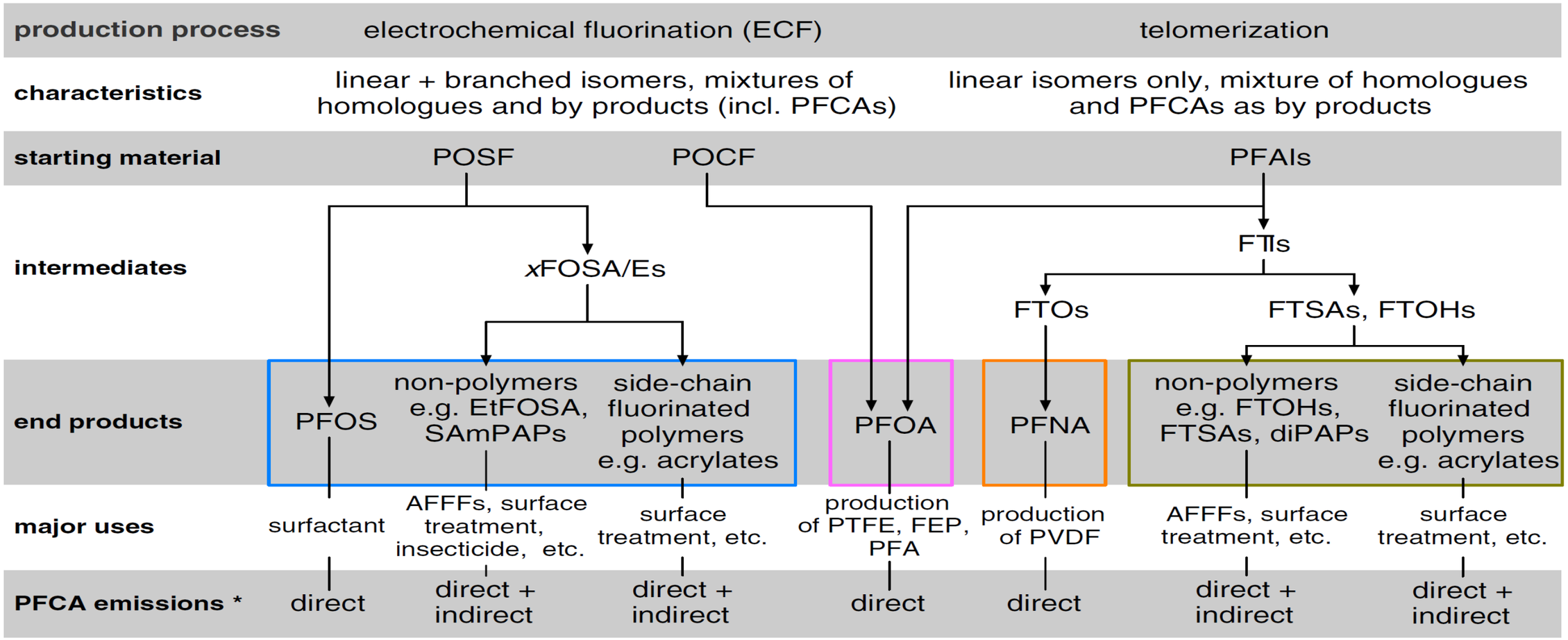


Figure 2. Historical and current production and identified uses of known PFOA-based products (Wang, 2014)



* direct = PFCAs are emitted as ingredients or impurities; indirect = PFCAs are emitted as degradation products of precursors

POSF-based products | PFOA-based products | PFNA-based products | fluorotelomer-based products

PFCA = perfluoroalkyl carboxylic acid; POSF = perfluorooctane sulfonyl fluoride; POCF = perfluorooctane carbonyl fluoride;
*x*FOSA/Es = (N-methyl/ethyl) perfluorooctane sulfonamide / sulfonamidoethanol; SAmPAPs = EtFOSE-based diphosphate;
PFAI = perfluoroalkyl iodide; FTI = fluorotelomer iodide; FTO = fluorotelomer olefins; FTSA = fluorotelomer sulfonic acid;
FTOH = fluorotelomer alcohol; PFOS = perfluorooctane sulfonic acid; PFOA = perfluorooctanoic acid; PFNA = perfluorononanoic acid;
diPAP = fluorotelomer diphosphate; AFFF = aqueous film-forming foam; PTFE = polytetrafluoroethylenee;
FEP = perfluorinated ethylene-propylene copolymers; PFA = perfluoroalkoxyl polymers; PVDF = polyvinylidene fluoride

Figure 3. Production and uses of PFOA, PFNA, POSF, and fluorotelomer-based products as well as their relevance to the emissions of C4–C14 PFCAs (Wang, 2014)

Electro-Chemical Fluorination (ECF) Cells
(Octanesulfonyl fluoride + HF + electricity)

Perfluorooctanesulfonyl fluoride (PFOSF)
chemical intermediate

Perfluorooctanesulfonic acid (PFOSA)
chemical intermediate
acid catalyst for photoresists

N-Alkylperfluorooctanesulfonamide (FOSA)
chemical intermediate
pesticide active ingredient

N-Alkylperfluorooctanesulfonamidoethanol (FOSE)
chemical intermediate

K, Li, DEA, NH_4 Salts
surfactant in fire fighting foam
surfactant for alkaline cleaners
emulsifier in floor polish
mist suppressant for metal plating baths
surfactant for etching acids for circuit boards
pesticide active ingredient for ant bait traps

Amines
mist suppressant for metal plating baths

Quaternary Ammonium Salts
mist suppressant for metal plating baths

Amphoterics
water/solvent repellency for leather/paper

Carboxylates
antistatic agent in photographic paper

Amides
pesticide active ingredient

Oxazolidinones
waterproofing casts/wound dressings

Alcohols

Silanes

Alkoxylates

Fatty Acid Esters

Adipates

Urethanes

Polyesters

Acrylates

Copolymers

Phosphate Esters

soil/oil/water repellency for:
carpet
fabric/upholstery
apparel
leather
metal/glass

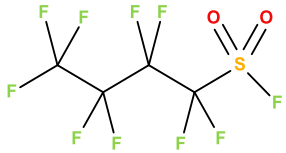
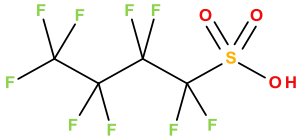
oil/water repellency for:
plates
food containers
bags
wraps
folding cartons
containers
carbonless forms
masking papers

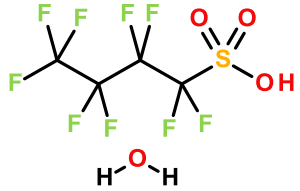
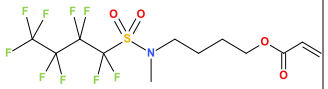
Figure 4. Perfluorooctyl Sulfonates: Major Product Categories (OECD, 2002)

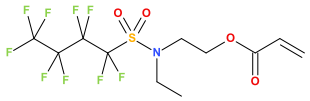
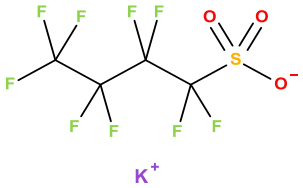
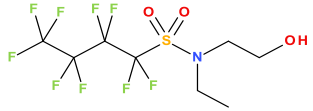
Appendix C

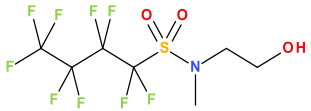
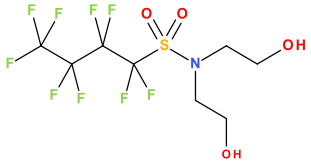
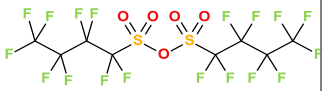
Appendix C – Export of Appendix B (Gross list of PFBS-related substances) from the M-759/2017 *Investigation of Sources to PFBS in the Environment*. NGI, 2017.

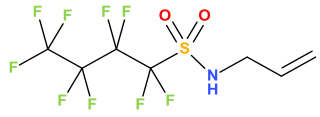
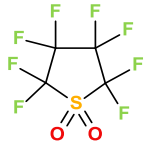
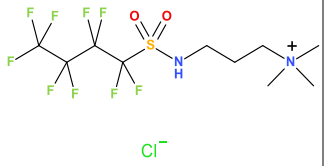
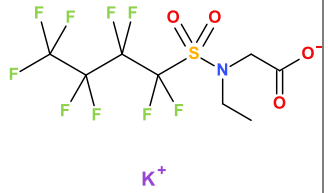
Appendix B Gross list of PFBS-related substances

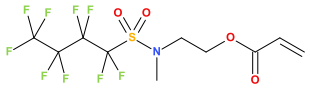
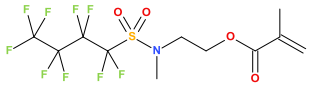
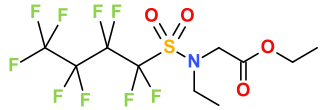
EC No	CAS No	Chemical Structure	Substance names and abbreviation	Chemical formula	MW	Melting and boiling point	Density	Other properties	C&L Inven-tory, Nov 2016
206-792-6	375-72-4		Perfluorobutane sulfonyl fluoride 1,1,2,2,3,3,4,4,4-No-nafluorobutane-1-sul-fonyl fluoride PBSF	$C_4F_{10}O_2S$	302.09	MP: -110 °C BP: 64-66	1.682 g/mL 25ºC 1,716 g/mL 20 ºC	Vapour pressure: 125 mm Hg 20 ºC; 16665 Pa Clear colourless liquid, moisture sensitive Solubility in water (23 ºC): <0.3 mg/L Refractive index: 1.3	Yes
206-793-1	375-73-5		Perfluorobutane sulfonic acid 1,1,2,2,3,3,4,4,4-No-nafluorobutane-1-sul-fonic acid PFBS	$C_4HF_9O_3S$	300.10	MP: 76-84 °C BP: 211 °C BP: 112-114 °C/ 14 mmHg	1.811 g/mL at 25 °C	Colourless liquid Solubility in water 0,5 g/L Refractive index: 1.3230	Yes

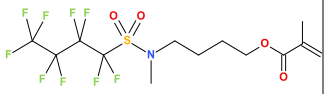
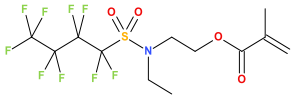
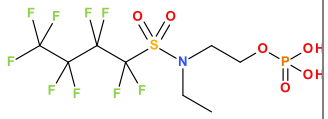
EC No	CAS No	Chemical Structure	Substance names and abbreviation	Chemical formula	MW	Melting and boiling point	Density	Other properties	C&L Inventory, Nov 2016
206-793-1	59933-66-3		Perfluorobutane sulfonic acid, hydrate 1,1,2,2,3,3,4,4,4-Nonafluorobutane-1-sulfonic acid , hydrate PFBS, hydrate	$C_4H_3F_9O_4S$	318.11				Yes
212-382-8	812-94-2		*N*-(4-Hydroxybutyl) *N*-methyl perfluorobutanesulfonamide 1,1,2,2,3,3,4,4,4-Nonafluoro-*N*-(4-hydroxybutyl) *N*- methyl butane-1-sulfonamide MeFBSB	$C_9H_{12}F_9NO_3S$	385.245	BP: 286.6 °C	1.528 g/cm^3	Flash Point: 127.1°C Refractive index: 1.384 Vapour Pressure. 0.000296mmHg at 25°C	No
216-085-4	1492-87-1		*N*-Methyl perfluorobutane-sulfonamidobutyl acrylate 4-[Methyl[(nonafluorobutyl) sulfonyl]amino]butyl acrylate	$C_{12}H_{14}F_9NO_4S$	439.29	BP: 332.5 °C	1.451 g/cm^3	Flash Point: 154.9°C Refractive index: 1.397 Vapour pressure: 0.000145 mmHg at 25°C	No

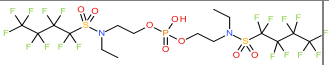
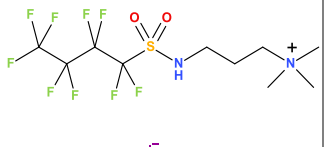
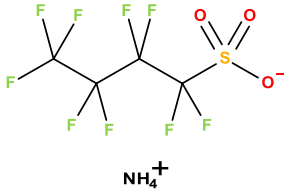
EC No	CAS No	Chemical Structure	Substance names and abbreviation	Chemical formula	MW	Melting and boiling point	Density	Other properties	C&L Inventory, Nov 2016
241-351-1	17329-79-2		*N*-Ethyl perfluorobutane sulfonamidoethyl acrylate 2-[Ethyl[(nonafluorobutyl)-sulfonyl]amino]ethyl acrylate EtFBSAC	$C_{11}H_{12}F_9NO_4S$	425.27	BP: 317.5 °C	1.485 g/cm^3	Flash Point: 145.8°C Refractive index: 1.393	No
249-616-3	29420-49-3		Potassium perfluorobutane sulfonate Potassium 1,1,2,2,3,3,4,4,4-nonafluorobutane-1-sulfonate K-PFBS	$C_4F_9KO_3S$	338.19	MP: 270 °C	0.69 g/cm^3	White crystalline powder/solid Solubility in water: 46 g/L at 20ºC Vapour pressure: <1.22 × 10^{-5} Pa	Yes
252-035-8	34449-89-3		*N*-Ethyl perfluorobutane-sulfonamidoethanol EtFBSE	$C_8H_{10}F_9NO_3S$	371.22	BP: 265.9 °C	1.575 g/cm^3	Vapour Pressure: 0.00122 mmHg at 25°C Refractive index: 1.378 Flash point: 114.6°C	No

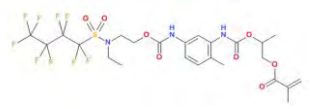
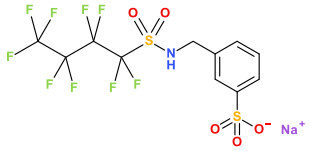
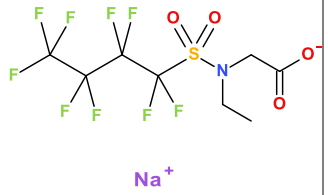
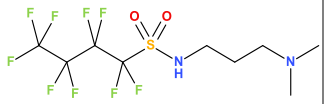
EC No	CAS No	Chemical Structure	Substance names and abbreviation	Chemical formula	MW	Melting and boiling point	Density	Other properties	C&L Inventory, Nov 2016
252-043-1	34454-97-2		*N*-Methyl perfluorobutane-sulfonamidoethanol 1,1,2,2,3,3,4,4,4-Nonafluoro-*N*-(2-hydroxyethyl)-*N*-methylbutane-1-sulfonamide MeFBSE	$C_7H_8F_9NO_3S$	357.19	MP: 64.7 °C BP: 258.9 °C	1.56 g/cm³ at 23 C	White to yellow waxy solid Vapour pressure = $3.0x10^{-5}$ mm Hg at 20 °C LogPow = 2,67 Water solubility: 141 mg/L at 23-24 °C.	Yes
252-044-7	34455-00-0		*N,N*-Bis(2-hydroxyethyl) perfluorobutanesulfonamide 1,1,2,2,3,3,4,4,4-Nonafluoro-*N,N*-bis(2-hydroxyethyl)butane-1-sulfonamide	$C_8H_{10}F_9NO_4S$	387.22	BP: 319.7 ºC	1.661 g/cm³	Flash Point: 147.1ºC Refractive Index: 1.395	Yes
253-270-9	36913-91-4		Perfluorosulfonic anhydride 1,1,2,2,3,3,4,4,4-Nonafluorobutane-1-sulfonic anhydride	$C_8F_{22}O_5S_2$	582.18	BP: 84 °C	1.898 g/mL 25°C	Refractive index: 1.3210	Yes

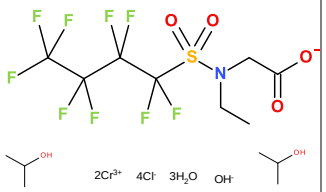
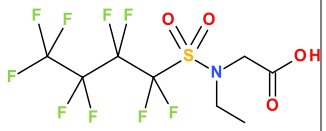
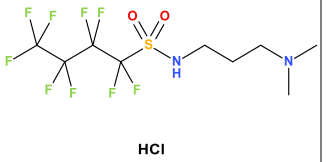
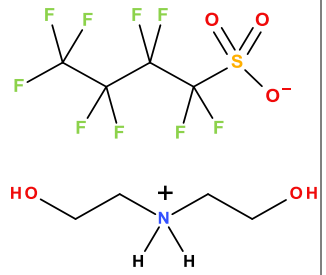
EC No	CAS No	Chemical Structure	Substance names and abbreviation	Chemical formula	MW	Melting and boiling point	Density	Other properties	C&L Inventory, Nov 2016
255-013-6	40630-65-7		*N*-Allyl perfluorobutanesulfonamide *N*-Allyl 1,1,2,2,3,3,4,4,4-nonafluorobutane-1-sulfonamide	$C_7H_6F_9NO_2S$	339.177	BP: 201.1 °C	1.554 g/cm^3	Vapour Pressure: 0.314 mmHg at 25°C Refractive index: 1.356 Flash Point:75.4ºC	No
255-641-0	42060-64-0		Perfluorosulfolane Octafluorotetrahydro-thiophene 1,1-dioxide	$C_4F_8O_2S$	264.092	BP: 180.9ºC	1.88 g/cm^3	Flash Point: 63.2ºC Refractive Index: 1.327 Vapour Pressure: 1.19 mm Hg at 25°C	Yes
258-597-0	53518-00-6		Perfluorobutanesulfonamide*N*-(*N′,N′,N′*-trimethyl-propanaminium) chloride	$C_{10}H_{16}ClF_9N_2O_2S$	434.75				No
266-728-8	67584-51-4		Potassium *N*-ethyl-*N*-[(nonafluorobutyl)sulphonyl]glycinate	$C_8H_7F_9KNO_4S$	423.291				No

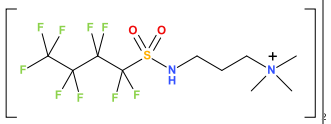
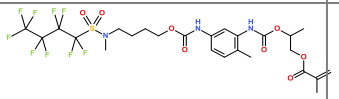
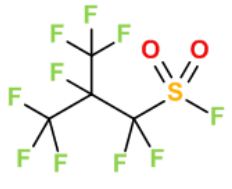
EC No	CAS No	Chemical Structure	Substance names and abbreviation	Chemical formula	MW	Melting and boiling point	Density	Other properties	C&L Inventory, Nov 2016
266-733-5	67584-55-8		*N*-Methyl perfluorobutane-sulfonamidoethyl acrylate 2-[Methyl[(nonafluorobutyl)-sulfonyl]amino]ethyl acrylate MeFBSAC C_4-acrylate	$C_{10}H_{10}F_9NO_4S$	411.239	MP: 54.7 °C BP: 300.5 °C	1.524 g/cm^3	White waxy solid Vapour pressure: 0,25 Pa at 25 °C Water solubility: 2 mg/L at 22 °C Flash Point: 135.6°C Refractive index: 1.388	Yes
266-737-7	67584-59-2		*N*-Methyl perfluorobutane-sulfonamidoethyl methacrylate 2-[Methyl[(nonafluorobutyl)-sulfonyl]amino]ethyl methacrylate MeFBSMAC	$C_{11}H_{12}F_9N\ O_4S$ 36737450	425.27	BP: 317.2 ºC	1.486 g/cm^3	Refractive Index: 1.392	No
266-741-9	67584-63-8		Ethyl *N*-ethyl-*N*-[(nonafluorobutyl)sulfonyl]-glycinate	$C_{10}H_{12}F_9NO_4S$	413.255	BP: 290.5 °C	1.504 g/cm^3	Flash Point: 129.5°C Refractive index: 1.382	No

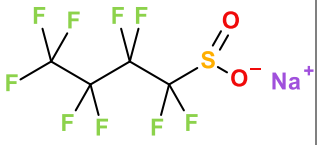
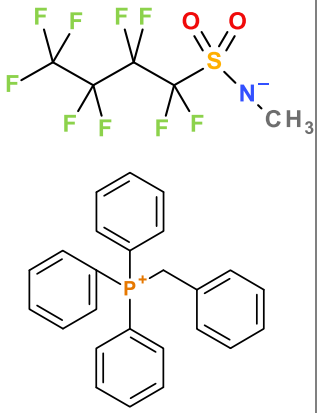
EC No	CAS No	Chemical Structure	Substance names and abbreviation	Chemical formula	MW	Melting and boiling point	Density	Other properties	C&L Inventory, Nov 2016
267-706-0	67906-39-2		*N*-Methyl perfluorobutane-sulfonamidobutyl methacrylate 4-[Methyl[(nonafluorobutyl)-sulfonyl]amino]butyl methacrylate	$C_{13}H_{16}F_9NO_4S$	453.32	BP: 348.2 °C	1.421 g/cm^3	Flash Point:164.4°C Refractive Index: 1.4	No
267-834-7	67939-33-7		*N*-Ethyl perfluorobutane sulfonamidoethyl methacrylate 2-[Ethyl[(nonafluorobutyl) sulfonyl]amino]ethyl methacrylate EtFBSMAC	$C_{12}H_{14}F_9NO_4S$	439.294	BP: 333.6 °C	1.452 g/cm^3	Flash Point: 155.6°C	No
267-861-4	67939-89-3		*N*-Ethylperfluorobutane-sulfonamidoethyl phosphate [Perfluorobutane sulfonamide-*N*-ethyl]-*N*-ethyl dihydrogenphosphate MonoPAP	$C_8H_{11}F_9NO_6PS$	451.20	BP: 391.7 °C	1.711 g/cm^3	Flash Point: 190.7°C Refractive index: 1.403	No

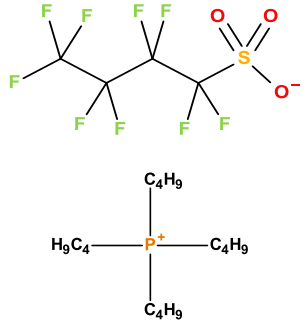
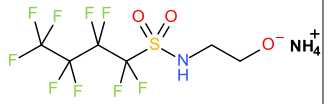
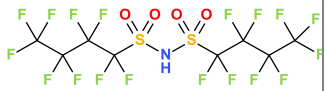
EC No	CAS No	Chemical Structure	Substance names and abbreviation	Chemical formula	MW	Melting and boiling point	Density	Other properties	C&L Inventory, Nov 2016
267-864-0	67939-91-7		Bis[2-[ethyl(perfluorobutanesulfonyl)amino]ethyl] hydrogenphosphate 1-Butanesulfonamide, N,N'-(phosphinicobis(oxy-2,1-ethanediyl))bis(N-ethyl-1,1,2,2,3,3,4,4,4-nonafluoro-	$C_{16}H_{19}F_{18}N_2O_8PS_2$	804.402				No
267-868-2	67939-95-1		Perfluorobutanesulfonamide*N*-(*N′,N′,N′*-trimethyl propanaminium) iodide	$C_{10}H_{16}F_9IN_2O_2S$	526.20				No
269-513-7	68259-10-9		Ammonium perfluorobutanesulfonate Ammonium 1,1,2,2,3,3,4,4,4-nonafluorobutane-1-sulfonate	$C_4H_4F_9NO_3S$	317.13				Yes

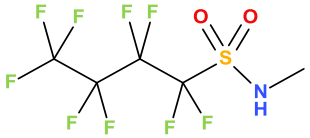
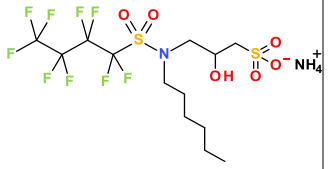
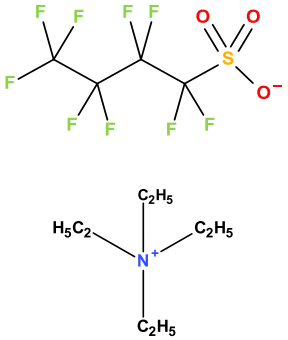
EC No	CAS No	Chemical Structure	Substance names and abbreviation	Chemical formula	MW	Melting and boiling point	Density	Other properties	C&L Inventory, Nov 2016
269-581-8	68298-76-0		2-[[[[5-[[[2-[Ethyl[(perfluoro-butyl)sulfonyl]amino]ethoxy]carbonyl]amino]-2-methylphenyl]amino]carbonyl]oxy]propyl methacrylate	$C_{24}H_{28}F_9N_3O_8S$	689.546		1.45 g/cm^3	Refractive index: 1.485	No
269-601-5	68299-19-4		Sodium [[(perfluorobutyl)-sulfonyl]amino]toluene sulfonate	$C_{11}H_8F_9NO_5S_2Na$	491.282				No
271-445-8	68555-68-0		Sodium *N*-ethyl-*N*-[(perfluorobutyl)sulfonyl] glycinate	$C_8H_7F_9NNaO_4S$	407.185	BP: 300.2 °C		Flash point: 135.3°C Vapour pressure: 0.000269 mmHg at 25°C	No
271-455-2	68555-77-1		N-[3-(dimethylamino)propyl]-1,1,2,2,3,3,4,4,4-nonafluorobutane-1-sulfonamide	$C_9H_{13}F_9N_2O_2S$	384.262	BP: 263.7 °C	1.458 g/cm^3	Flash Point: 113.3°C Refractive index: 1.381	No

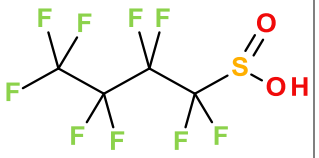
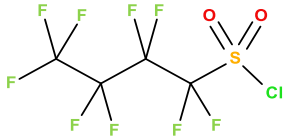
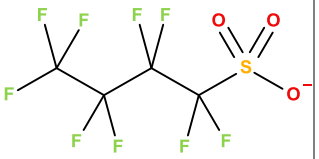
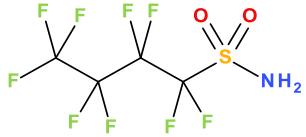
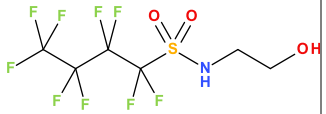
EC No	CAS No	Chemical Structure	Substance names and abbreviation	Chemical formula	MW	Melting and boiling point	Density	Other properties	C&L Inventory, Nov 2016
272-646-3	68900-97-0		Chromium (III) chloride hydroxide *N*-ethyl-*N*-perfluorobutyl sulfonyl glycinate	$C_{14}H_{28}Cl_4Cr_2F_9NO_9S$	803.228				No
273-332-9	68957-33-5		*N*-Ethyl perfluorobutane sulfonamidoacetic acid *N*-Ethyl-*N*-[(perfluorobutyl)-sulfonyl]glycine EtFBSAA	$C_8H_8F_9NO_4S$	385.201	BP: 300.2 °C	1.655 g/cm^3		No
273-351-2	68957-59-5		*N*-(3-(dimethyl)amino-propyl)perfluorobutane-sulfonamide monohydro-chloride	$C_9H_{14}ClF_9N_2O_2S$	420.72	BP: 263.7 °C		Flash point: 113.3°C Vapour Pressure: 0.0101 mm Hg at 25°C	No
274-465-5	70225-18-2		Bis(2-hydroxyethyl) ammonium perfluorobutanesulfonate 1,1,2,2,3,3,4,4,4-Nonafluorobutane-1-sulfonic acid, compound with 2,2'-iminodiethanol (1:1)	$C_8H_{12}F_9NO_5S$	405.232				No

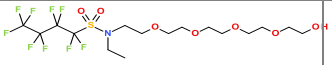
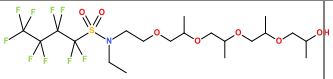
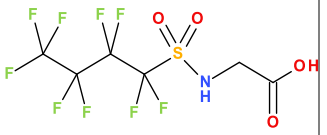
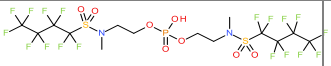
EC No	CAS No	Chemical Structure	Substance names and abbreviation	Chemical formula	MW	Melting and boiling point	Density	Other properties	C&L Inventory, Nov 2016
274-467-6	70225-22-8	 SO_4^{2-}	Di[Perfluorobutanesulfon-amide *N*-(*N′,N′,N′*-trimethyl propanaminium)] sulfate	$C_{20}H_{32}F_{18}N_4O_8S_3$	894.647				No
275-008-2	70900-38-8		2-[[[[2-methyl-5-[[[4-methyl-[(perfluorobutyl)sulfonyl]-amino]butoxy]carbonyl]-amino]phenyl]amino]-carbonyl]oxy]propyl methacrylate	$C_{25}H_{30}F_9N_3O_8S$	703.573		1.43 g/cm³	Refractive Index: 1.484	No
290-846-9	90268-45-4	 *Isobutanesulfonyl fluoride – one of the theoretically three isomers of the substance. The actual composition is not known.	Perfluorobutane sulfonyl fluoride, branched	$C_4F_{10}O_2S$	302.09				No

EC No	CAS No	Chemical Structure	Substance names and abbreviation	Chemical formula	MW	Melting and boiling point	Density	Other properties	C&L Inventory, Nov 2016
422-100-7	102061-82-5		Sodium perfluoro butanesulfinate Sodium 1,1,2,2,3,3,4,4,4-nonafluoro-1-butanesulfinate Na-PFBSi	$C_4HF_9O_2S.Na$	306.08		2.13 at 20 °C	Solid Vapour pressure: 2.1 Pa at 20 C	Yes
442-960-7	332350-93-3		Triphenyl(phenylmethyl)phosphonium 1,1,2,2,3,3,4,4,4-nonafluoro-N-methyl-1-butanesulfonamide (1:1)	$C_5H_3F_9NO_2S$ $C_{25}H_{22}P$	666.2		1.8 g/cm^3		Yes

EC No	CAS No	Chemical Structure	Substance names and abbreviation	Chemical formula	MW	Melting and boiling point	Density	Other properties	C&L Inventory, Nov 2016
444-440-5	220689-12-3		Tetrabutylphosphonium perfluorobutanesulfonate	$C_{20}H_{36}F_9O_3PS$	558	MP: 73.4 °C BP: ca. 285 °C	1.265 g/cm³ (20.1 °C)	Waxy solid Vapour pressure < 0.003 Pa at 25 °C $LogP_{ow}$ = 1.55-1.56 at 20 °C Water solubility: 824 mg/L at 20 °C, pH: 7.56	Yes
454-680-2	484024-67-1		Ammonium perfluorosulfonamido-ethanolate 1-Butanesulfonamide, 1,1,2,2,3,3,4,4,4-nonafluoro-N-(2-hydroxyethyl)-, monoammonium salt	$C_6H_8F_9N_2O_3S$	360,17				Yes
609-746-7	39847-39-7		Bis(perfluorobutane-sulfonyl)imide Bis(1,1,2,2,3,3,4,4,4-nonafluoro-1-butane-sulfonyl)imide	$C_8HF_{18}NO_4S_2$	581.19	BP: 274 °C	1.875 g/cm³	Vapour pressure: 0.006 mmHg at 25 °C Flash point: 119°C Refractive index: 1.326	Yes

EC No	CAS No	Chemical Structure	Substance names and abbreviation	Chemical formula	MW	Melting and boiling point	Density	Other properties	C&L Inventory, Nov 2016
614-396-3	68298-12-4		*N*-Methyl perfluorobutane sulfonamide *N*-Methyl 1,1,2,2,3,3,4,4,4-nonafluorobutane- 1-sulfonamide, MeFBSA	$C_5H_4F_9NO_2S$	313.138	BP: 159.2 °C	1.646 g/cm^3	Flash Point: 50.1°C	Yes
643-022-1	606967-06-0		1-Propanesulfonic acid, 3- [hexyl[(nonafluorobutyl)sulfonyl]amino]-2-hydroxy-, monoammonium salt	$C_{13}H_{23}F_9N_2O_6S_2$	538	BP: 118 ºC	1.1 g/ml	100% water soluble Vapour pressure 15.2 mm Hg at 20ºC	Yes
700-536-1	25628-08-4		Tetraethylammonium perfluorobutanesulfonate *N,N,N*-Triethylethanaminium 1,1,2,2,3,3,4,4,4-nonafluorobutane-1-sulfonate,	$C_{12}H_{20}F_9NO_3S$	541.56 429.3	MP: 50-53 °C MP: 184 C BP: 315 C	1.35 at 20 °C	Crystalline solid Ionic liquid Water solubility: 880 g/L at 20°C and pH = 5 Vapour pressure: 0 Pa	Yes

EC No	CAS No	Chemical Structure	Substance names and abbreviation	Chemical formula	MW	Melting and boiling point	Density	Other properties	C&L Inventory, Nov 2016
468-070-9	34642-43-8 (the pre-registration does not indicate a CAS number)		Perfluorobutanesulfinic acid 1,1,2,2,3,3,4,4,4-Nonafluoro-butane-1-sulfinic acid PFBSi	$C_4HF_9O_2S$	284.10				Yes
-	2991-84-6		Perfluorobutanesulfonyl chloride 1,1,2,2,3,3,4,4,4-Nonafluoro-1-butane-1-sulfonyl chloride PBSCl	$C_4ClF_9O_2S$	318.55				Yes
-	45187-15-3		Perfluorobutane sulfonate anion	$C_4F_9O_3S$	299.10				No
-	30334-69-1		Perfluorobutanesulfonamide FBSA	$C_4H_2F_9NO_2S$	299.12				No
-	34454-99-4		Perfluorobutanesulfonamidoethanol	$C_6H_6F_9NO_3S$	343.167				No

EC No	CAS No	Chemical Structure	Substance names and abbreviation	Chemical formula	MW	Melting and boiling point	Density	Other properties	C&L Inventory, Nov 2016
-	68298-79-3		Polyethylene glycol *N*-ethyl-perfluorobutanesulfonamide PEG *N*-EtFBSE	$C_{16}H_{26}F_9NO_7S$ $C_{10}H_{14}F_9NO_4S$	547.43 415.272	BP: 328.8 °C	1.51 g/cm^3	Refractive index: 1.391 Flash point: 152.7°C Vapour Pressure: 1.38 x 10^{-5} mm Hg at 25°C	No
-	68310-18-9		Polypropylene glycol *N*-ethyl-perfluorobutanesulfonamide PPG *N*-EtFBSE	$C_{20}H_{34}F_9NO_7S$	603.54				No
-	347872-22-4		Perfluorobutane sulfonamidoacetic acid FBSAA	$C_6H_4F_4NO_3S$	357.15				No
-	120945-47-3		Bis[2-(*N*-methyl-perfluorobutane sulfonamido)ethoxy] phosphoric acid	$C_{14}H_{15}F_{18}N_2O_8PS_2$					No

EC No	CAS No	Chemical Structure	Substance names and abbreviation	Chemical formula	MW	Melting and boiling point	Density	Other properties	C&L Inventory, Nov 2016
-	1017237-78-3	Polymeric	Fluoroacrylate copolymer 2-Propenoic acid, 2-[methyl[(1,1,2,2,3,3,4,4,4-nonafluorobutyl)-sulfonyl]amino]ethyl ester, telomer with 3-mercapto-1,2-propanediol, 2-methyloxirane polymer with oxirane di-2-propenoate (MSDS of 3M FC-4434)	Unspecified	NA	BP: 200 °C	1.15 g/mL at 25 °C	Vapour pressure 0.29 mm Hg at 20°C	Yes

Appendix D

Appendix D – Figures 2-16 of *PFBS in the Environment: Monitoring and Physical-Chemical Data Related to the Environmental Distribution of Perfluorobutanesulfonic Acid.* NGI, 2018

Appendix D – (*Figures 2-16*) of PFBS in the Environment: Monitoring and Physical-Chemical Data Related to the Environmental Distribution of Perfluorobutanesulfonic Acid. NGI, 2018

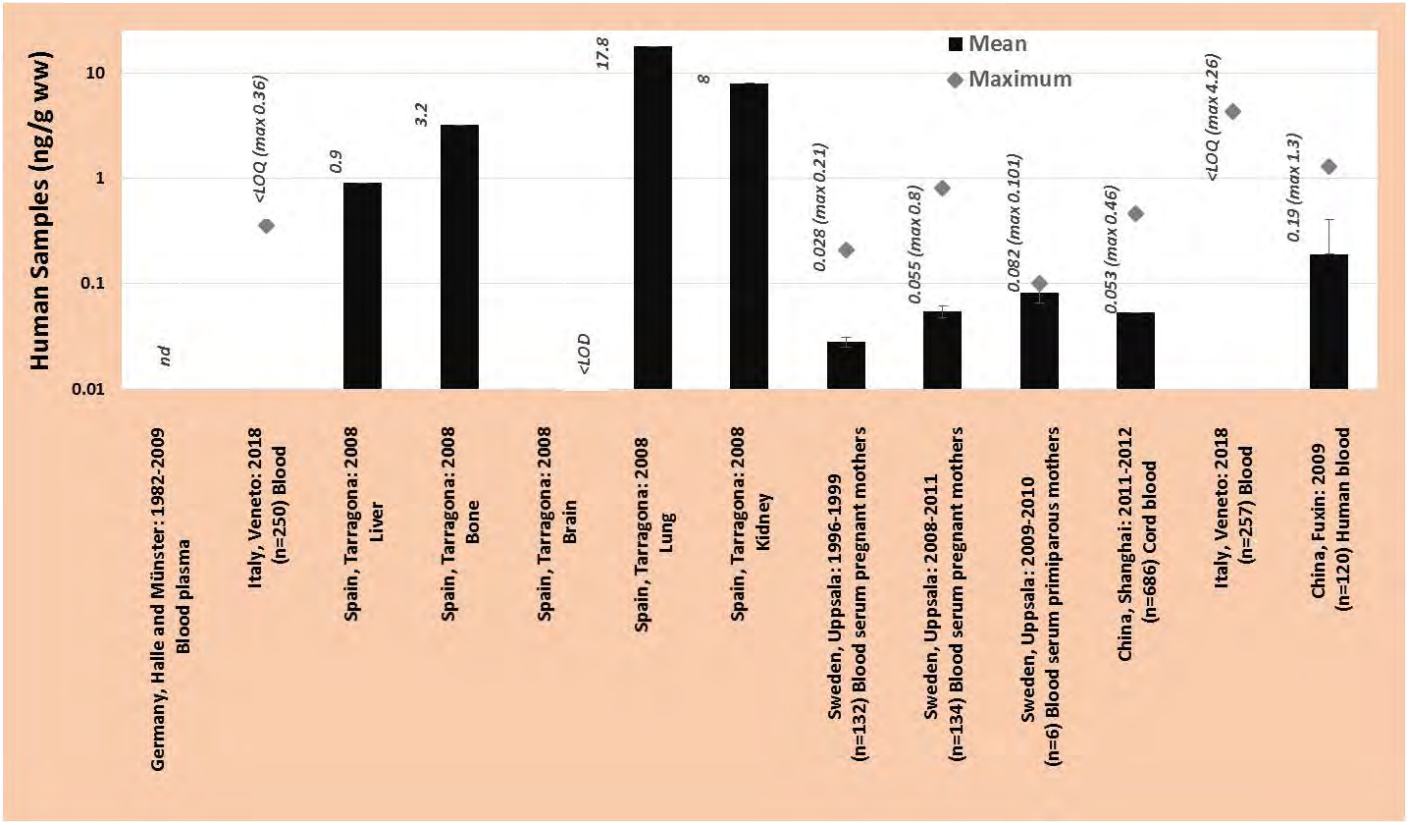


Figure 14. Concentrations of PFBS in human samples (ng/g ww), page 19 of PFBS in the Environment: Monitoring and Physical-Chemical Data Related to the Environmental Distribution of Perfluorobutanesulfonic Acid. NGI, 2018

Appendix D – (*Figures 2-16*) of PFBS in the Environment: Monitoring and Physical-Chemical Data Related to the Environmental Distribution of Perfluorobutanesulfonic Acid. NGI, 2018

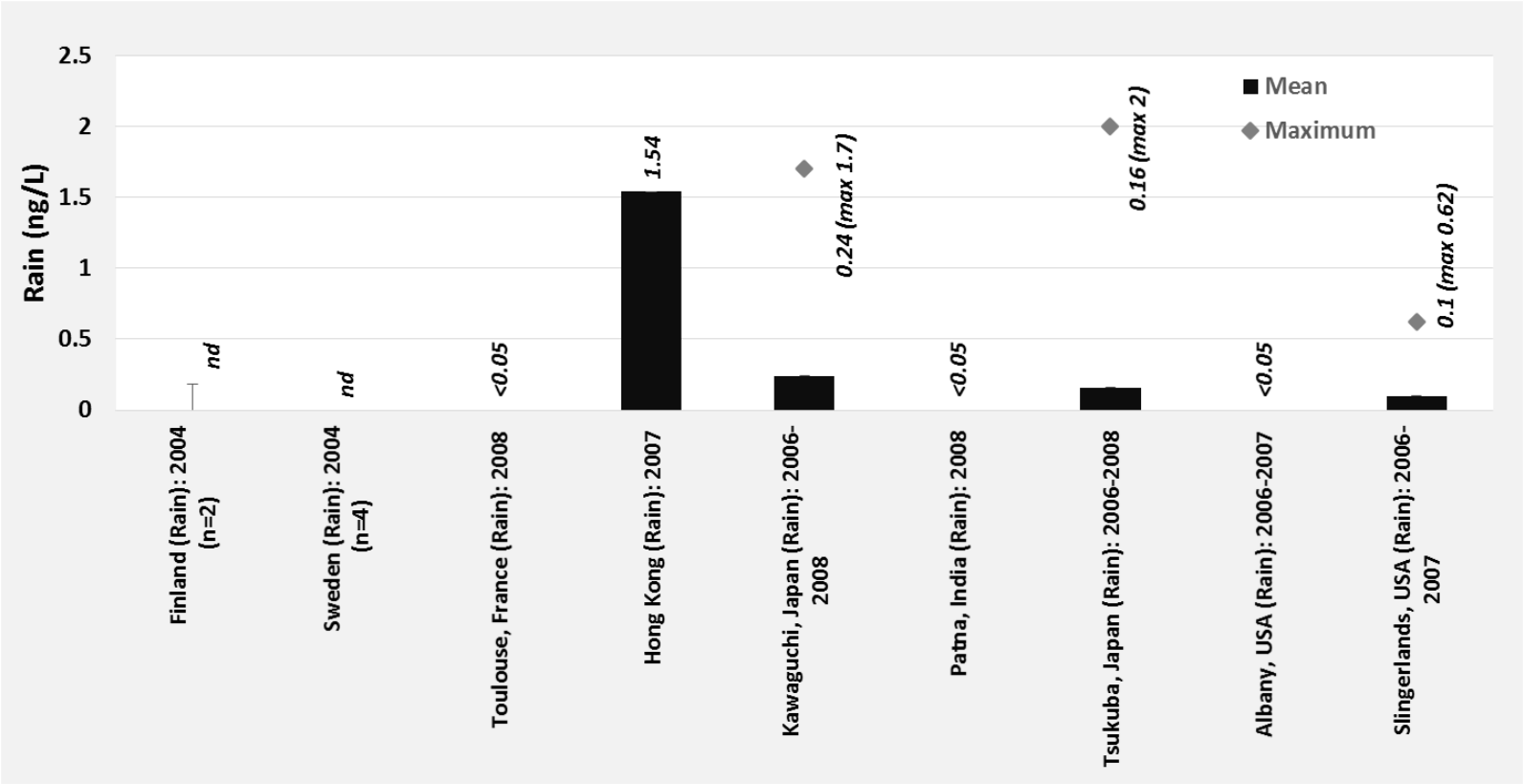


Figure 2. Environmental concentrations of PFBS in rain (ng/L). page 21, of PFBS in the Environment: Monitoring and Physical-Chemical Data Related to the Environmental Distribution of Perfluorobutanesulfonic Acid. NGI, 2018

Appendix D – (*Figures 2-16*) of PFBS in the Environment: Monitoring and Physical-Chemical Data Related to the Environmental Distribution of Perfluorobutanesulfonic Acid. NGI, 2018

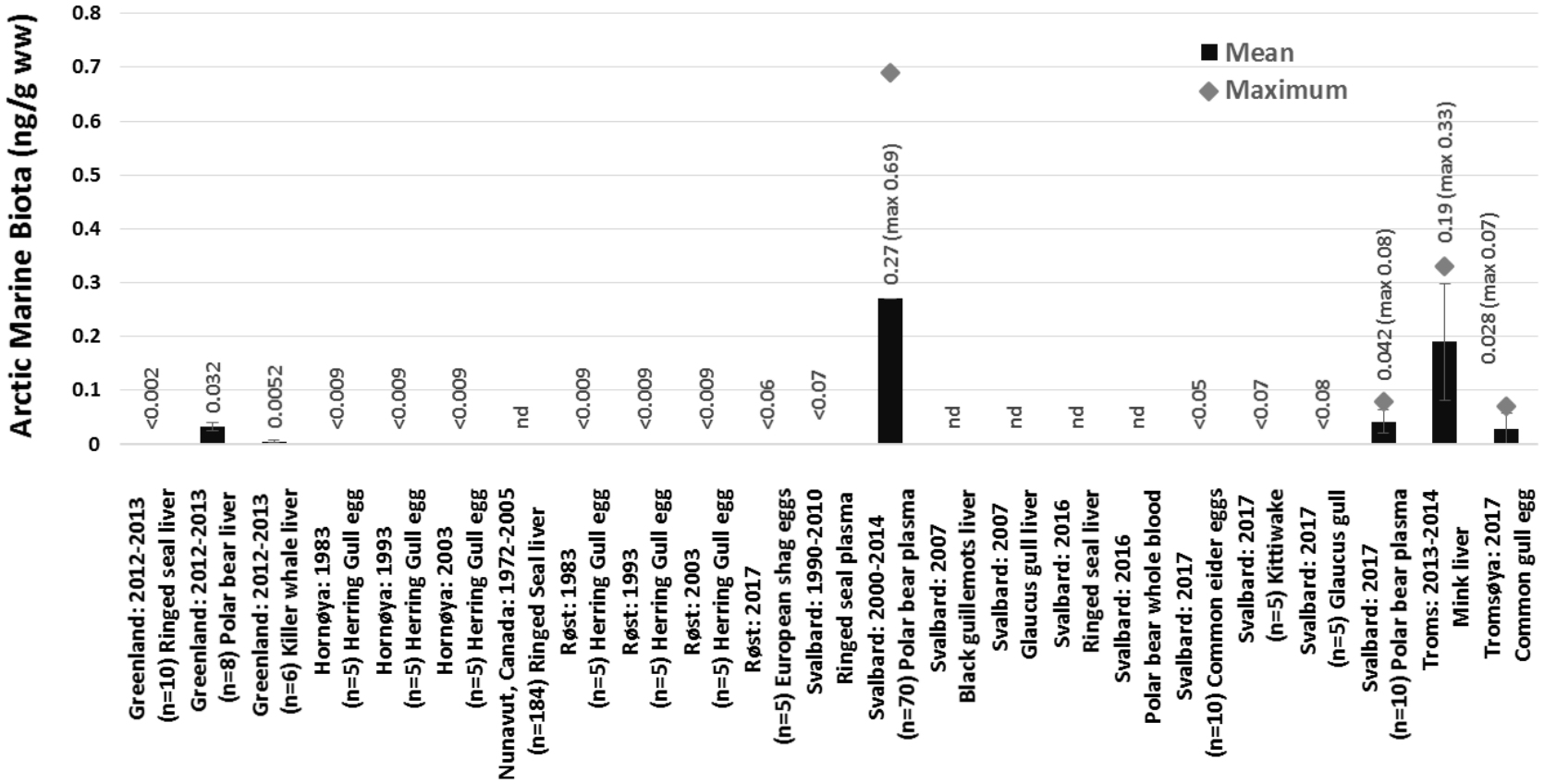


Figure 3. Environmental concentrations of PFBS in arctic marine biota (ng/g ww). Page 24 of PFBS in the Environment: Monitoring and Physical-Chemical Data Related to the Environmental Distribution of Perfluorobutanesulfonic Acid. NGI, 2018

Appendix D – (*Figures 2-16*) of PFBS in the Environment: Monitoring and Physical-Chemical Data Related to the Environmental Distribution of Perfluorobutanesulfonic Acid. NGI, 2018

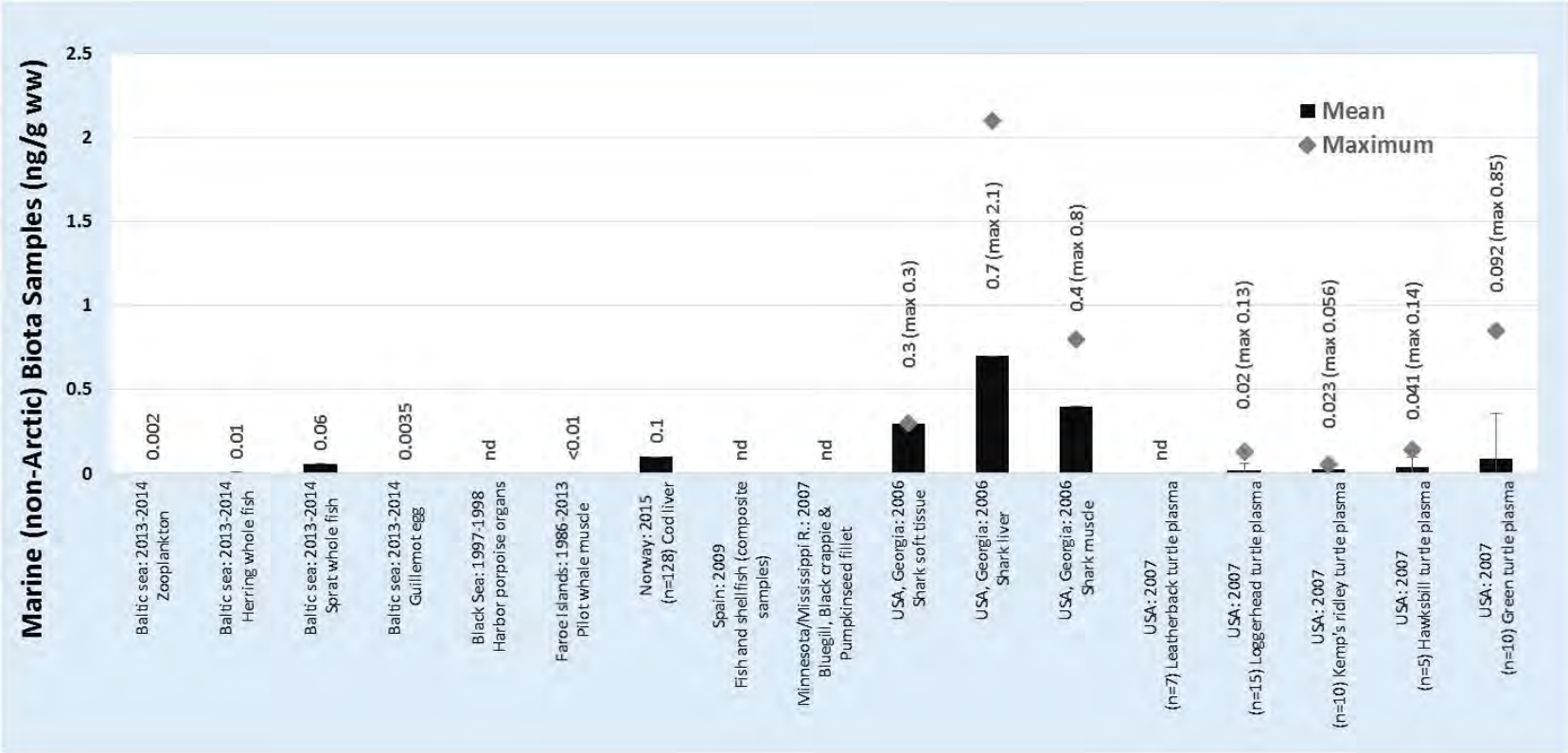


Figure 4. Environmental concentrations of PFBS in marine biota from other regions than the arctic (ng/g ww). Page 26 of PFBS in the Environment: Monitoring and Physical-Chemical Data Related to the Environmental Distribution of Perfluorobutanesulfonic Acid. NGI, 2018

Appendix D – (*Figures 2-16*) of PFBS in the Environment: Monitoring and Physical-Chemical Data Related to the Environmental Distribution of Perfluorobutanesulfonic Acid. NGI, 2018

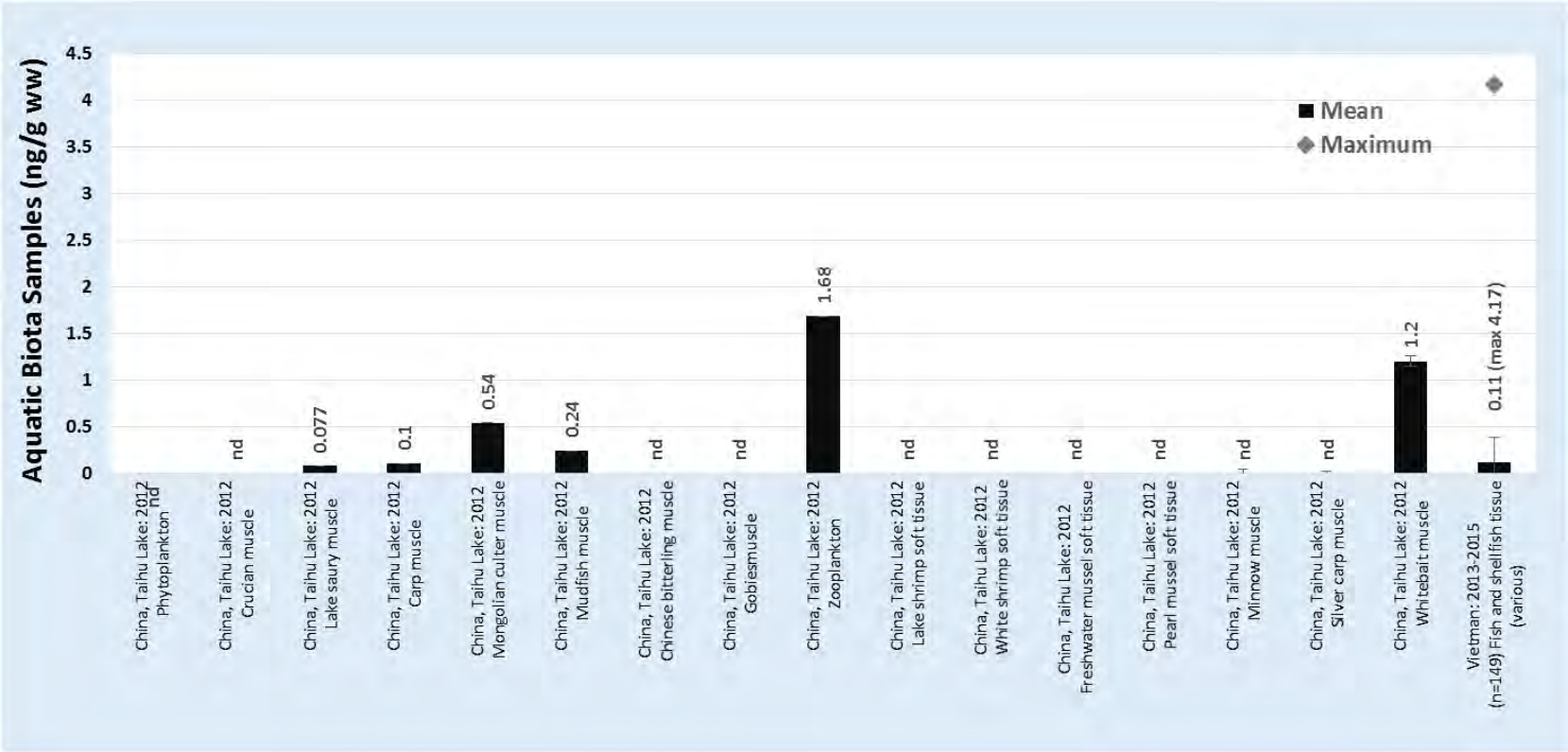


Figure 5. Environmental concentrations of PFBS in freshwater biota (ng/g ww). Page 28 of PFBS in the Environment: Monitoring and Physical-Chemical Data Related to the Environmental Distribution of Perfluorobutanesulfonic Acid. NGI, 2018.

Appendix D – (*Figures 2-16*) of PFBS in the Environment: Monitoring and Physical-Chemical Data Related to the Environmental Distribution of Perfluorobutanesulfonic Acid. NGI, 2018

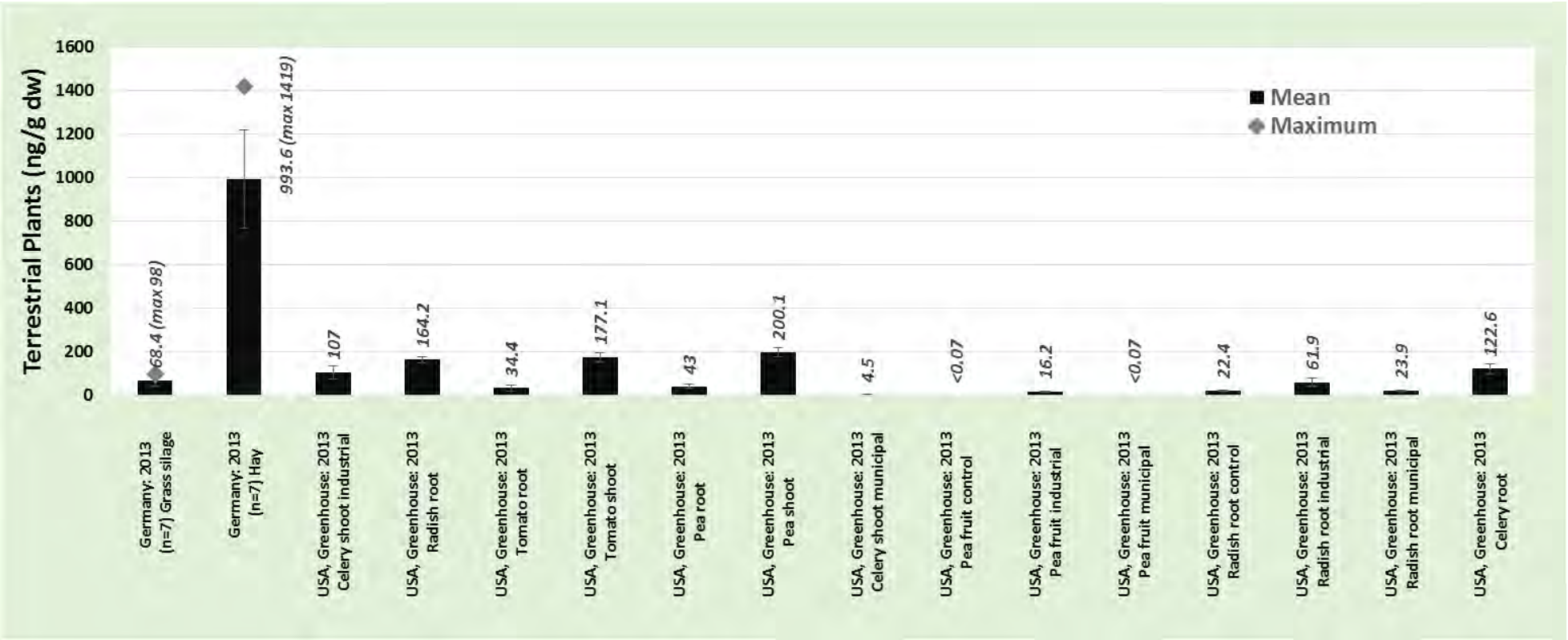


Figure 7. Environmental concentrations of PFBS in terrestrial plants (ng/g dw). Page 30 of PFBS in the Environment: Monitoring and Physical-Chemical Data Related to the Environmental Distribution of Perfluorobutanesulfonic Acid. NGI, 2018.

Appendix D – (*Figures 2-16*) of PFBS in the Environment: Monitoring and Physical-Chemical Data Related to the Environmental Distribution of Perfluorobutanesulfonic Acid. NGI, 2018

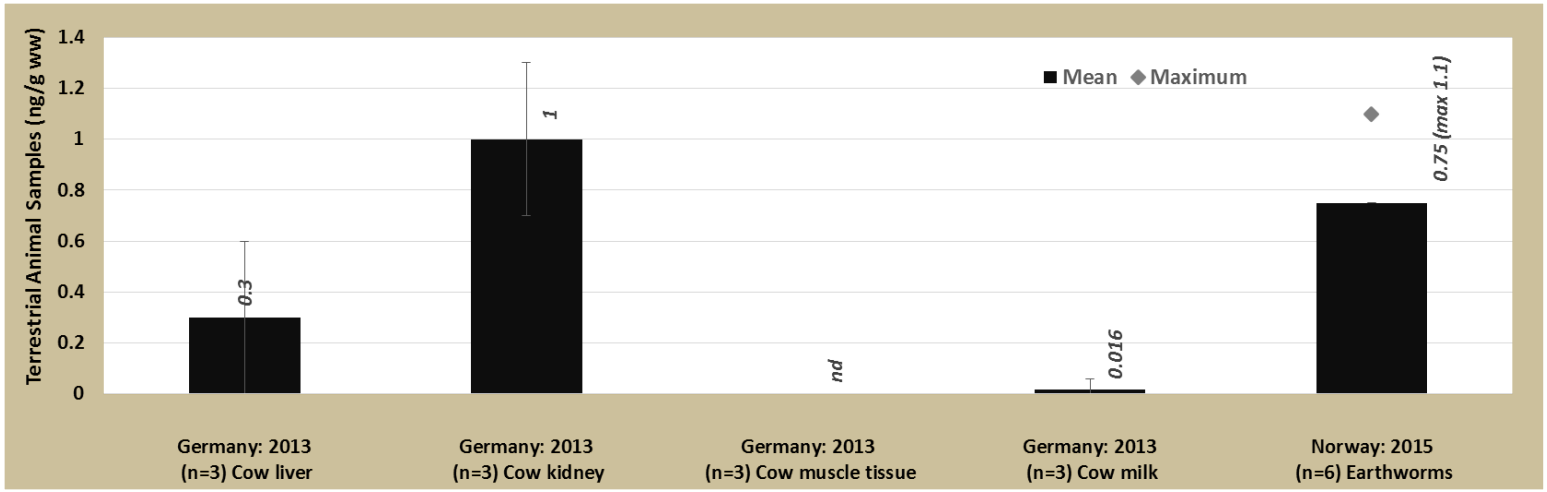


Figure 6. Environmental concentrations of PFBS in terrestrial biota (ng/g ww). Page 31 of PFBS in the Environment: Monitoring and Physical-Chemical Data Related to the Environmental Distribution of Perfluorobutanesulfonic Acid. NGI, 2018.

Appendix D – (*Figures 2-16*) of PFBS in the Environment: Monitoring and Physical-Chemical Data Related to the Environmental Distribution of Perfluorobutanesulfonic Acid. NGI, 2018

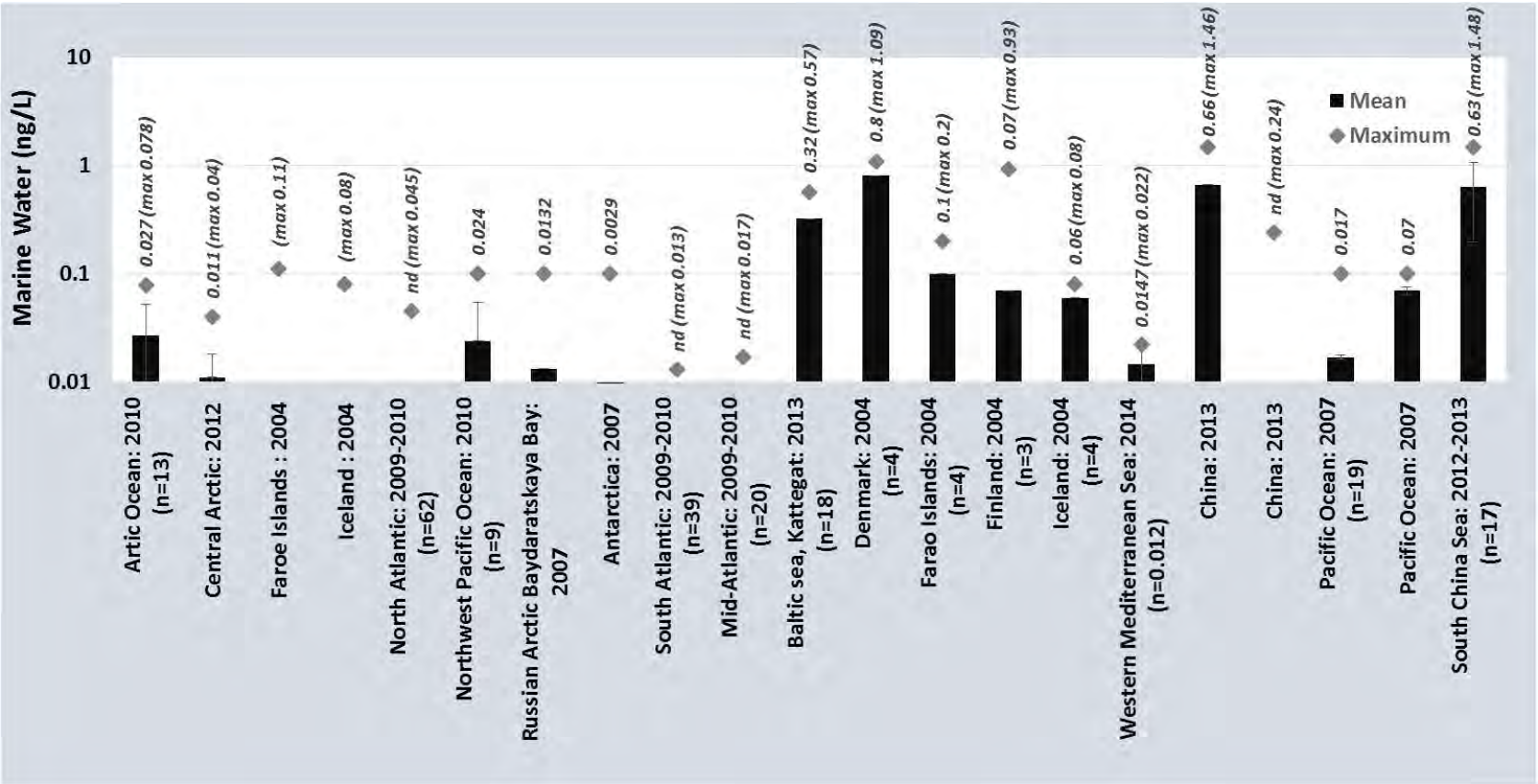


Figure 8. Environmental concentrations of PFBS in marine water samples (ng/L). Page 33 of PFBS in the Environment: Monitoring and Physical-Chemical Data Related to the Environmental Distribution of Perfluorobutanesulfonic Acid. NGI, 2018.

Appendix D – (*Figures 2-16*) of PFBS in the Environment: Monitoring and Physical-Chemical Data Related to the Environmental Distribution of Perfluorobutanesulfonic Acid. NGI, 2018

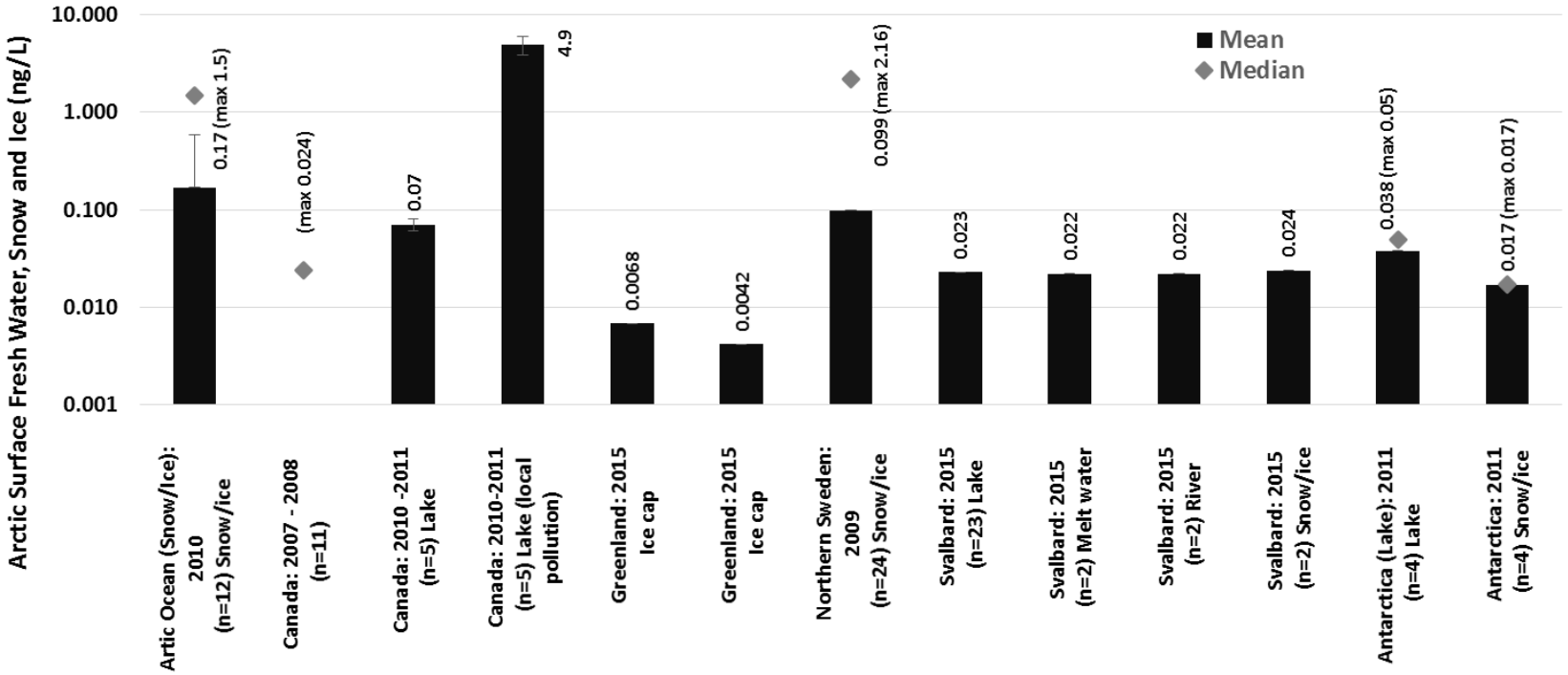


Figure 9. Environmental concentrations of PFBS in Arctic fresh water, snow and ice samples (ng/L). Note the logarithmic scale on the y-axis. Page 35 of PFBS in the Environment: Monitoring and Physical-Chemical Data Related to the Environmental Distribution of Perfluorobutanesulfonic Acid. NGI, 2018.

Appendix D – (*Figures 2-16*) of PFBS in the Environment: Monitoring and Physical-Chemical Data Related to the Environmental Distribution of Perfluorobutanesulfonic Acid. NGI, 2018

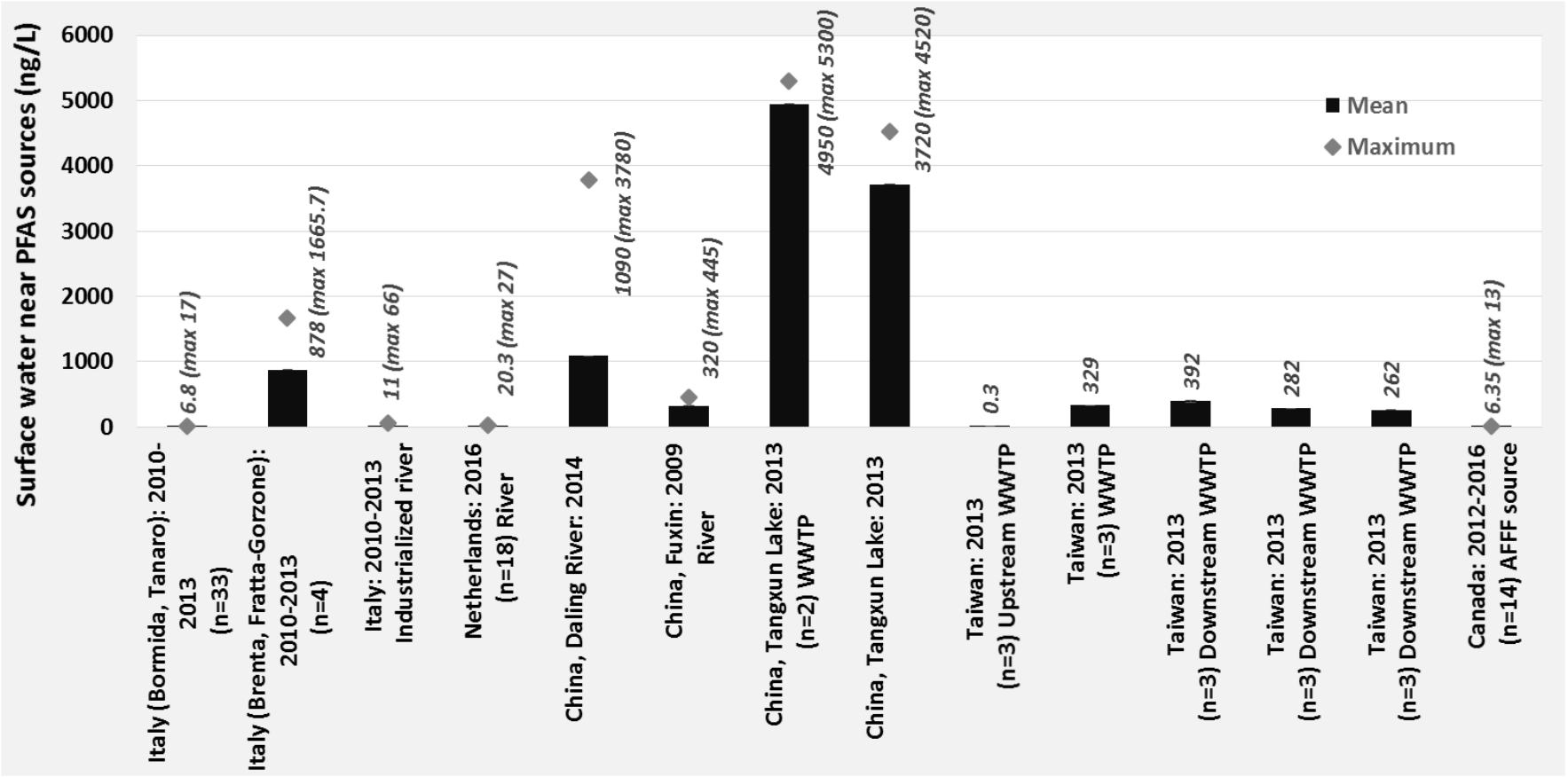


Figure 10. Environmental concentrations of PFBS in surface water near PFAS production facilities or known hotspots (ng/L). Page 37 of PFBS in the Environment: Monitoring and Physical-Chemical Data Related to the Environmental Distribution of Perfluorobutanesulfonic Acid. NGI, 2018.

Appendix D – (*Figures 2-16*) of PFBS in the Environment: Monitoring and Physical-Chemical Data Related to the Environmental Distribution of Perfluorobutanesulfonic Acid. NGI, 2018

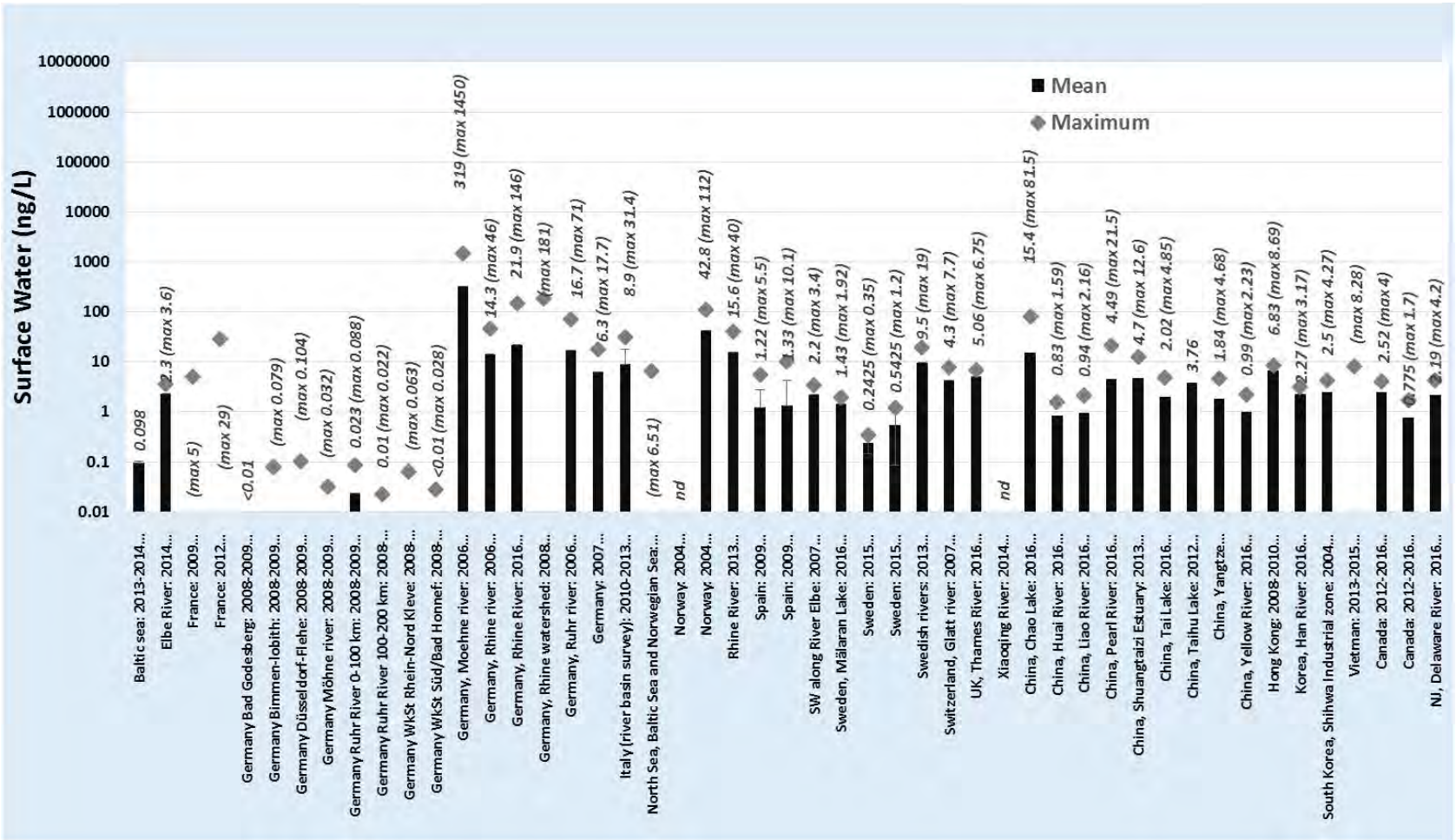


Figure 11. Environmental concentrations of PFBS in surface fresh water samples in non-Arctic areas (ng/L). Page 41 of PFBS in the Environment: Monitoring and Physical-Chemical Data Related to the Environmental Distribution of Perfluorobutanesulfonic Acid. NGI, 2018.

Appendix D – (*Figures 2-16*) of PFBS in the Environment: Monitoring and Physical-Chemical Data Related to the Environmental Distribution of Perfluorobutanesulfonic Acid. NGI, 2018

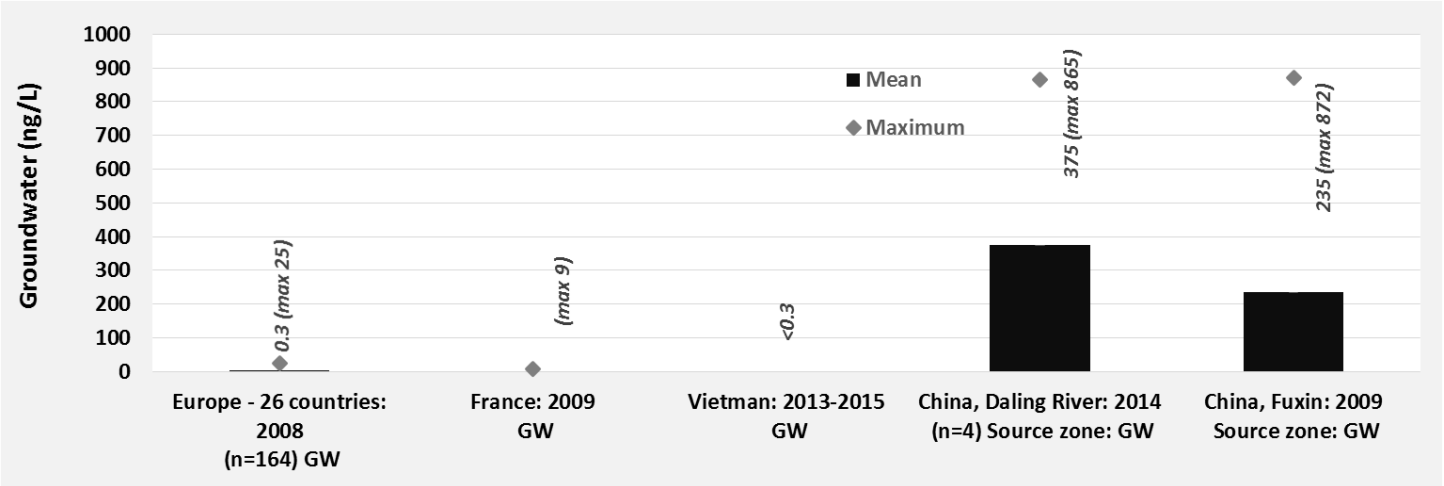


Figure 12. Environmental concentrations of PFBS in groundwater (ng/L). Page 42 of PFBS in the Environment: Monitoring and Physical-Chemical Data Related to the Environmental Distribution of Perfluorobutanesulfonic Acid. NGI, 2018.

Appendix D – (*Figures 2-16*) of PFBS in the Environment: Monitoring and Physical-Chemical Data Related to the Environmental Distribution of Perfluorobutanesulfonic Acid. NGI, 2018

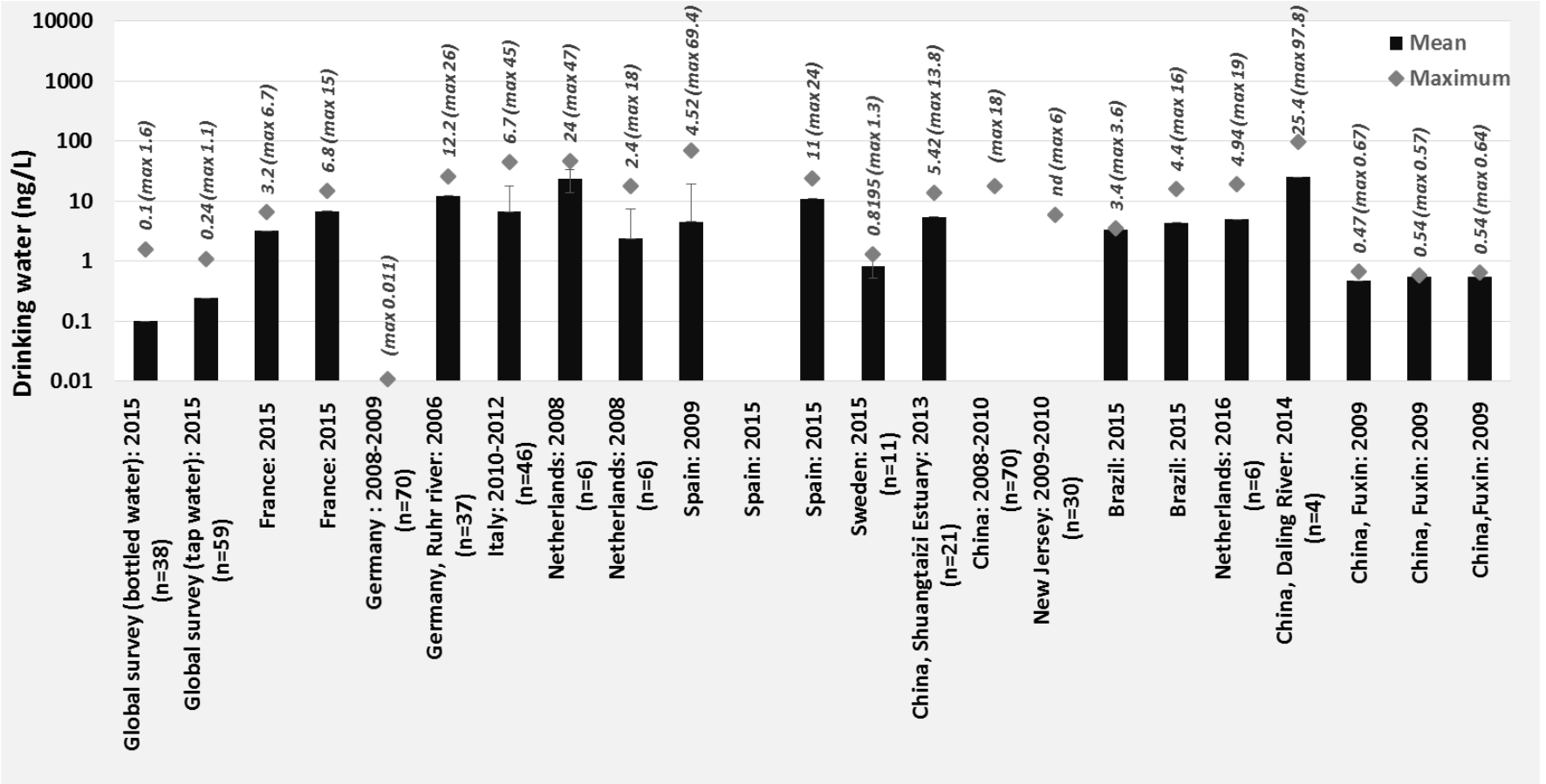


Figure 13. . Environmental concentrations of PFBS in drinking water (ng/L). Page 45 of PFBS in the Environment: Monitoring and Physical-Chemical Data Related to the Environmental Distribution of Perfluorobutanesulfonic Acid. NGI, 2018.

Appendix D – (*Figures 2-16*) of PFBS in the Environment: Monitoring and Physical-Chemical Data Related to the Environmental Distribution of Perfluorobutanesulfonic Acid. NGI, 2018

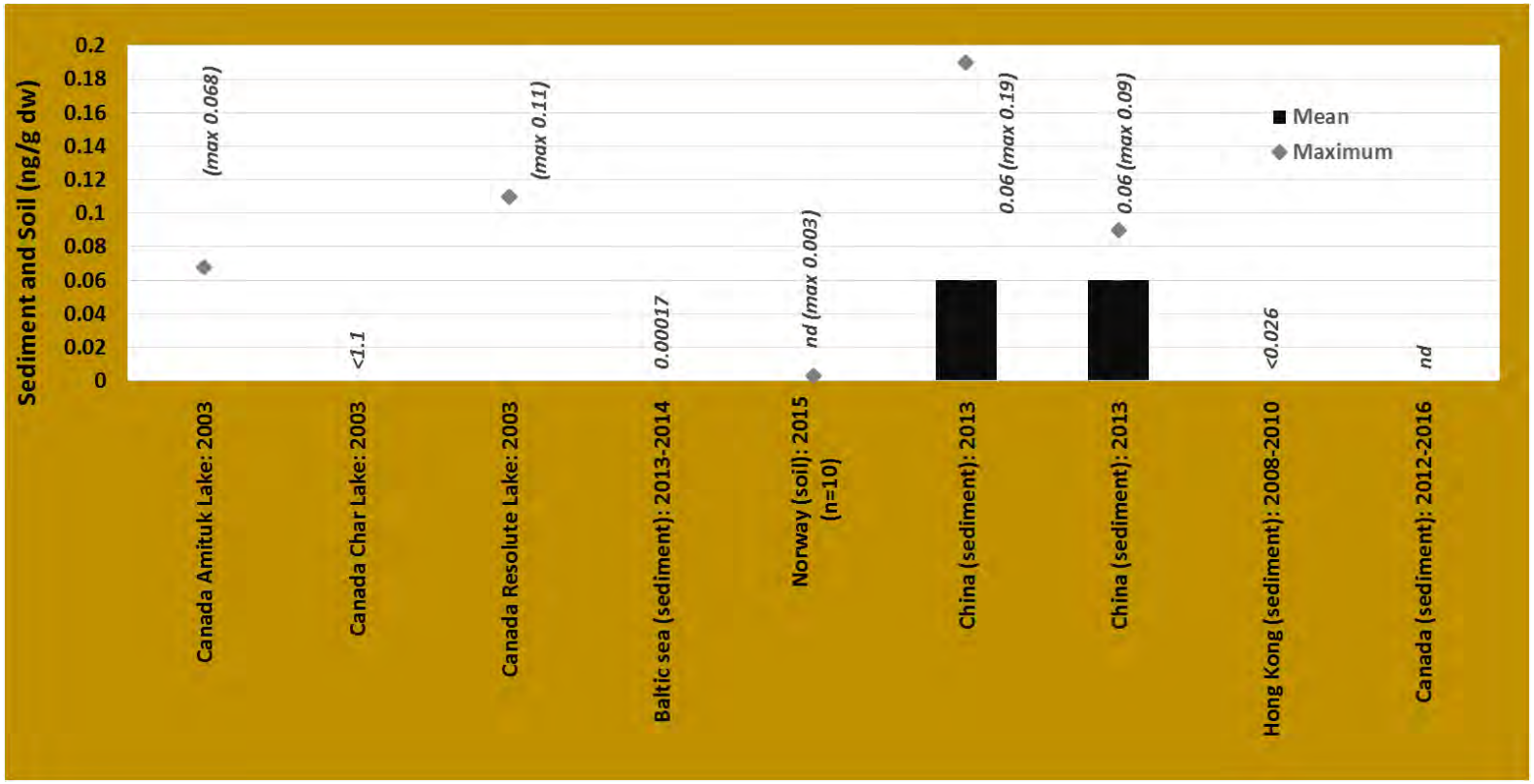


Figure 15. Environmental concentrations of PFBS in soil and sediment samples (ng/g dw). Page 47 of PFBS in the Environment: Monitoring and Physical-Chemical Data Related to the Environmental Distribution of Perfluorobutanesulfonic Acid. NGI, 2018.

Appendix D – (*Figures 2-16*) of PFBS in the Environment: Monitoring and Physical-Chemical Data Related to the Environmental Distribution of Perfluorobutanesulfonic Acid. NGI, 2018

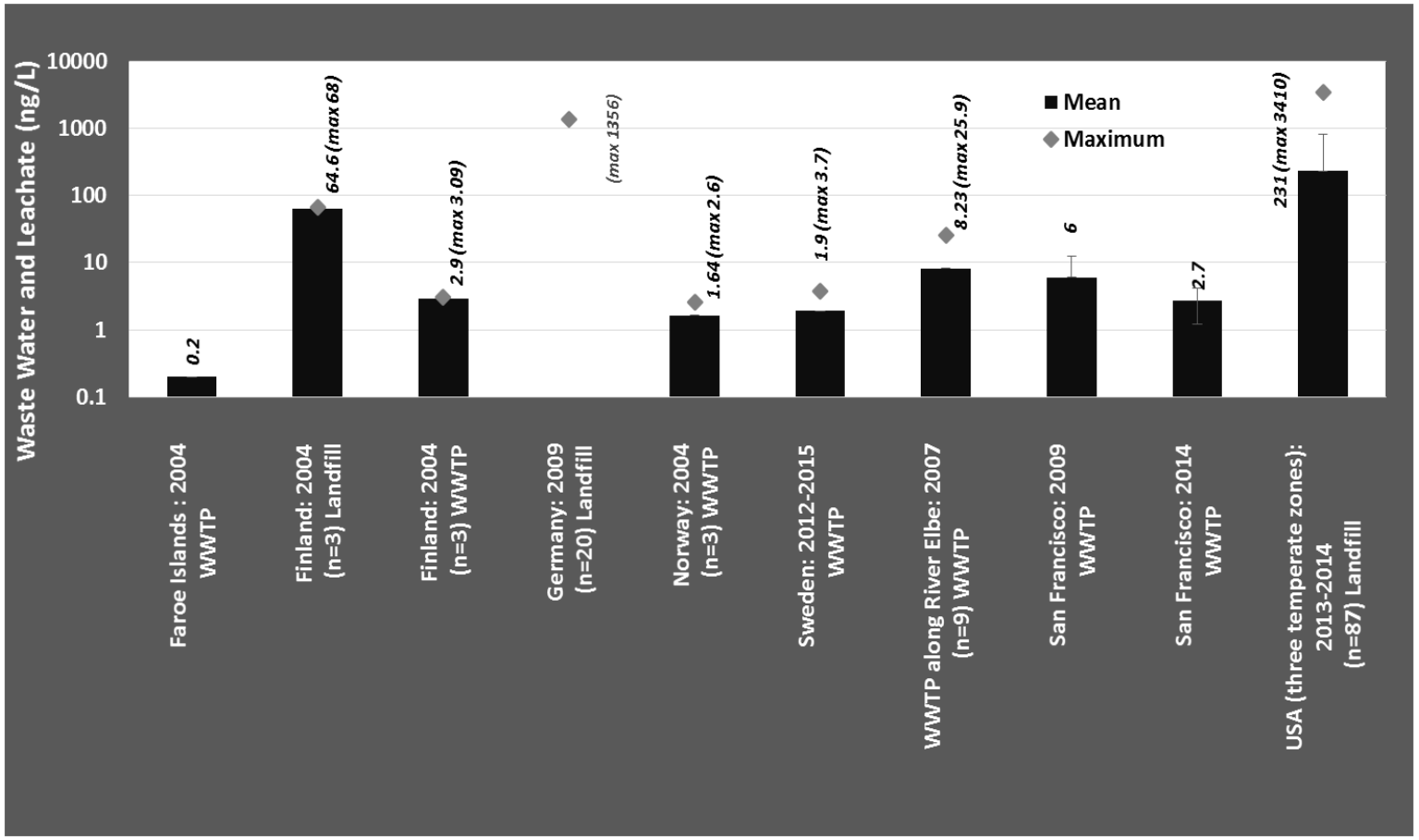


Figure 16. Environmental concentrations of PFBS in waste water and leachate samples (ng/L). Page 49 of PFBS in the Environment: Monitoring and Physical-Chemical Data Related to the Environmental Distribution of Perfluorobutanesulfonic Acid. NGI, 2018.

Appendix E

Appendix E – Figures and Water Well and Pump Records for PFBS Detection Counties in Michigan

Allegan County
City of Otsego

Calhoun County
Athens Day Care / Kids Time Day Care Center
Calhoun Interim School

Charlevoix County
Walloon Lake Water System

Ionia County
Eight Cap Ionia County Outreach School

Kent County
Spring Valley Mobile Home Park
Whispering Pines Estates

Mason County
Heritage Hills Mobile Home Park

Newaygo County
Village of Hesperia

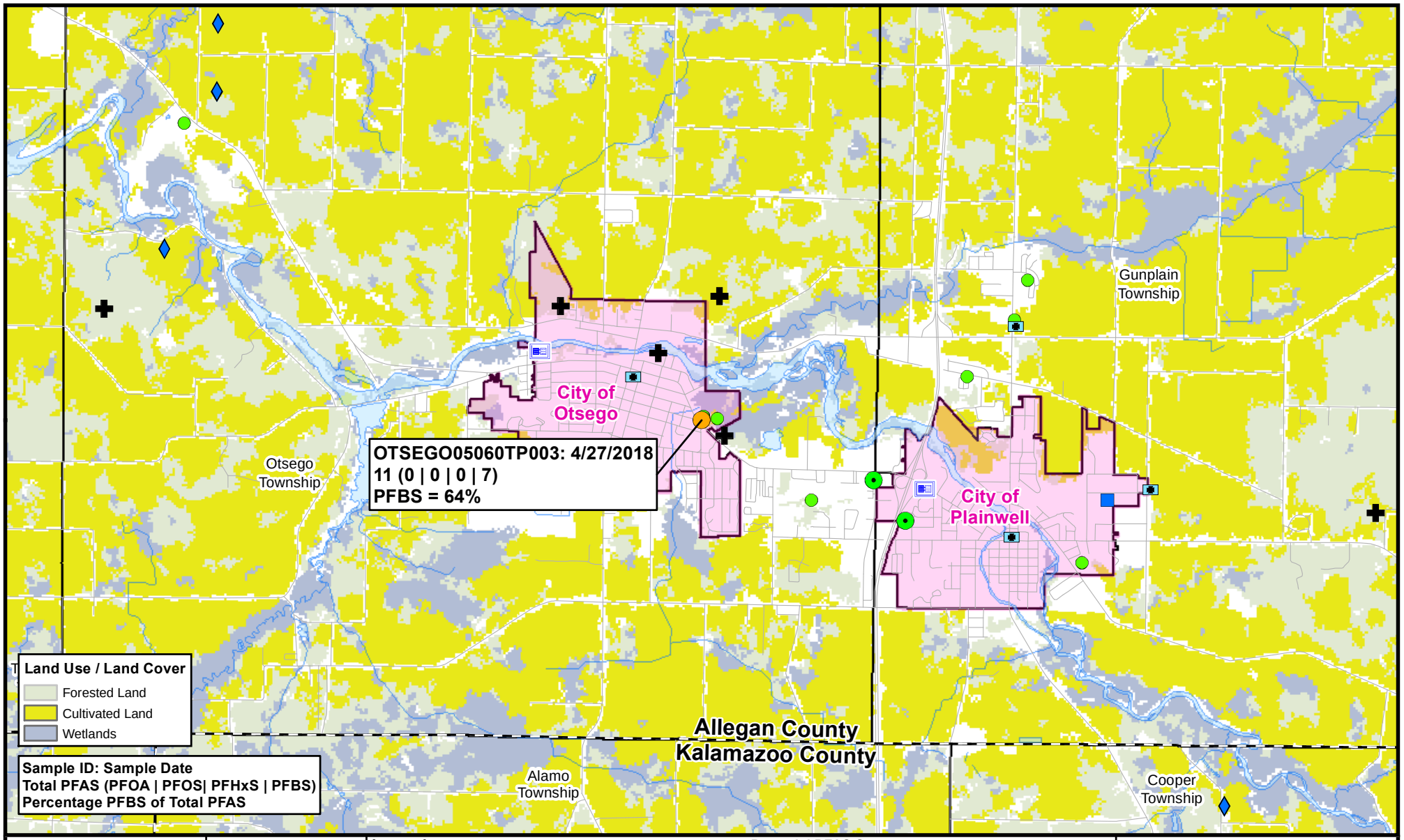
Oakland County
Heritage Apartments

Osceola County
City of Evart

Ottawa County
Crockery Mobile Home Park

Roscommon County
Roscommon C.O.O.R. School

Washtenaw County
Emerson Elementary School



DEQ

Drawn:	JS	3/7/2019
Approved:		3/7/2019
Project #:		

Legend

PFBS > 50% of Total PFAS

Total PFAS (ppt)

- >0 - 10
- >10 - 50
- >50 - 100
- >100 - 200
- >200

- PFAS Non-Detect
- PFAS Detection; PFBS < 50% of Total PFAS
- Village / City Boundary
- Township Boundary
- County Boundary

Potential PFAS Sources

- Petroleum Bulk Stations
- Petroleum Terminals
- Military Sites
- Airports
- Paints & Allied Products
- Electroplaters
- Plating and Polishing Sites
- Active Accepting Landfills
- Historic Landfills
- Superfund Sites
- Biosolids Field
- Fire Station
- WWTP

0 0.5 1 2 Miles

N

FIGURE 17
OTSEGO

ALLEGAN COUNTY, MI

LULC Data provided by USGS

G:\GrandRapids\DCS\GIS\ArcMap_GeoDB_Projects\ENV\GIS_Data\GIS\MDEQ CWS\MXD\PFBS_Evaluation\PFAS_Detects\Figure17_Otsego_Allegan.mxd

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID: 03011223301

Tax No:	Permit No:	County: Allegan	Township: Otsego

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
01N 12W	23	Active	5060	WELL 3

Well ID: 03000000175

Elevation: 712 ft.
Latitude: 42.455035
Longitude: -85.684487
Method of Collection: Interpolation-Aerial Photo

Distance and Direction from Road Intersection:
WSSN #05060;

Well Owner: OTSEGO

Well Address:
OTSEGO CITY WELL #3
OTSEGO, MI 49078

Owner Address:
OTSEGO, MI 49078

Drilling Method: Unknown
Well Depth: 90.00 ft. **Well Use:** Type I public
Well Type: New **Date Completed:**

Casing Type: Unknown **Height:** 0.00 ft. below grade
Casing Joint: Unknown
Casing Fitting: None

Diameter: 16.00 in. to 0.00 ft. depth

Borehole:

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: **HP:** 75.00
Manufacturer: Other **Pump Type:** Other
Model Number: **Pump Capacity:** 1000 GPM
Drop Pipe Length: 60.00 ft. **Pump Voltage:**
Drop Pipe Diameter: **Drilling Record ID:**
Draw Down Seal Used: No

Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 19.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown

Formation Description	Thickness	Depth to Bottom
Sand Gravel Clay W/Silt	90.00	90.00

Screen Installed: Yes **Filter Packed:** No
Screen Diameter: 13.50 in. **Blank:** 0.00 ft. Above
Screen Material Type:

Slot	Length	Set Between
0.00	20.00 ft.	0.00 ft. and 0.00 ft.

Fittings: None

Well Grouted: Yes **Grouting Method:** Unknown

Grouting Material	Bags	Additives	Depth
Unknown	0.00	None	0.00 ft. to 0.00 ft.

Wellhead Completion: Unknown

Geology Remarks:

Nearest Source of Possible Contamination:

Type	Distance	Direction
None		

Drilling Machine Operator Name:
Employment: Unknown

Contractor Type: Unknown **Reg No:**
Business Name:
Business Address:

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks: ORIGINAL WELLID# WAS 23010; NO LOG PROVIDED BY MDPH;CASING DIAM LISTED AS 34X16;PUMP VERTICAL TURBINE PULLED IN 1989;PUMP TDH (FT)=250;

Other Remarks: Pump Manufacturer:Pump Manufacturer unknown, Pump Type:Type Unknown

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No:	Permit No:	County: Allegan	Township: Otsego

Well ID: 03000000176

Elevation: 706 ft.
Latitude: 42.45557
Longitude: -85.683751
Method of Collection: Interpolation-Aerial Photo

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
01N 12W	23	Inactive	5060	OTSEGO CITY

Distance and Direction from Road Intersection:
WSSN #05060; KAL RIVER & 300' NE OF WELL #3

Well Owner: CITY OF OTSEGO

Well Address:
OTSEGO CITY WELL #4
OTSEGO, MI 49078

Owner Address:
OTSEGO, MI 49078

Drilling Method: Other
Well Depth: 121.00 ft. **Well Use:** Type I public
Well Type: New **Date Completed:** 4/13/1971

Casing Type: Unknown **Height:**
Casing Joint: Unknown
Casing Fitting: None

Diameter: 30.00 in. to 87.00 ft. depth

Borehole: 38.00 in. to 0.00 ft. depth

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: **HP:** 100.00
Manufacturer: Other **Pump Type:** Other
Model Number: **Pump Capacity:** 0 GPM
Drop Pipe Length: 87.00 ft. **Pump Voltage:**
Drop Pipe Diameter: **Drilling Record ID:**
Draw Down Seal Used: No

Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 12.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown
Pumping level 52.00 ft. after 8.00 hrs. at 1200 GPM

Screen Installed: Yes **Filter Packed:** No
Screen Diameter: 12.00 in. **Blank:** 1.70 ft. Above
Screen Material Type: Unknown

Slot	Length	Set Between
35.00	25.00 ft.	95.00 ft. and 120.00 ft.

Fittings: Other

Formation Description	Thickness	Depth to Bottom
Lithology Unknown Fill	14.00	14.00
Sand Fine	6.00	20.00
Sand Coarse	11.00	31.00
Boulders W/Gravel	15.00	46.00
Sand Silty	4.00	50.00
Sand Coarse	34.00	84.00
Sand Fine	2.00	86.00
Sand & Gravel Coarse	4.00	90.00
Sand Fine	7.00	97.00
Sand Coarse	10.00	107.00
Sand & Gravel Coarse	13.00	120.00
Clay	1.00	121.00

Well Grouted: Yes **Grouting Method:** Unknown

Grouting Material	Bags	Additives	Depth
Neat cement	0.00	None	

Geology Remarks:

Wellhead Completion: Unknown

Nearest Source of Possible Contamination:

Type	Distance	Direction
None		

Drilling Machine Operator Name: PAUL WYATT
Employment: Unknown

Contractor Type: Unknown **Reg No:** 33-1997
Business Name:
Business Address:

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks: ORIGINAL WELLID# WAS 23011; LOG SAYS SWL=12',PUMP LEVEL=62'; MDPH SAYS SWL=25', PUMP LEVEL=52';ADJUST LITH MEASURMENTS BY 3' DUE TO LOWERING THE SITE. 48 YDS OF NEAT CEMENT USED, VERRTICAL TURBINE PUMP PULLED IN 1988. RIG:RC;

Other Remarks: Drilling Method:Drilling Method unknown, Pump Manufacturer:Pump Manufacturer unknown, Pump Type:Type Unknown, Screen Fittings:Type Unknown

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID: 03011223303

Tax No:	Permit No:	County: Allegan	Township: Otsego

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
01N 12W	23	Active	5060	WELL 5

Well ID: 03000000177

Elevation: 711 ft.
Latitude: 42.455661
Longitude: -85.685185
Method of Collection: Interpolation-Aerial Photo

Distance and Direction from Road Intersection:
WSSN #05060; APPR 165' NORTH OF WELL #3

Well Owner: OTSEGO

Well Address:
OTSEGO CITY WELL #5
OTSEGO, MI 49078

Owner Address:
OTSEGO, MI 49078

Drilling Method: Unknown
Well Depth: 112.90 ft. **Well Use:** Type I public
Well Type: New **Date Completed:**

Casing Type: Steel - black **Height:** 0.00 ft. below grade
Casing Joint: Unknown
Casing Fitting: None

Diameter: 24.00 in. to 45.00 ft. depth
16.00 in. to 82.00 ft. depth

Borehole:

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: **HP:** 40.00
Manufacturer: Other **Pump Type:** Unknown
Model Number: **Pump Capacity:** 600 GPM
Drop Pipe Length: 40.00 ft. **Pump Voltage:**
Drop Pipe Diameter: **Drilling Record ID:**
Draw Down Seal Used: No

Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 16.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown
Pumping level 33.00 ft. after 0.00 hrs. at 0 GPM

Screen Installed: Yes **Filter Packed:** No
Screen Diameter: 12.00 in. **Blank:** 0.00 ft. Above
Screen Material Type:

Slot	Length	Set Between
35.00	30.00 ft.	0.00 ft. and 0.00 ft.

Fittings: None

Formation Description	Thickness	Depth to Bottom
Sand Gravely Fine To Medium	10.00	10.00
Sand Gravely Fine To Coarse	5.00	15.00
Sand Gravely Fine To Medium	5.00	20.00
Sand W/Clay Stoney	10.00	30.00
Gravel Sand Clay Coarse	5.00	35.00
Gravel & Sand Coarse	11.00	46.00
Sand & Stones Fine	5.00	51.00
Gravel Fine To Medium Sandy	15.00	66.00
Gravel & Sand Fine To Medium	5.00	71.00
Sand & Gravel	5.00	76.00
Sand Gravely W/Coal	5.00	81.00
Sand Fine To Coarse W/Stones	5.00	86.00
Sand Fine To Coarse Gravely	5.00	91.00

(Continued On Page 2)

Well Grouted: Yes **Grouting Method:** Unknown

Grouting Material	Bags	Additives	Depth
Unknown	0.00	None	0.00 ft. to 0.00 ft.

Wellhead Completion: Other, 12 inches above grade

Geology Remarks:

Nearest Source of Possible Contamination:

Type	Distance	Direction
None		

Drilling Machine Operator Name:
Employment: Unknown

(Continued on page 2)

General Remarks: ORIGINAL WELLID# WAS 23012; DUNBAR DRILLING; US MOTOR 1765 RPM, ID#R-8887-02-646
Other Remarks: Wellhead Completion:12 inch Above Grade, Pump Manufacturer:DEMING T75112

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID: 03011223303

Tax No:	Permit No:	County: Allegan	Township: Otsego

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
01N 12W	23	Active	5060	WELL 5

Well ID: 03000000177

Elevation: 711 ft.
Latitude: 42.455661
Longitude: -85.685185
Method of Collection: Interpolation-Aerial Photo

Distance and Direction from Road Intersection:
WSSN #05060; APPR 165' NORTH OF WELL #3

Well Owner: OTSEGO

Well Address:
OTSEGO CITY WELL #5
OTSEGO, MI 49078

Owner Address:
OTSEGO, MI 49078

(Continued from Page 1)

Formation Description	Thickness	Depth to Bottom
Gravel Fine To Medium Sandy	5.00	96.00
Gravel Fine To Coarse Sandy	13.00	109.00
Gray Clay	3.90	112.90

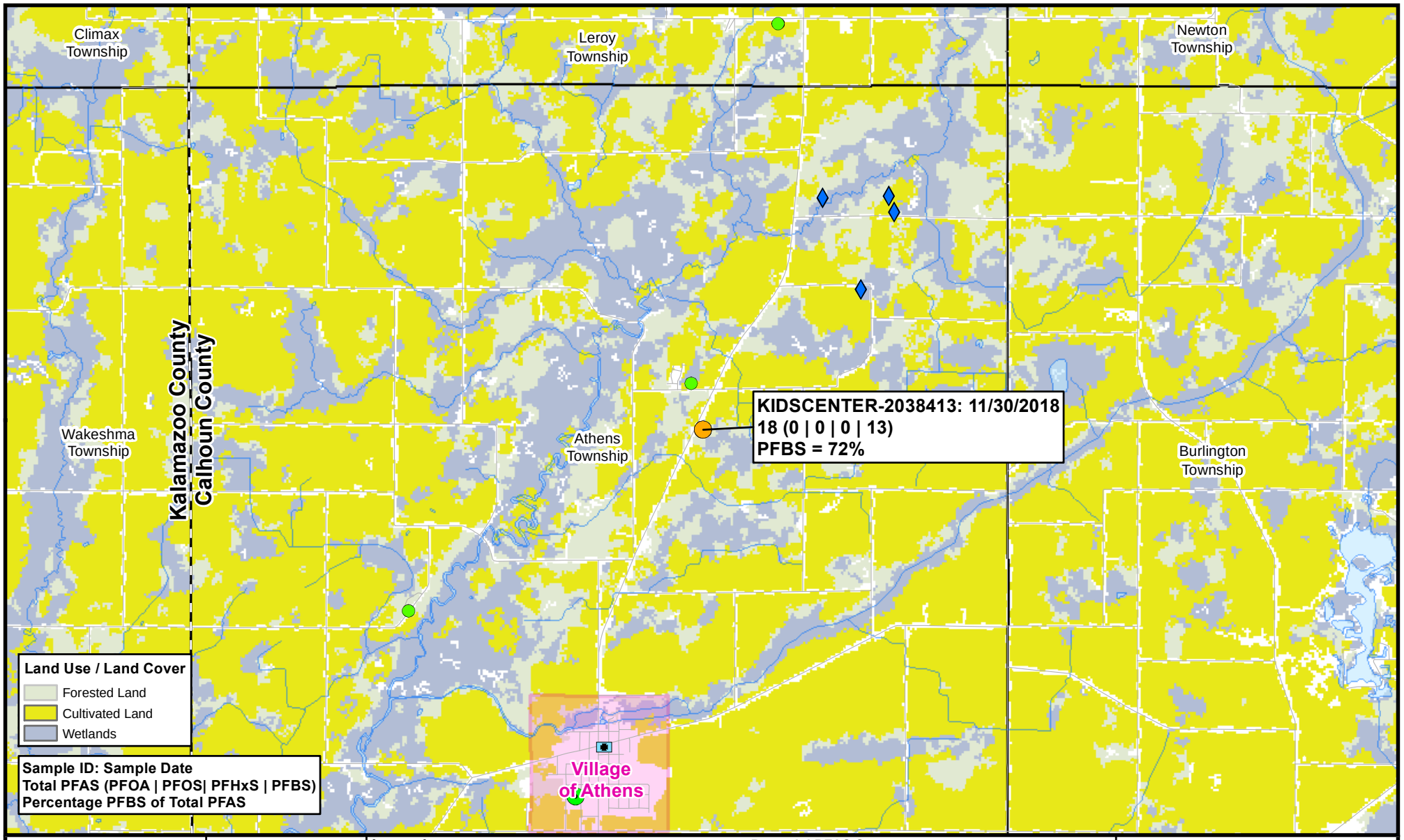
OTHER REMARKS:
Wellhead Completion:12 inch Above Grade, Pump Manufacturer:DEMING T75112

Contractor Type: Unknown **Reg No:**
Business Name:
Business Address:

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**



DEQ

Drawn:	JS	3/7/2019
Approved:		3/7/2019
Project #:		

Legend

PFBS > 50% of Total PFAS

Total PFAS (ppt)

- >0 - 10
- >10 - 50
- >50 - 100
- >100 - 200
- >200

- PFAS Non-Detect
- PFAS Detection; PFBS < 50% of Total PFAS
- Village / City Boundary
- Township Boundary
- County Boundary

Potential PFAS Sources

- Petroleum Bulk Stations
- Petroleum Terminals
- Military Sites
- Airports
- Paints & Allied Products
- Electroplaters
- Plating and Polishing Sites
- Active Accepting Landfills
- Historic Landfills
- Superfund Sites
- Biosolids Field
- Fire Station
- WWTP

0 0.5 1 2 Miles

N

FIGURE 18
KIDS TIME DAY CARE

CALHOUN COUNTY, MI

LULC Data provided by USGS

G:\GrandRapids\DCS\GIS\ArcMap_GeoDB_Projects\ENV\GIS_Data\GIS\MDEQ CWS\MXD\PFBS_Evaluation\PFAS_Detects\Figure18_Kids_Time_Day_Care_Calhoun.mxd

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID: 13740815401

Tax No:	Permit No:	County: Calhoun	Township: Athens

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
04S 08W	15	Active	2038413	001

Well ID: 13000001033

Elevation: 901 ft.
Latitude: 42.122276
Longitude: -85.221297
Method of Collection: GPS Differential (DGPS)

Distance and Direction from Road Intersection:
2038413;

Well Owner: ATHENS DAY CARE CENTER

Well Address:	Owner Address:
3540 M-66 SOUTH ATHENS, MI 49011	3540 M-66 SOUTH ATHENS, MI 49011

Drilling Method: Rotary
Well Depth: 40.00 ft. **Well Use:** Type II public
Well Type: New **Date Completed:** 11/19/1996

Casing Type: PVC plastic **Height:**
Casing Joint: Unknown
Casing Fitting: None

Diameter: 5.00 in. to 35.00 ft. depth

Borehole: 8.00 in. to 35.00 ft. depth

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: **HP:**
Manufacturer: A.Y. McDonald **Pump Type:** Submersible
Model Number: **Pump Capacity:** 10 GPM
Drop Pipe Length: 20.00 ft. **Pump Voltage:**
Drop Pipe Diameter: **Drilling Record ID:**
Draw Down Seal Used: No

Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 15.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown
Pumping level 25.00 ft. after 1.00 hrs. at 25 GPM

Formation Description	Thickness	Depth to Bottom
Brown Clay & Sand	14.00	14.00
Brown Clay	2.00	16.00
Clay & Stones	2.00	18.00
Gray Clay	15.00	33.00
Gravel & Sand	2.00	35.00
Lithology Unknown	4.00	39.00
Shale	2.00	41.00

Screen Installed: Yes **Filter Packed:** No
Screen Diameter: 4.00 in. **Blank:** 0.00 ft. Above
Screen Material Type:

Slot	Length	Set Between
30.00	5.00 ft.	35.00 ft. and 40.00 ft.

Fittings: Neoprene packer

Well Grouted: Yes **Grouting Method:** Unknown

Grouting Material	Bags	Additives	Depth
Bentonite slurry	0.00	None	0.00 ft. to 35.00 ft.

Wellhead Completion: Other, 12 inches above grade

Geology Remarks:

Nearest Source of Possible Contamination:

Type	Distance	Direction
Unknown	0 ft.	

Drilling Machine Operator Name: RICK FREY
Employment: Unknown

Contractor Type: Unknown **Reg No:** 13-1593
Business Name:
Business Address:

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks:
Other Remarks: Pump Manufacturer:MCDONALD

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No:	Permit No:	County: Calhoun	Township: Athens

Well ID: 13000001538

Elevation: 893 ft.
Latitude: 42.127097
Longitude: -85.224322
Method of Collection: GPS Std Positioning Svc SA Off

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
04S 08W	15	Plugged	40082	1

Distance and Direction from Road Intersection:
20' N. of Q. Rd. S. and .25 mi. E. of M-66

Well Owner:

Well Address:	Owner Address:
Birchwood Estates #1 MI	Birchwood Estates #1 MI

Drilling Method: Hollow Rod
Well Depth: 30.00 ft. **Well Use:** Type I public
Well Type: Unknown **Date Completed:** 4/13/1974

Casing Type: Steel - black **Height:**
Casing Joint: Threaded & coupled
Casing Fitting: Drive shoe

Diameter: 4.00 in. to 26.00 ft. depth

Borehole:

Pump Installed: No
Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 6.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown
Pumping level 6.00 ft. after 3.00 hrs. at 60 GPM

Screen Installed: Yes **Filter Packed:** No
Screen Diameter: 4.00 in. **Blank:** *u
Screen Material Type: Unknown

Slot	Length	Set Between
24.00	4.00 ft.	26.00 ft. and 30.00 ft.

Fittings: Neoprene packer

Formation Description	Thickness	Depth to Bottom
Red Clay Sandy	9.00	9.00
Sand Coarse	9.00	18.00
Sand & Gravel Coarse	6.00	24.00
Gray Clay Hard	2.00	26.00
Sand & Gravel Coarse	2.00	28.00
Sand & Gravel Coarse	2.00	30.00

Well Grouted: No

Geology Remarks:

Wellhead Completion: 12 inches above grade

Nearest Source of Possible Contamination:

Type	Distance	Direction
None		

Drilling Machine Operator Name:
Employment: Unknown

Contractor Type: Water Well Drilling Contractor **Reg No:** 13-0393
Business Name: R. Katz Well Drilling
Business Address: 180 S, Main

Abandoned Well Plugged: No

Reason Not Plugged:

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks:

Other Remarks:

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No:	Permit No:	County: Calhoun	Township: Athens

Well ID: 13000001539

Elevation: 893 ft.
Latitude: 42.127241
Longitude: -85.22276
Method of Collection: GPS Std Positioning Svc SA Off

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
04S 08W	15	Active	40082	2

Distance and Direction from Road Intersection:

Well Owner:

Well Address:	Owner Address:
Birchwood Estates #2 Athens, MI 49011	Birchwood Estates #2 Athens, MI 49011

Drilling Method: Unknown
Well Depth: 47.00 ft. **Well Use:** Type I public
Well Type: Unknown **Date Completed:** 1/1/1992

Casing Type: PVC plastic **Height:**
Casing Joint: Unknown
Casing Fitting: Unknown

Diameter: 5.00 in. to 37.00 ft. depth

Borehole:

Static Water Level: 9.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown
at 34 GPM

Screen Installed: No **Intake:** Unknown

Well Grouted: No

Wellhead Completion: Unknown

Nearest Source of Possible Contamination:
Type **Distance** **Direction**
Unknown

Abandoned Well Plugged: No

Reason Not Plugged:

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: **HP:**
Manufacturer: A.Y. McDonald **Pump Type:** Submersible
Model Number: **Pump Capacity:**
Drop Pipe Length: **Pump Voltage:**
Drop Pipe Diameter: **Drilling Record ID:**
Draw Down Seal Used: No

Pressure Tank Installed: Yes
Pressure Tank Type: Unknown
Manufacturer: Other
Model Number: PAD 86 **Tank Capacity:** 576.0 Gallons
Pressure Relief Valve Installed: No

Formation Description	Thickness	Depth to Bottom
Lithology Unknown	47.00	47.00

Geology Remarks:

Drilling Machine Operator Name: Dennis Calloway
Employment: Unknown

Contractor Type: Water Well Drilling Contractor **Reg No:**
Business Name: Katz Well Drilling
Business Address:

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks:

Other Remarks: Tank Manufacturer:6 Perma Tank

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No:	Permit No:	County: Calhoun	Township: Athens

Well ID: 13000001540

Elevation: 897 ft.
Latitude: 42.126834
Longitude: -85.223426
Method of Collection: GPS Std Positioning Svc SA Off

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
04S 08W	15	Active	40082	3

Distance and Direction from Road Intersection:
.25 mi. W. of M-66 on Q Dr. S., 100' N. of Q Dr. S.

Well Owner:

Well Address:	Owner Address:
Birchwood Estates #3 Athens, MI	Birchwood Estates #3 Athens, MI

Drilling Method: Rotary
Well Depth: 43.00 ft. **Well Use:** Type I public
Well Type: New **Date Completed:** 7/1/1988

Casing Type: PVC plastic **Height:**
Casing Joint: Unknown
Casing Fitting: Drive shoe

Diameter: 5.00 in. to 25.00 ft. depth

Borehole: 8.00 in. to 25.00 ft. depth

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: **HP:** 2.00
Manufacturer: A.Y. McDonald **Pump Type:** Submersible
Model Number: 1820053 **Pump Capacity:** 43 GPM
Drop Pipe Length: 22.00 ft. **Pump Voltage:**
Drop Pipe Diameter: **Drilling Record ID:**
Draw Down Seal Used: No

Pressure Tank Installed: Yes
Pressure Tank Type: Unknown
Manufacturer: Well-X-Trol
Model Number: WX 252 **Tank Capacity:** 30.0 Gallons
Pressure Relief Valve Installed: No

Static Water Level: 10.10 ft. Below Grade
Well Yield Test: **Yield Test Method:** Air
Pumping level 30.00 ft. after 3.00 hrs. at 40 GPM
Pumping level 25.00 ft. after 4.00 hrs. at 45 GPM

Formation Description	Thickness	Depth to Bottom
Gravel Coarse	9.00	9.00
Brown Clay	8.00	17.00
Gray Clay	8.00	25.00
Gravel Coarse	16.00	41.00
Sand Coarse	2.00	43.00

Screen Installed: Yes **Filter Packed:** No
Screen Diameter: 4.00 in. **Blank:** 2.00 ft. Above
Screen Material Type: Stainless steel-wire wrapped

Slot	Length	Set Between
15.00	8.00 ft.	25.00 ft. and 43.00 ft.

Fittings: Unknown

Well Grouted: Yes **Grouting Method:** Unknown

Grouting Material	Bags	Additives	Depth
Bentonite slurry	0.00	None	0.00 ft. to 25.00 ft.

Wellhead Completion: Pitless adapter, 12 inches above grade

Geology Remarks:

Nearest Source of Possible Contamination:

Type	Distance	Direction
Septic tank	100 ft.	Northwest

Drilling Machine Operator Name: Stan Schmanski
Employment: Unknown

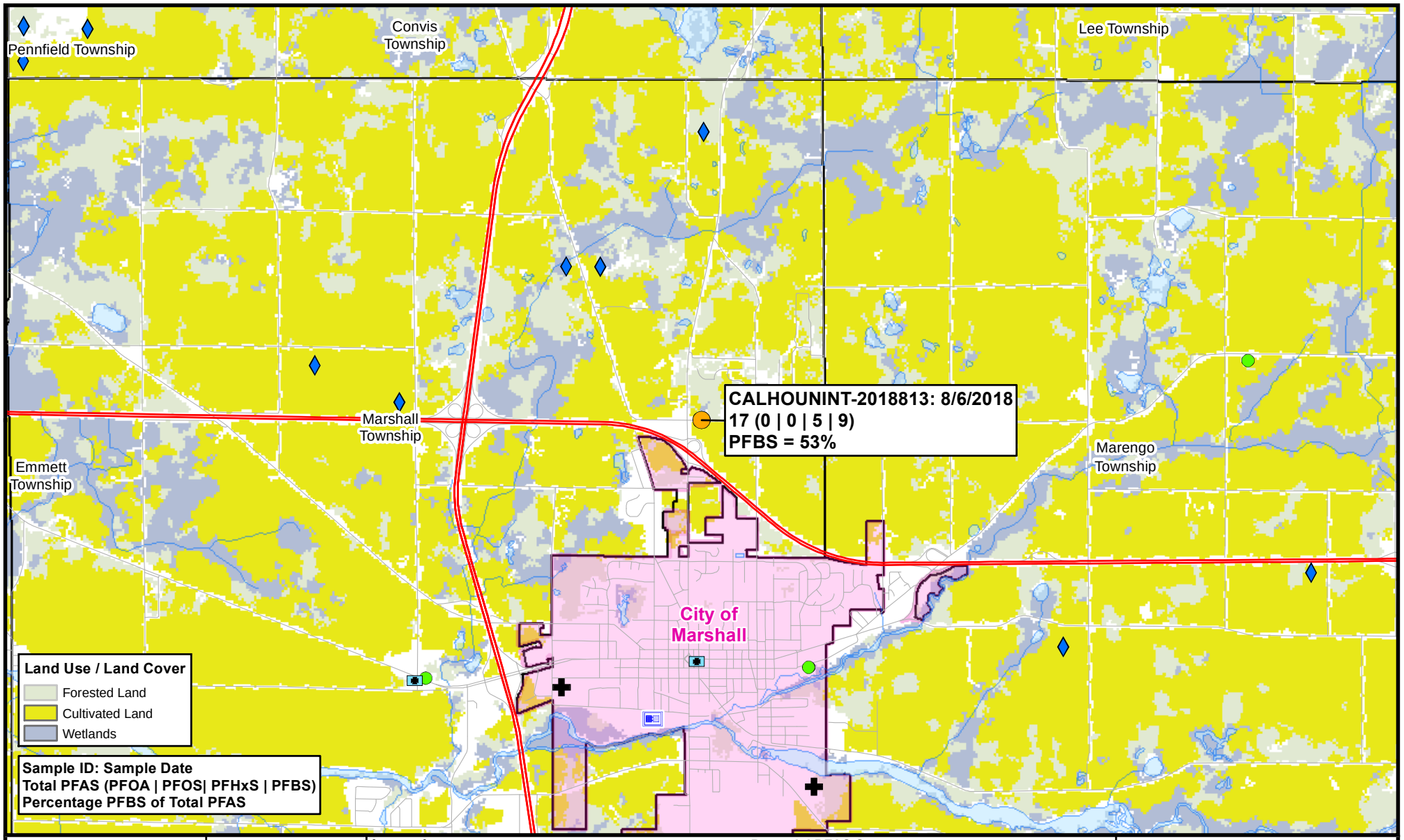
Contractor Type: Water Well Drilling Contractor **Reg No:** 13-1593
Business Name: Katz Well Drilling, Inc.
Business Address: 180 S Main, Ceresco, MI

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks:
Other Remarks:



DEQ

Drawn:	JS	3/7/2019
Approved:		3/7/2019
Project #:		

Legend

PFBS > 50% of Total PFAS

Total PFAS (ppt)

- >0 - 10
- >10 - 50
- >50 - 100
- >100 - 200
- >200

- PFAS Non-Detect
- PFAS Detection; PFBS < 50% of Total PFAS
- Village / City Boundary
- Township Boundary
- County Boundary

Potential PFAS Sources

- Petroleum Bulk Stations
- Petroleum Terminals
- Military Sites
- Airports
- Paints & Allied Products
- Electroplaters
- Plating and Polishing Sites
- Active Accepting Landfills
- Historic Landfills
- Superfund Sites
- Biosolids Field
- Fire Station
- WWTP

0 0.5 1 2 Miles

N

FIGURE 19
CALHOUN INTERM. SCHOOL DISTRICT

CALHOUN COUNTY, MI

Source: ESRI USA Topo Maps

G:\GrandRapids\DCS\GIS\ArcMap_GeoDB_Projects\ENV\GIS_Data\GIS\MDEQ CWS\MXD\PFBS_Evaluation\PFAS_Detects\Figure19_Calhoun_Interm_School_Dist_Calhoun.mxd

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No:	Permit No:	County: Calhoun	Township: Marshall

Well ID: 13000001572

Elevation: 978 ft.
Latitude: 42.29756698
Longitude: -84.96256279
Method of Collection: Address Matching-House Number

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
02S 06W	13	Active	2018813	001

Distance and Direction from Road Intersection:
17111 G Dr. North

Well Owner: Calhoun Interim School Dist.

Well Address:
17111 G. Drive North
Marshall, MI 49068

Owner Address:
17111 G. Drive North
Marshall, MI 49068

Drilling Method: Rotary
Well Depth: 200.00 ft. **Well Use:** Type II public
Well Type: Replacement **Date Completed:** 12/3/1993

Casing Type: Steel - black **Height:** 1.50 ft. above grade
Casing Joint: Threaded & coupled
Casing Fitting: Drive shoe

Diameter: 4.00 in. to 97.00 ft. depth

Borehole: 6.00 in. to 96.00 ft. depth

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: **HP:** 3.00
Manufacturer: Aermotor **Pump Type:** Submersible
Model Number: **Pump Capacity:** 40 GPM
Drop Pipe Length: 65.00 ft. **Pump Voltage:**
Drop Pipe Diameter: **Drilling Record ID:**
Draw Down Seal Used: No

Pressure Tank Installed: Yes
Pressure Tank Type: Unknown
Manufacturer: Unknown
Model Number: **Tank Capacity:** 250.0 Gallons
Pressure Relief Valve Installed: No

Static Water Level: 45.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Air
Pumping level 70.00 ft. after 1.00 hrs. at 90 GPM

Screen Installed: No **Intake:** Bedrock Well

Formation Description	Thickness	Depth to Bottom
Brown Clay	7.00	7.00
Brown Clay & Gravel	23.00	30.00
Sand & Gravel	15.00	45.00
Sand & Gravel Wet/Moist	12.00	57.00
Sand & Gravel	3.00	60.00
Brown Clay	20.00	80.00
Gray Clay & Sand	13.00	93.00
Sandstone Marshall Ss	107.00	200.00

Well Grouted: Yes **Grouting Method:** Unknown

Grouting Material	Bags	Additives	Depth
Neat cement	3.00	None	3.00 ft. to 40.00 ft.

Geology Remarks:

Wellhead Completion: Pitless adapter, Other, 12 inches above grade

Nearest Source of Possible Contamination:

Type	Distance	Direction
Septic tank	90 ft.	Northeast

Drilling Machine Operator Name:
Employment: Employee

Contractor Type: Water Well Drilling Contractor **Reg No:** 13-0210
Business Name: Walters Plumbing, LO
Business Address: , Battle Creek, MI

Abandoned Well Plugged: No
Reason Not Plugged: Well still in use for non-drinking water purposes

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks:
Other Remarks:

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID: 13720625301

Tax No:	Permit No:	County: Calhoun	Township: Marshall

Well ID: 13000000372

Elevation: 898 ft.
Latitude: 42.271017
Longitude: -84.947
Method of Collection: Interpolation-Aerial Photo

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
02S 06W	25	Active	4150	WELL 1 GREEN ST

Distance and Direction from Road Intersection:
WSSN 04150;

Well Owner: MARSHALL

Well Address:	Owner Address:
MARSHALL WELL #1 NORTH WELL MARSHALL, MI	109 EAST MICHIGAN AVE MARSHALL, MI

Drilling Method: Unknown
Well Depth: 100.00 ft. **Well Use:** Type I public
Well Type: Replacement **Date Completed:**

Casing Type: Unknown **Height:** 0.00 ft. below grade
Casing Joint: Unknown
Casing Fitting: Drive shoe

Diameter: 12.00 in. to 41.00 ft. depth

Borehole:

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: **HP:**
Manufacturer: Other **Pump Type:** Other
Model Number: **Pump Capacity:** 1201 GPM
Drop Pipe Length: 0.00 ft. **Pump Voltage:**
Drop Pipe Diameter: **Drilling Record ID:**
Draw Down Seal Used: No

Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 7.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown

Screen Installed: No **Intake:** Bedrock Well

Formation Description	Thickness	Depth to Bottom
No Lithology Information	100.00	100.00

Well Grouted: Yes **Grouting Method:** Unknown

Grouting Material	Bags	Additives	Depth
Unknown	0.00	None	0.00 ft. to 0.00 ft.

Wellhead Completion: Unknown

Geology Remarks:

Nearest Source of Possible Contamination:

Type	Distance	Direction
None		

Abandoned Well Plugged: No
Reason Not Plugged:

Drilling Machine Operator Name:
Employment: Unknown

Contractor Type: Unknown **Reg No:**
Business Name:
Business Address:

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks: ORIGINAL WELLID# WAS 25001; MDPH WELL # 5201, ROCK WELL, PUMP SETTING 20, DATE PULLED 1990. ISOLATION AREA 200' AUXILIARY POWER: GAS ENGINE, 1200GPM CAPACITY.

Other Remarks: Pump Manufacturer:VERTICAL TURBINE, Pump Type:Type Unknown

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID: 13720625302

Tax No:	Permit No:	County: Calhoun	Township: Marshall

Well ID: 13000000373

Elevation: 897 ft.
Latitude: 42.270828
Longitude: -84.947007
Method of Collection: Interpolation-Aerial Photo

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
02S 06W	25	Active	4150	WELL 2 GREEN ST

Distance and Direction from Road Intersection:
WSSN 04150; APPR 50' E OF MARSHALL AVE 50' S OF RIVER S

Well Owner: MARSHALL

Well Address:	Owner Address:
MARSHALL WELL #2 CENTER WELL MARSHALL, MI	109 EAST MICHIGAN AVE MARSHALL, MI

Drilling Method: Cable Tool
Well Depth: 100.00 ft. **Well Use:** Type I public
Well Type: Replacement **Date Completed:** 5/30/1950

Casing Type: Steel - black **Height:** 0.00 ft. below grade
Casing Joint: Unknown
Casing Fitting: Drive shoe

Diameter: 12.00 in. to 24.00 ft. depth

Borehole:

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: **HP:**
Manufacturer: Other **Pump Type:** Other
Model Number: **Pump Capacity:** 1285 GPM
Drop Pipe Length: 0.00 ft. **Pump Voltage:**
Drop Pipe Diameter: **Drilling Record ID:**
Draw Down Seal Used: No

Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 15.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown
Pumping level 3.00 ft. after 3.00 hrs. at 1200 GPM

Formation Description	Thickness	Depth to Bottom
Sand Gravel Clay W/Silt	22.00	22.00
Brown Sandstone Soft Gray	68.00	90.00
Shale	10.00	100.00

Screen Installed: No **Intake:** Bedrock Well

Well Grouted: Yes **Grouting Method:** Unknown

Grouting Material	Bags	Additives	Depth
Unknown	0.00	None	0.00 ft. to 0.00 ft.

Wellhead Completion: Unknown

Geology Remarks:

Nearest Source of Possible Contamination:

Type	Distance	Direction
None		

Abandoned Well Plugged: No
Reason Not Plugged:

Drilling Machine Operator Name: W.A. WALDEN
Employment: Unknown

Contractor Type: Unknown **Reg No:** 39-0671
Business Name:
Business Address:

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks: ORIGINAL WELLID# WAS 25005; MDPH WELL # 5202. BETWEEN RR TRACKS & KALAMAZOO RIVER AT POWER PLANT. MI DEPT OF HEALTH DATA 95' CASING; SWL=6. PUMP SETTING 20', PUMPING LEVEL 9. 200' ISOLATION. DATE PUMP PULLED 1986.

Other Remarks: Pump Manufacturer:VERTICAL TURBINE, Pump Type:Type Unknown

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID: 13720625303

Tax No:	Permit No:	County: Calhoun	Township: Marshall

Well ID: 13000000374

Elevation: 895 ft.
Latitude: 42.270623
Longitude: -84.946978
Method of Collection: Interpolation-Aerial Photo

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
02S 06W	25	Active	4150	WELL 3 GREEN ST

Distance and Direction from Road Intersection:
WSSN 04150; APPR 450' SE OF INTERSECTION LINCOLN AND GR

Well Owner: MARSHALL

Well Address:	Owner Address:
MARSHALL WELL #3 SOUTH WELL MARSHALL, MI	109 EAST MICHIGAN AVE MARSHALL, MI

Drilling Method: Cable Tool
Well Depth: 98.00 ft. **Well Use:** Type I public
Well Type: Replacement **Date Completed:** 10/10/1953

Casing Type: Unknown **Height:** 0.00 ft. below grade
Casing Joint: Unknown
Casing Fitting: Drive shoe

Diameter: 12.00 in. to 32.00 ft. depth

Borehole:

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: **HP:**
Manufacturer: Other **Pump Type:** Other
Model Number: **Pump Capacity:** 1201 GPM
Drop Pipe Length: 0.00 ft. **Pump Voltage:**
Drop Pipe Diameter: **Drilling Record ID:**
Draw Down Seal Used: No

Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 2.25 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown

Screen Installed: No **Intake:** Unknown

Formation Description	Thickness	Depth to Bottom
Lithology Unknown Fill	4.00	4.00
Muck	7.00	11.00
Gravel & Clay	4.00	15.00
Sandstone Soft	5.00	20.00
Sandstone Soft	21.00	41.00
Shale & Sandstone Broken	7.00	48.00
Sandstone Medium	47.00	95.00
Shale	3.00	98.00

Well Grouted: Yes **Grouting Method:** Unknown

Grouting Material	Bags	Additives	Depth
Unknown	0.00	None	0.00 ft. to 0.00 ft.

Geology Remarks:

Wellhead Completion: Unknown

Nearest Source of Possible Contamination:

Type	Distance	Direction
None		

Drilling Machine Operator Name:
Employment: Unknown

Contractor Type: Unknown **Reg No:** 38-0106
Business Name:
Business Address:

Abandoned Well Plugged: No
Reason Not Plugged:

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks: ORIGINAL WELLID# WAS 25006; MDPH WELL #5401. LOCATION AT PUMPING HOUSE; PUMP SETTING 20, PUMPING LEVEL 4.5, DATE PUMP PULLED 1989, 200' ISOLATION; ROCK WELL.

Other Remarks: Pump Manufacturer:VERTICAL TURBINE, Pump Type:Type Unknown

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID: 13720625304

Tax No:	Permit No:	County: Calhoun	Township: Marshall

Well ID: 13000000375

Elevation: 897 ft.
Latitude: 42.270851
Longitude: -84.94672
Method of Collection: Interpolation-Aerial Photo

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
02S 06W	25	Active	4150	WELL 4 GREEN ST

Distance and Direction from Road Intersection:
WSSN 04150; APP 500' SE OF THE INTERSECTION OF LINCOLN

Well Owner: MARSHALL

Well Address:	Owner Address:
MARSHALL WELL #4 EAST WELL MARSHALL, MI	109 EAST MICHIGAN MARSHALL, MI

Drilling Method: Cable Tool
Well Depth: 99.00 ft. **Well Use:** Type I public
Well Type: Replacement **Date Completed:** 11/19/1964

Casing Type: Unknown **Height:** 0.00 ft. below grade
Casing Joint: Unknown
Casing Fitting: Drive shoe

Diameter: 20.00 in. to 18.00 ft. depth
12.00 in. to 29.60 ft. depth

Borehole:

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: **HP:**
Manufacturer: Other **Pump Type:** Other
Model Number: **Pump Capacity:** 1153 GPM
Drop Pipe Length: 0.00 ft. **Pump Voltage:**
Drop Pipe Diameter: **Drilling Record ID:**
Draw Down Seal Used: No

Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 3.50 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown
Pumping level 1.00 ft. after 0.00 hrs. at 1200 GPM

Screen Installed: No **Intake:** Bedrock Well

Formation Description	Thickness	Depth to Bottom
Topsoil Fill	2.00	2.00
Muck	10.00	12.00
Clay Gravely	4.00	16.00
Sandstone Soft	2.00	18.00
See Comments	30.00	48.00
White Sandstone Medium	51.00	99.00

Well Grouted: Yes **Grouting Method:** Unknown

Grouting Material	Bags	Additives	Depth
Unknown	0.00	None	0.00 ft. to 0.00 ft.

Geology Remarks:

Wellhead Completion: Unknown

Nearest Source of Possible Contamination:

Type	Distance	Direction
None		

Drilling Machine Operator Name:
Employment: Unknown

Contractor Type: Unknown **Reg No:** 38-0106
Business Name:
Business Address:

Abandoned Well Plugged: No
Reason Not Plugged:

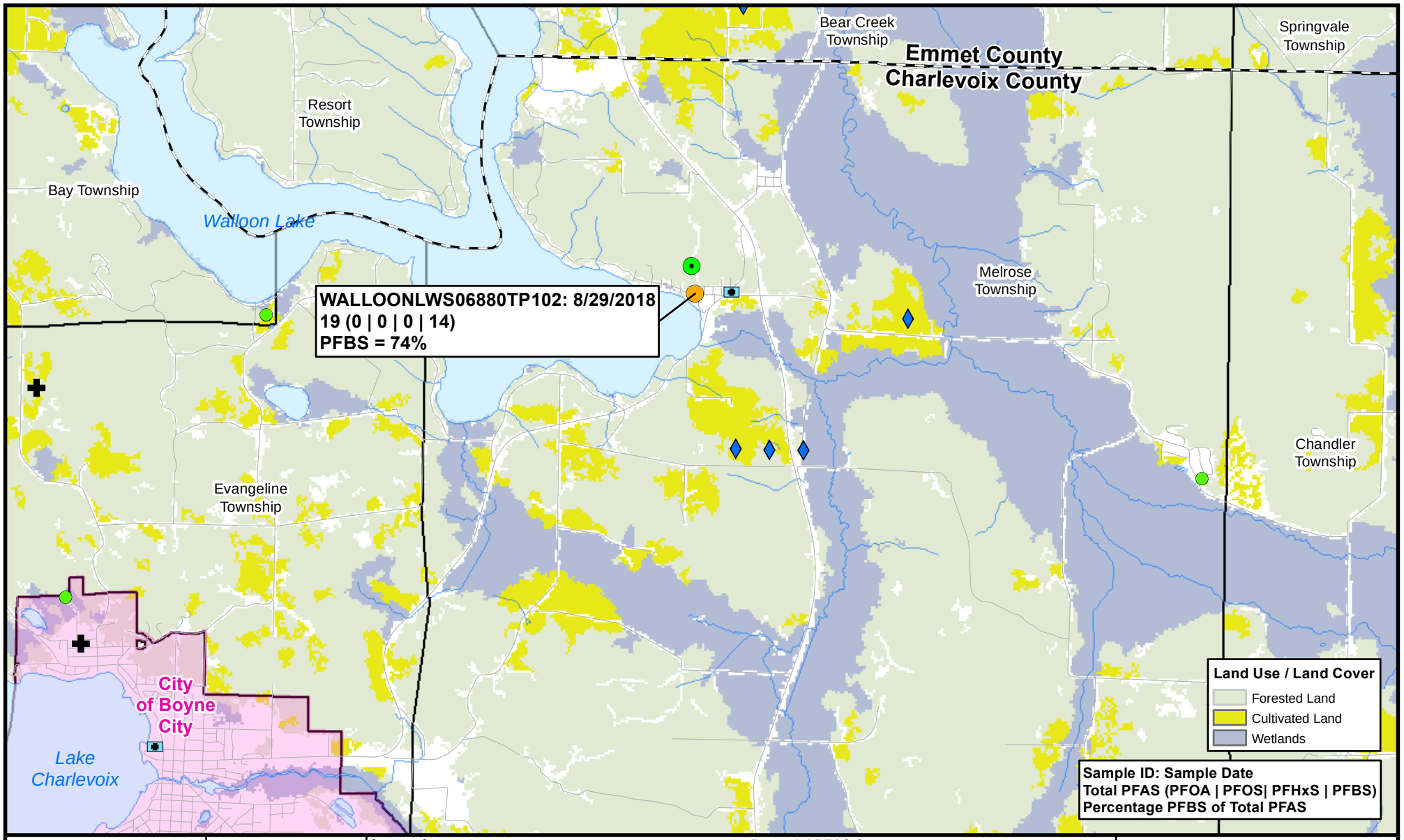
Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks: ORIGINAL WELLID# WAS 25007; MDPH WELL 6401; PUMP SETTING 20, PUMPING LEVEL 4'; PUMP PULLED 1988. 200' ISOLATION. LOCATED AT PUMPING STATION.

Other Remarks: Pump Manufacturer:VERTICAL TURBINE, Pump Type:Type Unknown



DEQ

Drawn:	JS	3/7/2019
Approved:		3/7/2019
Project #:		

Legend

PFBS > 50% of Total PFAS

Total PFAS (ppt)

- >0 - 10
- >10 - 50
- >50 - 100
- >100 - 200
- >200

- PFAS Non-Detect
- PFAS Detection; PFBS < 50% of Total PFAS
- Village / City Boundary
- Township Boundary
- County Boundary

Potential PFAS Sources

- Petroleum Bulk Stations
- Petroleum Terminals
- Military Sites
- Airports
- Paints & Allied Products
- Electroplaters
- Plating and Polishing Sites
- Active Accepting Landfills
- Historic Landfills
- Superfund Sites
- Biosolids Field
- Fire Station
- WWTP

0 0.5 1 2 Miles

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FIGURE 10
WALLOON LAKE WATER SYSTEM

CHARLEVOIX COUNTY, MI

LULC Data provided by USGS

G:\GrandRapids\DCS\GIS\ArcMap_GeoDB_Projects\ENV\GIS_Data\GIS\MDEQ CWS\MXD\PFBS_Evaluation\PFAS_Detects\Figure10_Walloon_Lake_Charlevoix.mxd

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No:	Permit No:	County: Charlevoix	Township: Melrose

Well ID: 15000000340

Elevation: 718 ft.
Latitude: 45.26636
Longitude: -84.93479
Method of Collection: Interpolation-Map

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
33N 05W	9	Unknown	6880	WALLOON LAKE

Distance and Direction from Road Intersection:
WSSN #06880;

Well Owner: WALLOON LAKE WATER SYSTEM

Well Address:
WALLOON LAKE WELL #2
WALLOON LAKE, MI

Owner Address:
WALLOON LAKE, MI

Drilling Method: Unknown
Well Depth: 59.00 ft. **Well Use:** Type I public
Well Type: Replacement **Date Completed:**

Casing Type: Steel - black **Height:** 0.00 ft. below grade
Casing Joint: Welded
Casing Fitting: None

Diameter: 8.00 in. to 31.00 ft. depth

Borehole:

Pump Installed: No
Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 21.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown

Formation Description	Thickness	Depth to Bottom
No Lithology Information	59.00	59.00

Screen Installed: Yes **Filter Packed:** No
Screen Diameter: 8.00 in. **Blank:** 0.00 ft. Above
Screen Material Type: Unknown

Slot	Length	Set Between
0.00	28.00 ft.	31.00 ft. and 59.00 ft.

Fittings: Other

Well Grouted: Unknown

Geology Remarks:

Wellhead Completion: Unknown

Nearest Source of Possible Contamination:

Type	Distance	Direction
None		

Drilling Machine Operator Name:
Employment: Unknown

Contractor Type: Unknown **Reg No:**
Business Name:
Business Address:

Abandoned Well Plugged: No
Reason Not Plugged: Unknown

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks: ORIGINAL WELLID# WAS 09004; NO OTHER INFORMATION.
Other Remarks: Screen Fittings:Type Unknown

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID: 15330509301

Tax No:	Permit No:	County: Charlevoix			Township: Melrose	
		Town/Range: 33N 05W	Section: 9	Well Status:	WSSN: 6880	Source ID/Well No: WALLOON LAKE

Well ID: 15000000339

Elevation: 799 ft.
Latitude: 45.269347
Longitude: -84.935314
Method of Collection: GPS Std Positioning Svc SA Off

Distance and Direction from Road Intersection: WSSN #06880;

Well Owner: WALLOON LAKE WATER SYSTEM

Well Address: WALLOON LAKE WELL #1 WALLOON LAKE, MI

Owner Address: WALLOON LAKE, MI

Drilling Method: Rotary
Well Depth: 284.00 ft. **Well Use:** Type I public
Well Type: Replacement **Date Completed:** 1/15/1985

Casing Type: PVC plastic **Height:**
Casing Joint: Unknown
Casing Fitting: None

Diameter: 8.00 in. to 193.00 ft. depth

Borehole: 12.50 in. to 284.00 ft. depth

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: **HP:**
Manufacturer: Other **Pump Type:** Submersible
Model Number: **Pump Capacity:** 243 GPM
Drop Pipe Length: 168.00 ft. **Pump Voltage:**
Drop Pipe Diameter: **Drilling Record ID:**
Draw Down Seal Used: No

Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 132.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown
Pumping level 138.00 ft. after 24.00 hrs. at 275 GPM

Screen Installed: No **Intake:** Bedrock Well

Formation Description	Thickness	Depth to Bottom
Sand	4.00	4.00
Clay & Sand	11.00	15.00
Sand & Gravel	50.00	65.00
Clay & Stones	32.00	97.00
Sand Gravel Clay	15.00	112.00
Sand & Gravel	8.00	120.00
Sand Gravel Clay	18.00	138.00
Clay Sand Gravel	13.00	151.00
Sand	13.00	164.00
Clay	4.00	168.00
Limestone W/Clay	20.00	188.00
Limestone	96.00	284.00

Well Grouted: Yes **Grouting Method:** Unknown

Grouting Material	Bags	Additives	Depth
Other	0.00	None	0.00 ft. to 30.00 ft.

Geology Remarks:

Wellhead Completion: Pitless adapter

Nearest Source of Possible Contamination:

Type	Distance	Direction
None		North

Drilling Machine Operator Name:
Employment: Unknown

Abandoned Well Plugged: No
Reason Not Plugged:

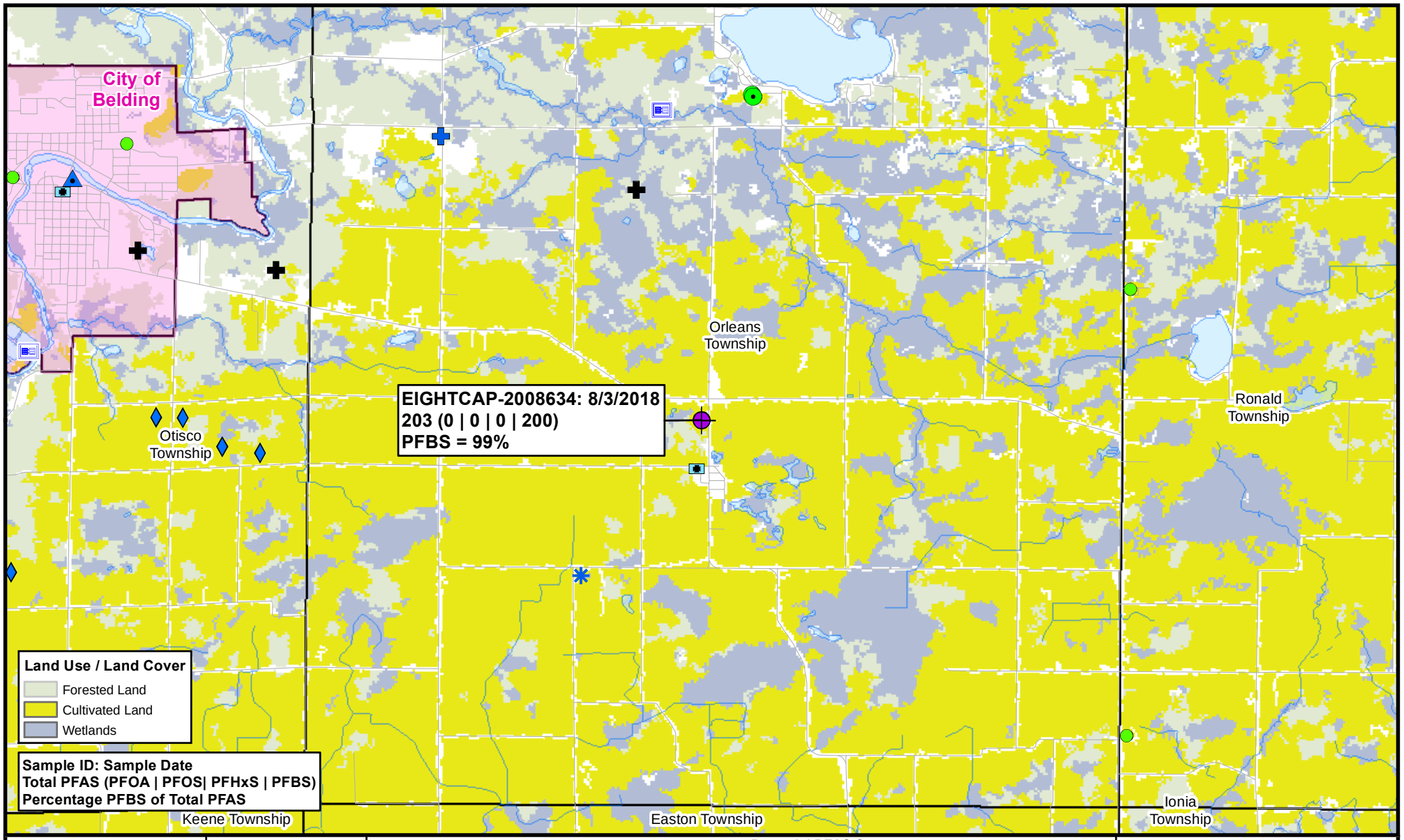
Contractor Type: Unknown **Reg No:** 45-0795
Business Name:
Business Address:

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks: ORIGINAL WELLID# WAS 09003;
Other Remarks: Grouting Material 1:Listed as other in Wellkey, Pump Manufacturer:PLEUCEP



DEQ

Drawn:	JS	3/7/2019
Approved:		3/7/2019
Project #:		

Legend

PFBS > 50% of Total PFAS

Total PFAS (ppt)

- >0 - 10
- >10 - 50
- >50 - 100
- >100 - 200
- >200

- PFAS Non-Detect
- PFAS Detection; PFBS < 50% of Total PFAS
- Village / City Boundary
- Township Boundary
- County Boundary

Potential PFAS Sources

- Petroleum Bulk Stations
- Petroleum Terminals
- Military Sites
- Airports
- Paints & Allied Products
- Electroplaters
- Plating and Polishing Sites
- Active Accepting Landfills
- Historic Landfills
- Superfund Sites
- Biosolids Field
- Fire Station
- WWTP

0 0.5 1 2 Miles

N

FIGURE 16
EIGHT CAP IONIA CO.
OUTREACH

IONIA COUNTY, MI

LULC Data provided by USGS

G:\GrandRapids\DCS\GIS\ArcMap_GeoDB_Projects\ENV\GIS_Data\GIS\MDEQ CWS\MXD\PFBS_Evaluation\PFAS_Detects\Figure16_Eight_Cap_Ionia_CO_Outreach_Ionia.mxd

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No:	Permit No:	County: Ionia	Township: Orleans

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
08N 07W	21	Active	2008634	001

Well ID: 34000002131

Elevation: 856 ft.
Latitude: 43.07337
Longitude: -85.13629
Method of Collection: GPS Std Positioning Svc SA Off

Distance and Direction from Road Intersection:

Well Owner:

Well Address:
MI

Owner Address:

Drilling Method: Unknown
Well Depth: 80.00 ft. **Well Use:** Type II public
Well Type: Unknown **Date Completed:** 12/30/1899
Casing Type: Unknown **Height:**
Casing Joint: Unknown
Casing Fitting:

Diameter: 6.00 in. to

Borehole:

Pump Installed: No
Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: Below Grade
Well Yield Test: **Yield Test Method:** Unknown

Screen Installed: No **Intake:** Unknown

Well Grouted: No

Wellhead Completion: Unknown

Formation Description	Thickness	Depth to Bottom
Lithology Unknown	80.00	80.00

Geology Remarks:

Nearest Source of Possible Contamination:
Type **Distance** **Direction**
Unknown

Abandoned Well Plugged: No

Reason Not Plugged: Unknown

Drilling Machine Operator Name:
Employment: Unknown

Contractor Type: Unknown **Reg No:**
Business Name:
Business Address:

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks:

Other Remarks:

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No:	Permit No:	County: Ionia	Township: Orleans

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
08N 07W	3	Active	40209	1

Well ID: 34000002295

Elevation:

Latitude: 43.10799

Longitude: -85.12903

Method of Collection: GPS Std Positioning Svc SA Off

Distance and Direction from Road Intersection:
ABOUT 100 YDS WEST OF PUBLIC LANSING 100 YARDS SOUTH ON LONG LAKE RD AT TRAILER PARK

Well Owner: CLIDE ADAMS

Well Address:
LONG LAKE MHP Well 1
MI

Owner Address:
1660 VINING RD
GREENVILLE, MI

Drilling Method: Cable Tool
Well Depth: 43.00 ft. **Well Use:** Type I public
Well Type: New **Date Completed:** 6/8/1986

Casing Type: Steel - unknown **Height:**
Casing Joint: Threaded & coupled
Casing Fitting: Drive shoe

Diameter: 4.00 in. to 33.00 ft. depth

Borehole:

Pump Installed: No
Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 15.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown
Pumping level 30.00 ft. after 6.00 hrs. at 30 GPM
Pumping level 25.00 ft. after 3.00 hrs. at 18 GPM

Formation Description	Thickness	Depth to Bottom
Sand Medium	20.00	20.00
Sand & Clay Fine	10.00	30.00
Sand Coarse W/Stones	13.00	43.00
Gray Clay	39.00	82.00
Sand Medium	2.00	84.00
Gray Clay	18.00	102.00

Screen Installed: Yes **Filter Packed:** No
Screen Diameter: 3.00 in. **Blank:** 1.00 ft. Above
Screen Material Type: Unknown

Slot	Length	Set Between
10.00	10.00 ft.	33.00 ft. and 43.00 ft.

Fittings: Neoprene packer

Well Grouted: Yes **Grouting Method:** Unknown

Grouting Material	Bags	Additives	Depth
Bentonite dry granular	3.00	None	43.00 ft. to 102.00 ft.

Geology Remarks:

Wellhead Completion: 12 inches above grade

Nearest Source of Possible Contamination:

Type	Distance	Direction
Septic tank	200 ft.	Southwest

Drilling Machine Operator Name:
Employment: Unknown

Contractor Type: Water Well Drilling Contractor **Reg No:** 34-1796
Business Name: BANHAGEL WELL DRILLING
Business Address:

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks:

Other Remarks:

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No:	Permit No:	County: Ionia	Township: Orleans

Well ID: 34000002296

Elevation:

Latitude: 43.10809

Longitude: -85.12885

Method of Collection: GPS Std Positioning Svc SA Off

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
08N 07W	3	Active	40209	2

Distance and Direction from Road Intersection:

Well Owner: GLEN HISOCK

Well Address:
LONG LAKE MHP Well 2
MI

Owner Address:
ORLEANS , MI

Drilling Method: Cable Tool
Well Depth: 57.00 ft. **Well Use:** Type I public
Well Type: New **Date Completed:** 1/2/1973

Casing Type: Steel - unknown **Height:**
Casing Joint: Welded
Casing Fitting: Drive shoe

Diameter: 4.00 in. to 52.00 ft. depth

Borehole:

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: **HP:** 1.00
Manufacturer: Aermotor **Pump Type:** Submersible
Model Number: **Pump Capacity:** 20 GPM
Drop Pipe Length: 45.00 ft. **Pump Voltage:**
Drop Pipe Diameter: **Drilling Record ID:**
Draw Down Seal Used: No

Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 32.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown
at 20 GPM
at 20 GPM

Formation Description	Thickness	Depth to Bottom
Sand	6.00	6.00
Sand & Clay	4.00	10.00
Clay Hard	20.00	30.00
Sand Silty	7.00	37.00
Sand Water Bearing	20.00	57.00

Screen Installed: Yes **Filter Packed:** No
Screen Diameter: 3.00 in. **Blank:**
Screen Material Type: Stainless steel-wire wrapped

Slot	Length	Set Between
12.00	5.00 ft.	52.00 ft. and 57.00 ft.

Fittings: Neoprene packer

Well Grouted: No

Geology Remarks:

Wellhead Completion: Pitless adapter

Nearest Source of Possible Contamination:

Type	Distance	Direction
Unknown		
Unknown		

Drilling Machine Operator Name:
Employment: Unknown

Contractor Type: Water Well Drilling Contractor **Reg No:** 34-0700
Business Name: KARL GEIGER, JR.
Business Address: BELDING

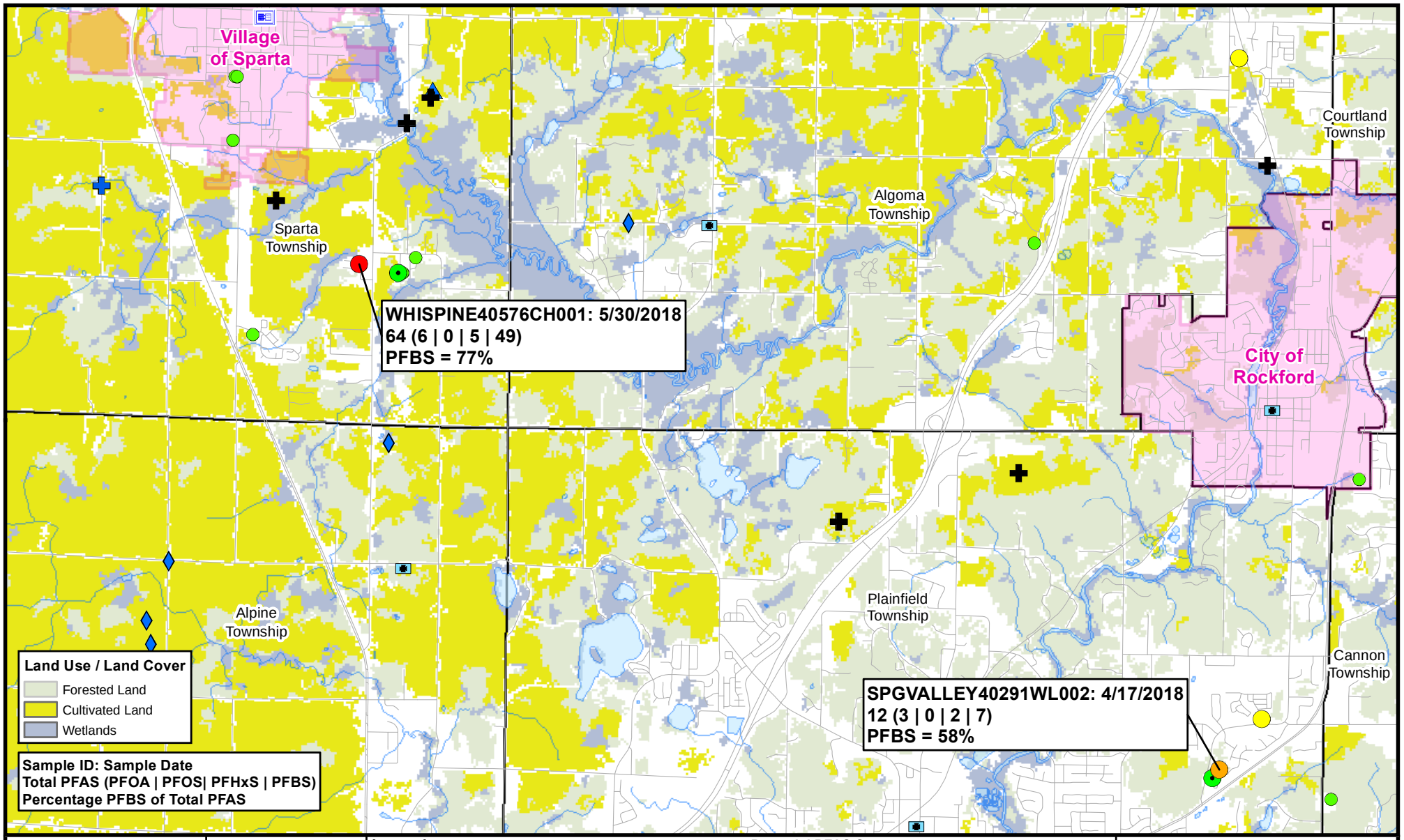
Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks:

Other Remarks:



DEQ

Drawn:	JS	3/7/2019
Approved:		3/7/2019
Project #:		

Legend

PFBS > 50% of Total PFAS

Total PFAS (ppt)

- >0 - 10
- >10 - 50
- >50 - 100
- >100 - 200
- >200

- PFAS Non-Detect
- PFAS Detection; PFBS < 50% of Total PFAS
- Village / City Boundary
- Township Boundary
- County Boundary

Potential PFAS Sources

- Petroleum Bulk Stations
- Petroleum Terminals
- Military Sites
- Airports
- Paints & Allied Products
- Electroplaters
- Plating and Polishing Sites
- Active Accepting Landfills
- Historic Landfills
- Superfund Sites
- Biosolids Field
- Fire Station
- WWTP

0 0.5 1 2 Miles

N

FIGURE 15
WHISPERING PINES & SPRING VALLEY MOBILE HOME PARK

KENT COUNTY, MI

LULC Data provided by USGS

G:\GrandRapids\DCS\GIS\ArcMap_GeoDB_Projects\ENV\GIS_Data\GIS\MDEQ CWS\MXD\PFBS_Evaluation\PFAS_Detects\Figure15_WhisperingPines_and_SpringValleyMHP_Kent.mxd

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No:	Permit No:	County: Kent	Township: Plainfield

Well ID: 41000004826

Elevation:

Latitude: 43.08113

Longitude: -85.56581

Method of Collection: GPS Std Positioning Svc SA Off

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
08N 11W	13	Active	40291	WELL 2

Distance and Direction from Road Intersection:
1/4 MILE NORTH OF WOLVERINE BLVD. SPRING VALLEY WELL #2

Well Owner: SPRING VALLEY #2-JAMES VOJAK

Well Address:	Owner Address:
6460 NORTHLAND DR ROCKFORD, MI 49341	37700 KNOLL DR WAYNE, MI 48184

Drilling Method: Rotary
Well Depth: 115.00 ft. **Well Use:** Type I public
Well Type: New **Date Completed:** 7/31/1980

Casing Type: Steel - unknown **Height:**
Casing Joint: Welded
Casing Fitting: None

Diameter: 6.00 in. to 58.00 ft. depth

Borehole:

Pump Installed: No
Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 14.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown
Pumping level 35.00 ft. after 1.00 hrs. at 50 GPM

Screen Installed: Yes **Filter Packed:** No
Screen Diameter: 6.00 in. **Blank:**
Screen Material Type: Stainless steel-wire wrapped

Slot	Length	Set Between
7.00	8.00 ft.	58.00 ft. and 66.00 ft.

Fittings: Neoprene packer

Formation Description	Thickness	Depth to Bottom
Sand	25.00	25.00
Clay	4.00	29.00
Sand	15.00	44.00
Clay	7.00	51.00
Sand	7.00	58.00
Sand & Gravel	8.00	66.00
Clay	10.00	76.00
Sand & Gravel	5.00	81.00
Clay & Gravel W/Stones	34.00	115.00

Well Grouted: No

Geology Remarks:

Wellhead Completion: 12 inches above grade

Nearest Source of Possible Contamination:

Type	Distance	Direction
Surface water	200 ft.	West

Drilling Machine Operator Name:
Employment: Unknown

Contractor Type: Water Well Drilling Contractor **Reg No:** 39-0312
Business Name: WEBBER WELL DRILLING
Business Address: 12831 LONG LAKE, DRIVE

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks:

Other Remarks:

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No:	Permit No:	County: Kent	Township: Plainfield

Well ID: 41000013675

Elevation:

Latitude: 43.08019

Longitude: -85.56677

Method of Collection: GPS Std Positioning Svc SA Off

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
08N 11W	13	Active	40291	WELL 3

Distance and Direction from Road Intersection:
2/10 OF A MILE NORTH OF M-44 300 FT EAST OF NORTHLAND RD

Well Owner: SPRING VALLEY MHP #3

Well Address:
6460 NORTHLAND DR., N.E.
ROCKFORD, MI 49341

Owner Address:
6460 NORTHLAND DR., N.E.
ROCKFORD, MI 49341

Drilling Method: Rotary
Well Depth: 57.00 ft. **Well Use:** Type I public
Well Type: New **Date Completed:** 6/4/2003

Casing Type: PVC plastic **Height:** 1.00 ft. above grade
Casing Joint: Solvent welded/glued
Casing Fitting: Centralizer

Diameter: 5.00 in. to 51.00 ft. depth

Borehole: 8.75 in. to 60.00 ft. depth

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: 7/9/2003 **HP:** 5.00
Manufacturer: Grundfos **Pump Type:** Submersible
Model Number: 75S50-8 **Pump Capacity:** 75 GPM
Drop Pipe Length: 42.00 ft. **Pump Voltage:**
Drop Pipe Diameter: 2.00 in. **Drilling Record ID:**
Draw Down Seal Used: Yes

Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 10.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Test pump
Pumping level 46.00 ft. after 8.00 hrs. at 75 GPM

Screen Installed: Yes **Filter Packed:** Yes
Screen Diameter: 5.00 in. **Blank:** 0.00 ft.
Screen Material Type: Stainless steel-wire wrapped

Slot	Length	Set Between
20.00	6.00 ft.	51.00 ft. and 57.00 ft.

Fittings: Other

Formation Description	Thickness	Depth to Bottom
Sand	4.00	4.00
Sand & Gravel	15.00	19.00
Gray Clay	25.00	44.00
Sand & Gravel	15.00	59.00
Gray Clay & Gravel	2.00	61.00

Well Grouted: Yes **Grouting Method:** Grout pipe outside casing

Grouting Material	Bags	Additives	Depth
Neat cement	10.00	None	0.00 ft. to 48.00 ft.

Geology Remarks:

Wellhead Completion: Pitless adapter, 12 inches above grade

Nearest Source of Possible Contamination:

Type	Distance	Direction
Sewer line	100 ft.	North
None		

Drilling Machine Operator Name: JIM MORSE
Employment: Employee

Contractor Type: Water Well Drilling Contractor **Reg No:** 70-2354
Business Name: Raymer Company
Business Address: 1357 Comstock Street, Marne, MI, 49435

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks: NOTES: Q/S =2.0, BAKER 5" X 5'X 2" TYPE I APPROVED PITLESS ADAPTER INSTALLED, #10-3 W/G H.D. DOUBLE JACKETED ELECTRIC CABLE, 52 FT OF AIRLINE, DELUXE CONTROL BOX, 230 VOLT, 1 PHASE.

Other Remarks: Screen Fittings:5 INCH FEMALE ADAPTER

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No:	Permit No:	County: Kent	Township: Plainfield

Well ID: 41000020214

Elevation:

Latitude: 43.086588

Longitude: -85.559736

Method of Collection: Interpolation-Aerial Photo

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
08N 11W	12	Active	40296	WELL 3

Distance and Direction from Road Intersection:
WOODLAND ESTATES WELL #3

Well Owner: WOODLAND ESTATES

Well Address:	Owner Address:
6737 NORTHLAND DR ROCKFORD, MI	6737 NORTHLAND DR ROCKFORD, MI

Drilling Method: Cable Tool
Well Depth: 75.00 ft. **Well Use:** Type I public
Well Type: Unknown **Date Completed:** 7/20/1982

Casing Type: Unknown **Height:**
Casing Joint: Unknown
Casing Fitting: Drive shoe

Diameter: 6.00 in. to 65.00 ft. depth

Borehole:

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: 7/20/1982 **HP:** 7.50
Manufacturer: Unknown **Pump Type:** Submersible
Model Number: **Pump Capacity:** 135 GPM
Drop Pipe Length: 53.00 ft. **Pump Voltage:**
Drop Pipe Diameter: **Drilling Record ID:**
Draw Down Seal Used: No

Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 24.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown

Formation Description	Thickness	Depth to Bottom
Clay	2.00	2.00
Sand	7.00	9.00
Clay	3.00	12.00
Sand	63.00	75.00

Screen Installed: Yes **Filter Packed:** No
Screen Diameter: 6.00 in. **Blank:**
Screen Material Type: Stainless steel-slotted

Slot	Length	Set Between
10.00	10.00 ft.	65.00 ft. and 75.00 ft.

Fittings: Neoprene packer

Well Grouted: No

Geology Remarks:

Wellhead Completion: Pitless adapter

Nearest Source of Possible Contamination:

Type	Distance	Direction
Unknown	200 ft.	

Drilling Machine Operator Name:
Employment: Unknown

Abandoned Well Plugged: No

Reason Not Plugged: Unknown

Contractor Type: Water Well Drilling Contractor **Reg No:**
Business Name: J.M. KLEYNENBERG AND SONS
Business Address:

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks:

Other Remarks:

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No:	Permit No: WS-02008	County: Kent	Township: Plainfield

Well ID: 41000014611

Elevation: 810 ft.
Latitude: 43.08673
Longitude: -85.5599
Method of Collection: GPS Std Positioning Svc SA Off

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
08N 11W	12	Active	40296	WELL 4

Distance and Direction from Road Intersection:
100' EAST OF WOODLAND ESTATES DR. - 100' N. OF NORTHLAND DR.

Well Owner: WOODLAND ESTATES

Well Address:	Owner Address:
4329 BRIAR RIDGE ROCKFORD, MI 49341	4329 BRIAR RIDGE ROCKFORD, MI 49341

Drilling Method: Rotary
Well Depth: 118.00 ft. **Well Use:** Type I public
Well Type: New **Date Completed:** 3/13/2002

Casing Type: Steel - black **Height:** 1.00 ft. above grade
Casing Joint: Threaded & coupled
Casing Fitting: Centralizer

Diameter: 6.00 in. to 98.00 ft. depth

Borehole: 10.00 in. to 118.00 ft. depth

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: 6/20/2002 **HP:** 7.50
Manufacturer: Grundfos **Pump Type:** Submersible
Model Number: 150S75-4 **Pump Capacity:** 110 GPM
Drop Pipe Length: 84.00 ft. **Pump Voltage:**
Drop Pipe Diameter: 3.00 in. **Drilling Record ID:**
Draw Down Seal Used: No

Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 22.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Test pump
Pumping level 60.63 ft. after 8.00 hrs. at 155 GPM

Formation Description	Thickness	Depth to Bottom
Sand	8.00	8.00
Brown Clay	5.00	13.00
Sand	67.00	80.00
Sand & Gravel	38.00	118.00

Screen Installed: Yes **Filter Packed:** Yes
Screen Diameter: 6.00 in. **Blank:** 0.00 ft.
Screen Material Type: Stainless steel-wire wrapped

Slot	Length	Set Between
40.00	20.00 ft.	98.00 ft. and 118.00 ft.

Fittings: Other

Well Grouted: Yes **Grouting Method:** Grout pipe outside casing

Grouting Material	Bags	Additives	Depth
Neat cement	30.00	None	0.00 ft. to 88.00 ft.

Wellhead Completion: 12 inches above grade

Geology Remarks:

Nearest Source of Possible Contamination:

Type	Distance	Direction
Septic tank	150 ft.	East
None		

Drilling Machine Operator Name: CURTIS MASUNAS
Employment: Employee

Contractor Type: Water Well Drilling Contractor **Reg No:** 70-2055
Business Name: Raymer Company
Business Address: 1357 Comstock Street, Marne, MI, 49435

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks: PUMP CONDITIONS OF SERVICE - 110 G.P.M. @ 187 FT. TDH. ENGINEER = LARRY WILSON P.E. - V-TECH ENGINEERING, INC. - 460 VOLT 3 PHASE

Other Remarks: Screen Fittings:fnpt x plate, Elevation Collection Method:Unknown

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No:	Permit No:	County: Kent	Township: Sparta

Well ID: 41000020205

Elevation:

Latitude: 43.13376

Longitude: -85.6923

Method of Collection: GPS Std Positioning Svc SA Off

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
09N 12W	26	Active	40576	WELL 1

Distance and Direction from Road Intersection:
ALPINE AND SCHULTZ WHISPERING PINES MHP WELL 1

Well Owner: NORTHERN PROPERTIES

Well Address:	Owner Address:
9397 ALPINE SPARTA, MI	9397 ALPINE SPARTA, MI

Drilling Method: Cable Tool
Well Depth: 38.00 ft. **Well Use:** Type I public
Well Type: New **Date Completed:** 3/19/1974

Casing Type: Steel - unknown **Height:**
Casing Joint: Threaded & coupled
Casing Fitting: Drive shoe

Diameter: 4.00 in. to 33.00 ft. depth

Borehole:

Pump Installed: No
Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 5.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown
Pumping level 30.00 ft. after 2.00 hrs. at 60 GPM

Formation Description	Thickness	Depth to Bottom
Sand	20.00	20.00
Sand & Gravel	18.00	38.00

Screen Installed: Yes **Filter Packed:** No
Screen Diameter: 3.00 in. **Blank:**
Screen Material Type: Stainless steel-slotted

Slot	Length	Set Between
10.00	5.00 ft.	33.00 ft. and 38.00 ft.

Fittings: Neoprene packer

Well Grouted: No

Geology Remarks:

Wellhead Completion: 12 inches above grade

Nearest Source of Possible Contamination:

Type	Distance	Direction
Septic tank	300 ft.	East

Drilling Machine Operator Name:
Employment: Unknown

Contractor Type: Water Well Drilling Contractor **Reg No:** 41-1194
Business Name: BELL WELL DRILLING
Business Address:

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks:

Other Remarks:

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No:	Permit No:	County: Kent	Township: Sparta

Well ID: 41000020206

Elevation:

Latitude: 43.13409

Longitude: -85.69225

Method of Collection: GPS Std Positioning Svc SA Off

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
09N 12W	26	Active	40576	WELL 2

Distance and Direction from Road Intersection:
SCHULTZ AND ALPINE WHISPERING PINES WELL #2

Well Owner: VICTOR HANSEN

Well Address:	Owner Address:
9397 ALPINE SPARTA, MI	9397 ALPINE SPARTA, MI

Drilling Method: Cable Tool
Well Depth: 37.00 ft. **Well Use:** Type I public
Well Type: New **Date Completed:** 3/25/1974

Casing Type: Steel - unknown **Height:**
Casing Joint: Threaded & coupled
Casing Fitting: Unknown

Diameter: 4.00 in. to 32.00 ft. depth

Borehole:

Pump Installed: No
Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 5.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown
Pumping level 30.00 ft. after 2.00 hrs. at 60 GPM

Formation Description	Thickness	Depth to Bottom
Sand	20.00	20.00
Gravel & Clay	12.00	32.00
Gravel & Sand	5.00	37.00

Screen Installed: Yes **Filter Packed:** No
Screen Diameter: 3.00 in. **Blank:**
Screen Material Type: Stainless steel-slotted

Slot	Length	Set Between
10.00	5.00 ft.	32.00 ft. and 37.00 ft.

Fittings: Neoprene packer

Well Grouted: No

Geology Remarks:

Wellhead Completion: 12 inches above grade

Nearest Source of Possible Contamination:

Type	Distance	Direction
Septic tank	325 ft.	East

Drilling Machine Operator Name:
Employment: Unknown

Contractor Type: Water Well Drilling Contractor **Reg No:** 41-1194
Business Name: BELL WELLDRILLING
Business Address:

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks:

Other Remarks:

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No:	Permit No:	County: Kent	Township: Sparta

Well ID: 41000015845

Elevation:
Latitude: 43.133
Longitude: -85.6859
Method of Collection: GPS Std Positioning Svc SA Off

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
09N 12W	25	Active	40284	WELL 2

Distance and Direction from Road Intersection:

Well Owner: PARKWOOD GREEN #2

Well Address:	Owner Address:
630 SCHULTZ RD SPARTA, MI	630 SCHULTZ RD SPARTA, MI

Drilling Method: Unknown
Well Depth: 9999.00 ft. **Well Use:** Type I public
Well Type: Unknown **Date Completed:**

Casing Type: Unknown **Height:**
Casing Joint: Unknown
Casing Fitting: Unknown

Diameter:

Borehole:

Pump Installed: No
Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: Below Grade
Well Yield Test: **Yield Test Method:** Unknown

Screen Installed: No **Intake:** Unknown

Well Grouted: No

Wellhead Completion: Unknown

Formation Description	Thickness	Depth to Bottom
Lithology Unknown	9999.00	9999.00

Geology Remarks:

Nearest Source of Possible Contamination:

Type	Distance	Direction
Unknown		
Unknown		

Abandoned Well Plugged: No

Reason Not Plugged:

Drilling Machine Operator Name:
Employment: Unknown

Contractor Type: Unknown **Reg No:**
Business Name:
Business Address:

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks: NO WELL LOG. ENTERED FOR GPS COORDINATES
Other Remarks:

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No:	Permit No:	County: Kent	Township: Sparta

Well ID: 41000015844

Elevation:
Latitude: 43.1329
Longitude: -85.6866
Method of Collection: GPS Std Positioning Svc SA Off

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
09N 12W	25	Active	40284	WELL 1

Distance and Direction from Road Intersection:

Well Owner: PARKWOOD GREEN #1

Well Address:	Owner Address:
630 SCHULTZ RD SPARTA , MI	630 SCHULTZ RD SPARTA , MI

Drilling Method: Unknown
Well Depth: 9999.00 ft. **Well Use:** Type I public
Well Type: Unknown **Date Completed:**

Casing Type: Unknown **Height:**
Casing Joint: Unknown
Casing Fitting: Unknown

Diameter:

Borehole:

Pump Installed: No
Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: Below Grade
Well Yield Test: **Yield Test Method:** Unknown

Screen Installed: No **Intake:** Unknown

Well Grouted: No

Wellhead Completion: Unknown

Formation Description	Thickness	Depth to Bottom
Lithology Unknown	9999.00	9999.00

Geology Remarks:

Nearest Source of Possible Contamination:

Type	Distance	Direction
Unknown		
Unknown		

Abandoned Well Plugged: No

Reason Not Plugged:

Drilling Machine Operator Name:
Employment: Unknown

Contractor Type: Unknown **Reg No:**
Business Name:
Business Address:

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks: NO WELL LOG. ENTERED FOR GPS COORDINATES
Other Remarks:

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No:	Permit No:	County: Kent	Township: Sparta

Well ID: 41000015843

Elevation:

Latitude: 43.1345

Longitude: -85.6842

Method of Collection: GPS Std Positioning Svc SA Off

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
09N 12W	25	Active	40284	WELL 3

Distance and Direction from Road Intersection:
1000' E. OF ALPINE AVE. 75' S. OF SCHULTZ

Well Owner: PARKWOOD GREEN #3

Well Address:	Owner Address:
630 SCHULTZ RD. SPARTA, MI	630 SCHULTZ RD. SPARTA, MI

Drilling Method: Cable Tool
Well Depth: 32.00 ft. **Well Use:** Type I public
Well Type: New **Date Completed:** 9/18/1976

Casing Type: Steel - unknown **Height:**
Casing Joint: Threaded & coupled
Casing Fitting: Drive shoe

Diameter: 6.00 in. to 26.00 ft. depth

Borehole:

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: **HP:** 3.00
Manufacturer: Goulds **Pump Type:** Submersible
Model Number: D300 **Pump Capacity:** 75 GPM
Drop Pipe Length: 25.00 ft. **Pump Voltage:**
Drop Pipe Diameter: **Drilling Record ID:**
Draw Down Seal Used: No

Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 9.50 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown
Pumping level 16.00 ft. after 4.00 hrs. at 100 GPM

Formation Description	Thickness	Depth to Bottom
Sand	14.00	14.00
Red Clay	1.00	15.00
Gravel	17.00	32.00

Screen Installed: Yes **Filter Packed:** No
Screen Diameter: 6.00 in. **Blank:**
Screen Material Type: Stainless steel-wire wrapped

Slot	Length	Set Between
20.00	6.00 ft.	26.00 ft. and 32.00 ft.

Fittings: None

Well Grouted: No

Geology Remarks:

Wellhead Completion: 12 inches above grade

Nearest Source of Possible Contamination:

Type	Distance	Direction
Sewer line	150 ft.	West
None		

Drilling Machine Operator Name:
Employment: Unknown

Contractor Type: Water Well Drilling Contractor **Reg No:**
Business Name: C.S. RAYMER CO, INC
Business Address:

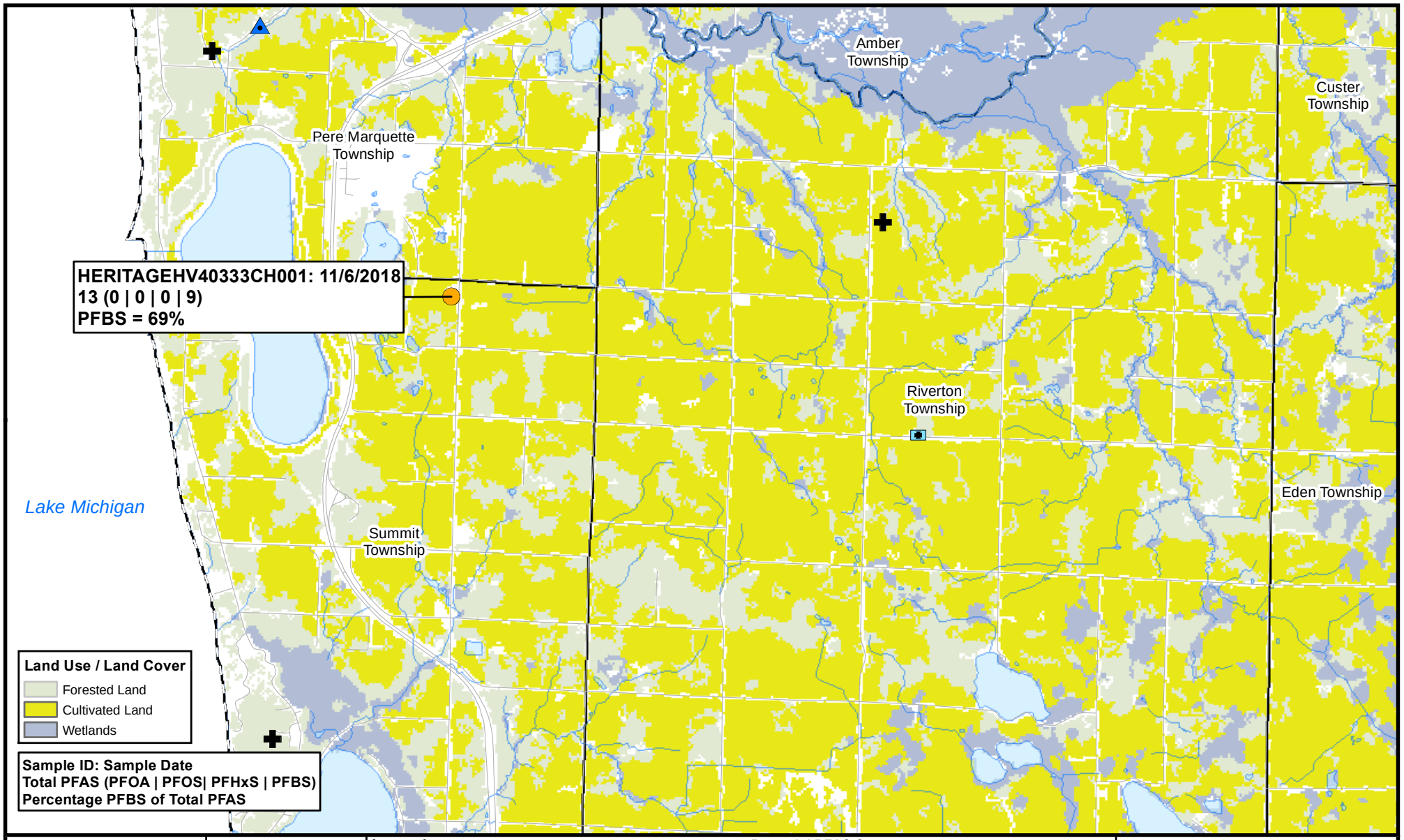
Water Well Contractor's Certification

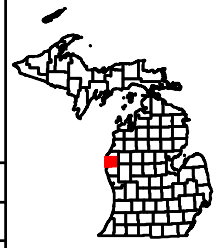
This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks:

Other Remarks:





Legend

PFBS > 50% of Total PFAS

Total PFAS (ppt)

- >0 - 10
- >10 - 50
- >50 - 100
- >100 - 200
- >200

- PFAS Non-Detect
- PFAS Detection; PFBS < 50% of Total PFAS
- Village / City Boundary
- Township Boundary
- County Boundary

Potential PFAS Sources

- Petroleum Bulk Stations
- Petroleum Terminals
- Military Sites
- Airports
- Paints & Allied Products
- Electroplaters
- Plating and Polishing Sites
- Active Accepting Landfills
- Historic Landfills
- Superfund Sites
- Biosolids Field
- Fire Station
- WWTP

0 0.5 1 2 Miles

N

Drawn:	JS	3/7/2019
Approved:		3/7/2019
Project #:		

FIGURE 12
HERITAGE HILLS
MOBILE HOME PARK

MASON COUNTY, MI

LULC Data provided by USGS

G:\GrandRapids\DCS\GIS\ArcMap_GeoDB_Projects\ENV\GIS_Data\GIS\MDEQ CWS\MXD\PFBS_Evaluation\PFAS_Detects\Figure12_Heritage_Hills_MHP_Mason.mxd

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No:	Permit No:	County: Mason	Township: Summit

Well ID: 53000000582

Elevation:

Latitude: 43.8905

Longitude: -86.40009

Method of Collection: Interpolation-Aerial Photo

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
17N 18W	12	Active	40333	1

Distance and Direction from Road Intersection:
400' South of Kinney Rd., on west side of Pere Marquette Rd.

Well Owner: Larry Martz

Well Address:	Owner Address:
Heritage Hills #1 Ludington, MI	3677 S. Pere Marquette Ludington, MI

Drilling Method: Cable Tool
Well Depth: 103.00 ft. **Well Use:** Type I public
Well Type: Unknown **Date Completed:** 7/13/1970

Casing Type: Steel - black **Height:** 0.00 ft. below grade
Casing Joint: Threaded & coupled
Casing Fitting: Drive shoe

Diameter: 6.00 in. to 93.00 ft. depth

Borehole:

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: **HP:** 3.00
Manufacturer: Red Jacket **Pump Type:** Submersible
Model Number: 300T1-8FC **Pump Capacity:**
Drop Pipe Length: 81.00 ft. **Pump Voltage:**
Drop Pipe Diameter: **Drilling Record ID:**
Draw Down Seal Used: No

Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 58.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown

Screen Installed: Yes **Filter Packed:** No
Screen Diameter: 6.00 in. **Blank:**
Screen Material Type: Stainless steel-wire wrapped

Slot	Length	Set Between
8.00	10.00 ft.	93.00 ft. and 103.00 ft.

Fittings: Other

Formation Description	Thickness	Depth to Bottom
Black Topsoil	1.00	1.00
Red Clay	18.00	19.00
Red Clay & Gravel	31.00	50.00
Clay & Sand	10.00	60.00
Red Clay & Gravel	30.00	90.00
Sand Coarse Water Bearing	13.00	103.00

Well Grouted: No

Geology Remarks:

Wellhead Completion: Pitless adapter

Nearest Source of Possible Contamination:

Type	Distance	Direction
Unknown	80 ft.	

Drilling Machine Operator Name:
Employment: Unknown

Contractor Type: Water Well Drilling Contractor **Reg No:** 53-0405
Business Name: Cameron Bros.
Business Address: R#2, Freesoil, MI

Abandoned Well Plugged: No

Reason Not Plugged: Unknown

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks:

Other Remarks: Screen Fittings:lead packer

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No:	Permit No:	County: Mason	Township: Pere Marquette

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
17N 18W	12	Active	40333	2

Well ID: 53000002966

Elevation:

Latitude: 43.8905

Longitude: -86.39987

Method of Collection: Interpolation-Aerial Photo

Distance and Direction from Road Intersection:
400' South of Kinney Rd., on west side of Pere Marquette Rd.

Well Owner: HERITAGE HILLS MOBILE HOME

Well Address:	Owner Address:
Heritage Hills #2 LUDINGTON, MI 49431	Heritage Hills #2 LUDINGTON, MI 49431

Drilling Method: Cable Tool
Well Depth: 104.00 ft. **Well Use:** Type I public
Well Type: Unknown **Date Completed:** 4/29/1985

Casing Type: Steel - unknown **Height:**
Casing Joint: Threaded & coupled
Casing Fitting: Drive shoe

Diameter: 4.00 in. to 94.00 ft. depth

Borehole:

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: **HP:** 2.00
Manufacturer: Grundfos **Pump Type:** Submersible
Model Number: SP8-7 **Pump Capacity:** 60 GPM
Drop Pipe Length: 84.00 ft. **Pump Voltage:**
Drop Pipe Diameter: **Drilling Record ID:**
Draw Down Seal Used: No

Pressure Tank Installed: Yes
Pressure Tank Type: Diaphragm/bladder
Manufacturer: Clayton Mark
Model Number: 220-05 **Tank Capacity:** 300.0 Gallons
Pressure Relief Valve Installed: No

Static Water Level: 53.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Test pump
3.00 hrs. at 75 GPM
Pumping level 69.00 ft. after 7.00 hrs. at 50 GPM

Formation Description	Thickness	Depth to Bottom
Brown Clay	6.00	6.00
Red Clay & Stones	45.00	51.00
Red Clay & Sand Fine W/Stones	4.00	55.00
Sand Medium To Coarse Water Bearing	5.00	60.00
Sand Medium To Coarse W/Clay	9.00	69.00
Sand Medium To Coarse Water Bearing	23.00	92.00
Sand & Gravel Medium To Coarse Water Bearing	12.00	104.00

Screen Installed: Yes **Filter Packed:** No
Screen Diameter: 4.00 in. **Blank:**
Screen Material Type: Stainless steel-wire wrapped

Slot	Length	Set Between
10.00	10.79 ft.	94.00 ft. and 104.00 ft.

Fittings: Other

Well Grouted: No

Geology Remarks:
COARSE WATER SAND AND CLAY ON BOTTOM

Wellhead Completion: Pitless adapter

Nearest Source of Possible Contamination:

Type	Distance	Direction
Drainfield/Dry well	75 ft.	North

Abandoned Well Plugged: No

Reason Not Plugged: Unknown

Drilling Machine Operator Name: UNKNOWN
Employment: Unknown

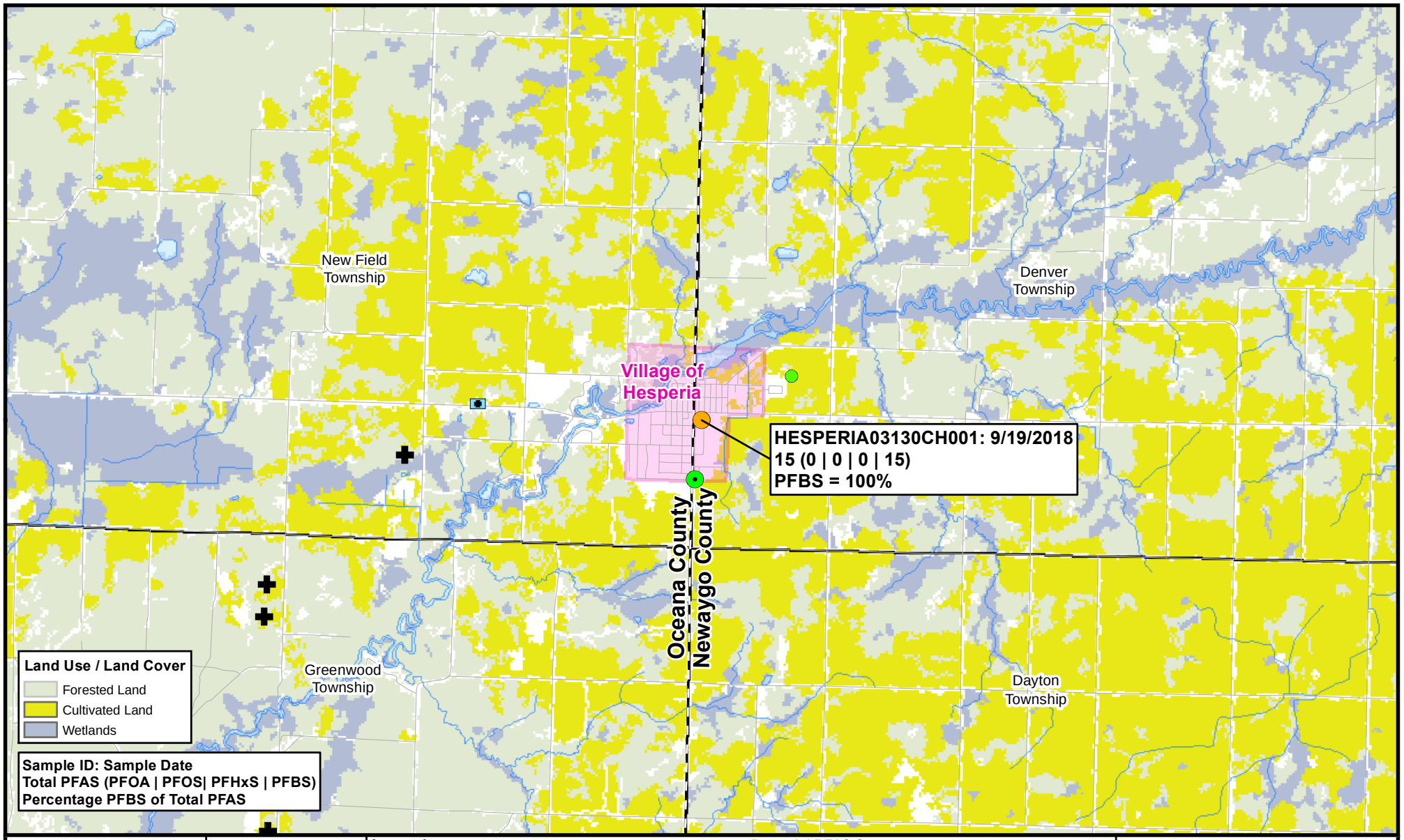
Contractor Type: Water Well Drilling Contractor **Reg No:**
Business Name: LYLE REENE AND SON
Business Address:

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks: SEE ATTACHED FOR TEST PUMP RESULTS
Other Remarks: Screen Fittings:LEAD PACKER



DEQ

Drawn:	JS	3/7/2019
Approved:		3/7/2019
Project #:		

Legend

PFBS > 50% of Total PFAS

Total PFAS (ppt)

- >0 - 10
- >10 - 50
- >50 - 100
- >100 - 200
- >200

- PFAS Non-Detect
- PFAS Detection; PFBS < 50% of Total PFAS
- Village / City Boundary
- Township Boundary
- County Boundary

Potential PFAS Sources

- Petroleum Bulk Stations
- Petroleum Terminals
- Military Sites
- Airports
- Paints & Allied Products
- Electroplaters
- Plating and Polishing Sites
- Active Accepting Landfills
- Historic Landfills
- Superfund Sites
- Biosolids Field
- Fire Station
- WWTP

0 0.5 1 2 Miles

N

FIGURE 13
HISPERIA

NEWAYGO COUNTY, MI

LULC Data provided by USGS

G:\GrandRapids\DCS\GIS\ArcMap_GeoDB_Projects\ENV\GIS_Data\GIS\MDEQ CWS\MXD\PFBS_Evaluation\PFAS_Detects\Figure13_Hisperia_Newaygo.mxd

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No:	Permit No:	County: Newaygo	Township: Denver

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
14N 14W	31	Active	3130	WL001

Well ID: 62000004491

Elevation: 752 ft.
Latitude: 43.568146
Longitude: -86.038742
Method of Collection: GPS Std Positioning Svc SA Off

Distance and Direction from Road Intersection:

Well Owner: VILLAGE OF HESPERIA

Well Address:
HESPERIA WELL #1
HESPERIA, MI

Owner Address:
HESPERIA, MI

Drilling Method: Unknown
Well Depth: 135.00 ft. **Well Use:** Type I public
Well Type: New **Date Completed:** 1/1/1974

Casing Type: Steel - black **Height:**
Casing Joint: Unknown
Casing Fitting: None

Diameter: 10.00 in. to 110.00 ft. depth

Borehole:

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: 1/1/1965 **HP:**
Manufacturer: Other **Pump Type:** Unknown
Model Number: **Pump Capacity:** 280 GPM
Drop Pipe Length: **Pump Voltage:**
Drop Pipe Diameter: **Drilling Record ID:**
Draw Down Seal Used: No

Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 20.30 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown
Pumping level 73.00 ft. after 0.00 hrs. at 0 GPM

Screen Installed: Yes **Filter Packed:** No
Screen Diameter: 9.50 in. **Blank:** 0.00 ft. Above
Screen Material Type: Unknown

Slot	Length	Set Between
12.00	25.00 ft.	110.00 ft. and 135.00 ft.

Fittings: None

Formation Description	Thickness	Depth to Bottom
Sand Fine Silty	15.00	15.00
Sand & Gravel Fine To Medium	25.00	40.00
Gravel Fine Sandy	10.00	50.00
Sand Fine To Medium Gravely	5.00	55.00
Red Clay Gravely	25.00	80.00
Tan Sand Fine To Medium Silty	27.00	107.00
Sand Fine To Medium	15.00	122.00
Sand Fine To Medium	10.00	132.00
Sand Medium	3.00	135.00

Well Grouted: No

Geology Remarks:

Wellhead Completion: Unknown

Nearest Source of Possible Contamination:

Type	Distance	Direction
Unknown		

Drilling Machine Operator Name:
Employment: Unknown

Contractor Type: Unknown **Reg No:** 64-0471
Business Name:
Business Address:

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks:

Other Remarks: Pump Manufacturer:Layne and Bowler

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No:	Permit No:	County: Newaygo	Township: Denver

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
14N 14W	31	Active	3130	WL002

Well ID: 62000004492

Elevation: 750 ft.
Latitude: 43.567824
Longitude: -86.038463
Method of Collection: GPS Std Positioning Svc SA Off

Distance and Direction from Road Intersection:

Well Owner: VILLAGE OF HESPERIA

Well Address:
HESPERIA WELL #2
HESPERIA, MI

Owner Address:
HESPERIA, MI

Drilling Method: Unknown
Well Depth: 135.30 ft. **Well Use:** Type I public
Well Type: New **Date Completed:** 1/1/1950

Casing Type: Unknown **Height:** 0.00 ft. below grade
Casing Joint: Unknown
Casing Fitting: None

Diameter: 10.00 in. to 109.00 ft. depth

Borehole:

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: **HP:**
Manufacturer: Unknown **Pump Type:** Unknown
Model Number: **Pump Capacity:** 220 GPM
Drop Pipe Length: **Pump Voltage:**
Drop Pipe Diameter: **Drilling Record ID:**
Draw Down Seal Used: No

Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 999.99 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown

Screen Installed: Yes **Filter Packed:** No
Screen Diameter: 10.00 in. **Blank:** 0.00 ft. Above
Screen Material Type: Unknown

Slot	Length	Set Between
12.00	25.00 ft.	110.00 ft. and 135.00 ft.

Fittings: None

Formation Description	Thickness	Depth to Bottom
Clay Sandy	26.00	26.00
Sand & Gravel Dry	14.00	40.00
Clay Sandy Water Bearing	10.00	50.00
Red Clay Firm	20.00	70.00
Clay Sandy	5.00	75.00
Sand Water Bearing	20.00	95.00
Clay Sandy	10.00	105.00
Sand Water Bearing	29.00	134.00
Blue Clay Hard	3.00	137.00

Well Grouted: Unknown

Geology Remarks:

Wellhead Completion: Unknown

Nearest Source of Possible Contamination:

Type	Distance	Direction
Unknown		

Drilling Machine Operator Name:
Employment: Unknown

Contractor Type: Unknown **Reg No:** 64-0471
Business Name:
Business Address:

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks:

Other Remarks:

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No:	Permit No:	County: Newaygo	Township: Denver

Well ID: 62000004493

Elevation: 774 ft.
Latitude: 43.562095
Longitude: -86.039118
Method of Collection: GPS Std Positioning Svc SA Off

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
14N 14W	31	Active	3130	WL003

Distance and Direction from Road Intersection:

Well Owner: VILLAGE OF HESPERIA

Well Address:
HESPERIA WELL #3
HEPERIA, MI

Owner Address:
HESPERIA, MI

Drilling Method: Unknown
Well Depth: 125.00 ft. **Well Use:** Type I public
Well Type: New **Date Completed:** 1/1/1979

Casing Type: Unknown **Height:** 0.00 ft. below grade
Casing Joint: Unknown
Casing Fitting: None

Diameter: 12.00 in. to 0.00 ft. depth

Borehole:

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: 1/1/2007 **HP:**
Manufacturer: Unknown **Pump Type:** Unknown
Model Number: **Pump Capacity:** 180 GPM
Drop Pipe Length: **Pump Voltage:**
Drop Pipe Diameter: **Drilling Record ID:**
Draw Down Seal Used: No

Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 24.50 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown

Formation Description	Thickness	Depth to Bottom
Topsoil	5.00	5.00
Clay Hard	20.00	25.00
Gravel	7.00	32.00
Clay Sandy	28.00	60.00
Sand W/Clay	20.00	80.00
Sand Coarse	45.00	125.00

Screen Installed: Yes **Filter Packed:** No
Screen Diameter: 12.00 in. **Blank:** 0.00 ft. Above
Screen Material Type: Unknown

Slot	Length	Set Between
12.00	30.00 ft.	

Fittings: None

Well Grouted: No

Geology Remarks:

Wellhead Completion: Unknown

Nearest Source of Possible Contamination:

Type	Distance	Direction
Unknown		

Drilling Machine Operator Name:
Employment: Unknown
Pump Installer: PEERLESS

Contractor Type: Unknown **Reg No:**
Business Name:
Business Address:

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks:
Other Remarks:

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No:	Permit No:	County: Newaygo	Township: Denver

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
14N 14W	30	Active	40587	1

Well ID: 62000005254

Elevation: 764 ft.
Latitude: 43.57272
Longitude: -86.02529
Method of Collection: Interpolation-Aerial Photo

Distance and Direction from Road Intersection:

Well Owner: EVERGREEN VILLAGE MH PARK

Well Address:	Owner Address:
Evergreen MHP #1 Hesperia, MI	Evergreen MHP #1 Hesperia, MI

Drilling Method: Unknown
Well Depth: 161.00 ft. **Well Use:** Type I public
Well Type: Unknown **Date Completed:** 7/1/1984

Casing Type: Steel - unknown **Height:** 1.00 ft. above grade
Casing Joint: Threaded & coupled
Casing Fitting: Unknown

Diameter: 4.00 in. to 148.00 ft. depth

Borehole:

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: **HP:** 5.00
Manufacturer: Flint & Walling **Pump Type:** Submersible
Model Number: 4F85B50 **Pump Capacity:** 100 GPM
Drop Pipe Length: 114.00 ft. **Pump Voltage:** 220
Drop Pipe Diameter: **Drilling Record ID:**
Draw Down Seal Used: No

Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 19.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown
Pumping level 50.00 ft. after 2.00 hrs. at 100 GPM
Pumping level 50.00 ft. after 4.00 hrs. at 100 GPM

Formation Description	Thickness	Depth to Bottom
Loam Sandy	6.00	6.00
Gravel & Stones	24.00	30.00
Red Clay Soft	7.00	37.00
Sand Fine Silty	6.00	43.00
Gravel Fine	9.00	52.00
Gravel & Sand	7.00	59.00
Sand Medium	20.00	79.00
Sand Coarse	25.00	104.00
Sand Medium	38.00	142.00
Gravel Fine	19.00	161.00

Screen Installed: Yes **Filter Packed:** No
Screen Diameter: 4.00 in. **Blank:** 1.00 ft. Above
Screen Material Type: Stainless steel-wire wrapped

Slot	Length	Set Between
12.00	10.00 ft.	148.00 ft. and 158.00 ft.

Fittings: Neoprene packer

Well Grouted: No

Geology Remarks:

Wellhead Completion: Unknown

Nearest Source of Possible Contamination:

Type	Distance	Direction
Unknown		

Drilling Machine Operator Name:
Employment: Unknown

Abandoned Well Plugged: No

Reason Not Plugged: Unknown

Contractor Type: Water Well Drilling Contractor **Reg No:** 64-0529
Business Name: DALE TIMMICH WELL DRILLING
Business Address:

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks:

Other Remarks:

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No:	Permit No:	County: Newaygo	Township: Denver

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
14N 14W	30	Active	40587	2

Well ID: 62000005255

Elevation: 764 ft.
Latitude: 43.57291
Longitude: -86.02531
Method of Collection: Interpolation-Map

Distance and Direction from Road Intersection:

Well Owner: EVERGREEN VILLAGE MH PARK

Well Address:
Evergreen MHP #2
Hesperia, MI 49421

Owner Address:
Evergreen MHP #2
Hesperia, MI 49421

Drilling Method: Rotary
Well Depth: 158.00 ft. **Well Use:** Type I public
Well Type: Unknown **Date Completed:** 12/1/1984

Casing Type: Steel - unknown **Height:**
Casing Joint: Threaded & coupled
Casing Fitting: Drive shoe

Diameter: 5.00 in. to 148.00 ft. depth

Borehole:

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: **HP:** 5.00
Manufacturer: Unknown **Pump Type:** Submersible
Model Number: **Pump Capacity:** 95 GPM
Drop Pipe Length: 114.00 ft. **Pump Voltage:**
Drop Pipe Diameter: **Drilling Record ID:**
Draw Down Seal Used: No

Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 18.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown
Pumping level 50.00 ft. after 2.00 hrs. at 100 GPM
Pumping level 50.00 ft. after 4.00 hrs. at 100 GPM

Formation Description	Thickness	Depth to Bottom
Loam Sandy	6.00	6.00
Gravel & Stones	19.00	25.00
Red Clay Soft	6.00	31.00
Sand Fine Silty	10.00	41.00
Gravel Fine	9.00	50.00
Gravel Medium	11.00	61.00
Sand Medium	19.00	80.00
Sand Coarse	24.00	104.00
Gravel Medium	38.00	142.00
Gravel Fine	16.00	158.00

Screen Installed: Yes **Filter Packed:** No
Screen Diameter: 4.00 in. **Blank:** 1.00 ft. Above
Screen Material Type: Stainless steel-wire wrapped

Slot	Length	Set Between
12.00	10.00 ft.	148.00 ft. and 158.00 ft.

Fittings: Neoprene packer

Well Grouted: No

Geology Remarks:

Wellhead Completion: Unknown

Nearest Source of Possible Contamination:

Type	Distance	Direction
Unknown		

Drilling Machine Operator Name:
Employment: Unknown

Contractor Type: Water Well Drilling Contractor **Reg No:** 64-0529
Business Name: DALE TIMMICH WELL DRILLING
Business Address:

Abandoned Well Plugged: No

Reason Not Plugged: Unknown

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks:

Other Remarks:

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No:	Permit No:	County: Newaygo	Township: Denver

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
14N 14W	30	Active	40587	3

Well ID: 62000009344

Elevation:

Latitude: 43.57301

Longitude: -86.0255

Method of Collection: Interpolation-Aerial Photo

Distance and Direction from Road Intersection:
1/3 MILE N OF M-20 OR SMITH RD 500 ' E OF THE MHP EVERGREEN VILLAGE MHP

Well Owner: EVERGREEN VILLAGE MHP

Well Address:	Owner Address:
146 N SMITH HESPERIA, MI 49421	146 N SMITH HESPERIA, MI 49421

Drilling Method: Rotary
Well Depth: 160.00 ft. **Well Use:** Type I public
Well Type: New **Date Completed:** 6/25/1997

Casing Type: PVC plastic **Height:** 5.00 ft. above grade
Casing Joint: Unknown
Casing Fitting: None

Diameter: 5.00 in. to 145.00 ft. depth

Borehole: 8.50 in. to 160.00 ft. depth

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: **HP:** 5.00
Manufacturer: Flint & Walling **Pump Type:** Submersible
Model Number: 4F85B50 **Pump Capacity:** 100 GPM
Drop Pipe Length: 112.00 ft. **Pump Voltage:**
Drop Pipe Diameter: **Drilling Record ID:**
Draw Down Seal Used: No

Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 17.40 ft. Below Grade
Well Yield Test: **Yield Test Method:** Air
Pumping level 80.00 ft. after 1.00 hrs. at 100 GPM

Screen Installed: Yes **Filter Packed:** No
Screen Diameter: 3.75 in. **Blank:**
Screen Material Type: Stainless steel-slotted

Slot	Length	Set Between
12.00	15.00 ft.	145.00 ft. and 160.00 ft.

Fittings: Neoprene packer

Formation Description	Thickness	Depth to Bottom
Sand	15.00	15.00
Red Clay & Sand	5.00	20.00
Sand	10.00	30.00
Red Clay	1.00	31.00
Sand Fine	10.00	41.00
Gravel Fine	20.00	61.00
Sand	19.00	80.00
Sand Coarse	24.00	104.00
Gravel Fine	36.00	140.00
Sand Coarse	20.00	160.00

Well Grouted: Yes **Grouting Method:** Unknown

Grouting Material	Bags	Additives	Depth
Bentonite slurry	8.00	Unknown	0.00 ft. to 140.00 ft.

Geology Remarks:

Wellhead Completion: Pitless adapter, 12 inches above grade

Nearest Source of Possible Contamination:

Type	Distance	Direction
None		

Drilling Machine Operator Name:
Employment: Unknown

Contractor Type: Water Well Drilling Contractor **Reg No:** 64-2104
Business Name: TIMMICH'S WELL DRILLING
Business Address:

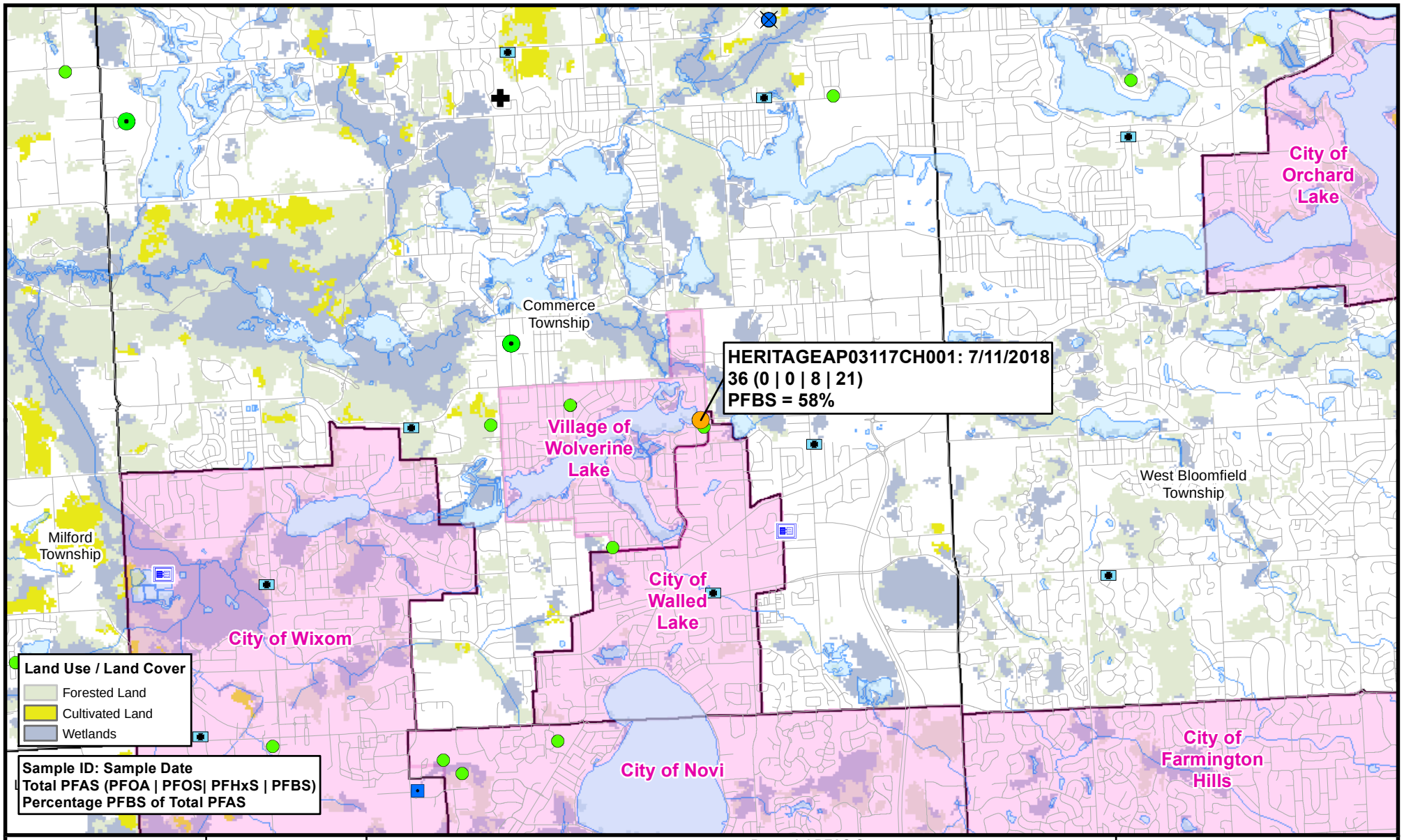
Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks:

Other Remarks:



DEQ

Drawn:	JS	3/7/2019
Approved:		3/7/2019
Project #:		

Legend

PFBS > 50% of Total PFAS

Total PFAS (ppt)

- >0 - 10
- >10 - 50
- >50 - 100
- >100 - 200
- >200

- PFAS Non-Detect
- PFAS Detection; PFBS < 50% of Total PFAS
- Village / City Boundary
- Township Boundary
- County Boundary

Potential PFAS Sources

- Petroleum Bulk Stations
- Petroleum Terminals
- Military Sites
- Airports
- Paints & Allied Products
- Electroplaters
- Plating and Polishing Sites
- Active Accepting Landfills
- Historic Landfills
- Superfund Sites
- Biosolids Field
- Fire Station
- WWTP

0 0.5 1 2 Miles

N

FIGURE 21
HERITAGE APARTMENTS

OAKLAND COUNTY, MI

Source: ESRI USA Topo Maps

G:\GrandRapids\DCS\GIS\ArcMap_GeoDB_Projects\ENV\GIS_Data\GIS\MDEQ CWS\MXD\PFBS_Evaluation\PFAS_Detects\Figure21_Heritage_Apartments_Oakland.mxd

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No:	Permit No:	County: Oakland	Township: Commerce

Well ID: 63000017124

Elevation: 921 ft.
Latitude: 42.55638
Longitude: -83.47416
Method of Collection: Interpolation-Aerial Photo

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
02N 08E	23	Active	3117	Heritage Apts Well

Distance and Direction from Road Intersection:
2375 South Commerce, Walled Lake, MI 48390

Well Owner: Al Van Acker

Well Address:
Heritage Apartments Well #1
Walled Lake, MI 48390

Owner Address:
963 Sherbrooke
Commerce Twp, MI 48382

Drilling Method: Unknown
Well Depth: 0.00 ft. **Well Use:** Type I public
Well Type: New **Date Completed:**

Casing Type: Unknown **Height:**
Casing Joint: Unknown
Casing Fitting: Unknown

Diameter:

Borehole:

Pump Installed: No
Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 999.99 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown

Screen Installed: No **Intake:** Unknown

Well Grouted: No

Wellhead Completion: 12 inches above grade

Formation Description	Thickness	Depth to Bottom
Lithology Unknown	0.00	0.00

Geology Remarks:
unknown Lithology- No well record

Nearest Source of Possible Contamination:

Type	Distance	Direction
Unknown		

Drilling Machine Operator Name:
Employment: Unknown

Contractor Type: Unknown **Reg No:**
Business Name:
Business Address:

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks: No well record available
Other Remarks:

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No:	Permit No:	County: Oakland	Township: Commerce

Well ID: 63000042626

Elevation:

Latitude: 42.55619

Longitude: -83.47423

Method of Collection: GPS Std Positioning Svc SA Off

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
02N 08E	23	Active	3117	#2 SOUTH

Distance and Direction from Road Intersection:
HERITAGE HILL APTS

Well Owner: HARB DHILLON

Well Address:	Owner Address:
2375 S. COMMERCE WALLED LAKE, MI 48390	2375 S. COMMERCE WALLED LAKE, MI 48390

Drilling Method: Rotary
Well Depth: 51.00 ft. **Well Use:** Type I public
Well Type: New **Date Completed:** 2/14/2012

Casing Type: PVC plastic **Height:** 1.00 ft. above grade
Casing Joint: Unknown
Casing Fitting:

Diameter: 5.00 in. to 46.00 ft. depth SDR: 21.00

Borehole: 8.75 in. to 50.00 ft. depth

Static Water Level: 10.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Other
Pumping level 16.00 ft. after 4.00 hrs. at 60 GPM

Screen Installed: Yes **Filter Packed:** Yes
Screen Diameter: 5.00 in. **Blank:** 1.00 ft. Above
Screen Material Type: Stainless steel-wire wrapped

Slot	Length	Set Between
10.00	5.00 ft.	46.00 ft. and 51.00 ft.

Fittings: Neoprene packer, Bottom plug

Well Grouted: Yes **Grouting Method:** Unknown

Grouting Material	Bags	Additives	Depth
Neat cement	20.00	None	0.00 ft. to 46.00 ft.

Wellhead Completion: Pitless adapter

Nearest Source of Possible Contamination:

Type	Distance	Direction
Septic tank	51 ft.	East

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: **HP:** 2.00
Manufacturer: Franklin Electric **Pump Type:** Submersible
Model Number: 35SDOP **Pump Capacity:** 35 GPM
Drop Pipe Length: 45.00 ft. **Pump Voltage:** 230
Drop Pipe Diameter: 1.25 in. **Drilling Record ID:**
Draw Down Seal Used: No

Pressure Tank Installed: Yes
Pressure Tank Type: Diaphragm/bladder
Manufacturer: Well-Mate
Model Number: WM6 **Tank Capacity:** 20.0 Gallons
Pressure Relief Valve Installed: Yes

Formation Description	Thickness	Depth to Bottom
Brown Sand & Gravel	13.00	13.00
Brown Sand	10.00	23.00
Black Marl	4.00	27.00
Gray Clay	8.00	35.00
Sand & Gravel	16.00	51.00

Geology Remarks:

Drilling Machine Operator Name: PHILLIP LAYMAN
Employment: Employee

Contractor Type: Water Well Drilling Contractor **Reg No:** 63-2401
Business Name: BW LAYMAN
Business Address:

Water Well Contractor's Certification

This well/pump was constructed under my supervision and I hereby certify that the work complies with Part 127 Act 368 PA 1978 and the well code.

Signature of Registered Contractor **Date**

General Remarks: VFD PUMP SYSTEM
Other Remarks: Yield Test Method:AIR AND TEST PUMP

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No: 17-23-352-013	**Permit No:**	**County:** Oakland		**Township:** Commerce
		Town/Range: 02N 08E	**Section:** 23	**Well Status:** Active	**WSSN:** 1669	**Source ID/Well No:** #2

Well ID: 63000042038

Elevation:
Latitude: 42.55722
Longitude: -83.47416
Method of Collection: Interpolation-Map

Distance and Direction from Road Intersection:
1/2 MI S OF GLENGARY RD, 1/10 MI W OF S. COMMERCE RD

Well Owner: SAM BRIKHO LAKESIDE APTS LLC

Well Address:	**Owner Address:**
2475 S. COMMERCE ROAD WALLED LAKE, MI 48390	2475 S. COMMERCE ROAD WALLED LAKE, MI 48390

Drilling Method: Rotary
Well Depth: 62.00 ft. **Well Use:** Type I public
Well Type: New **Date Completed:** 9/1/2011

Casing Type: PVC plastic **Height:** 1.00 ft. above grade
Casing Joint: Solvent welded/glued
Casing Fitting: None

Diameter: 5.00 in. to 52.00 ft. depth SDR: 21.00

Borehole: 8.75 in. to 62.00 ft. depth

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: **HP:** 1.00
Manufacturer: Sta-Rite **Pump Type:** Submersible
Model Number: S20P45P10 **Pump Capacity:** 30 GPM
Drop Pipe Length: 40.00 ft. **Pump Voltage:** 230
Drop Pipe Diameter: 1.25 in. **Drilling Record ID:**
Draw Down Seal Used: No

Pressure Tank Installed: Yes
Pressure Tank Type: Diaphragm/bladder
Manufacturer: Well-X-Trol
Model Number: WM-25 **Tank Capacity:** 86.0 Gallons
Pressure Relief Valve Installed: Yes

Static Water Level: 20.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Air
Pumping level 62.00 ft. after 0.50 hrs. at 50 GPM

Formation Description	Thickness	Depth to Bottom
Brown Sand	35.00	35.00
Gray Clay	10.00	45.00
Gray Sand	17.00	62.00

Screen Installed: Yes **Filter Packed:** Yes
Screen Diameter: 5.00 in. **Blank:**
Screen Material Type: PVC-slotted

Slot	Length	Set Between
12.00	10.00 ft.	52.00 ft. and 62.00 ft.

Fittings: None

Well Grouted: Yes **Grouting Method:** Grout pipe outside casing

Grouting Material	Bags	Additives	Depth
Neat cement	12.00	None	0.00 ft. to 50.00 ft.

Wellhead Completion: Pitless adapter

Geology Remarks:

Nearest Source of Possible Contamination:

Type	Distance	Direction
Sewer line	60 ft.	West

Drilling Machine Operator Name: ED BIRKEMIER WELL DRILLING
Employment: Subcontractor
Pump Installer: AYERS WATER SYSTEMS
Contractor Type: Water Well Drilling Contractor **Reg No:** 63-2202
Business Name: AYERS WATER SYSTEMS
Business Address:

Water Well Contractor's Certification

This well/pump was constructed under my supervision and I hereby certify that the work complies with Part 127 Act 368 PA 1978 and the well code.

Signature of Registered Contractor **Date**

General Remarks:
Other Remarks:

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No:	Permit No:	County: Oakland	Township: Commerce

Well ID: 63000035878

Elevation:

Latitude: 42.55706

Longitude: -83.474218

Method of Collection: Interpolation-Map

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
02N 08E	23	Active	1669	#1

Distance and Direction from Road Intersection:
100' WEST OF S. COMMERCE, 1 BLOCK N. OF DECKER

Well Owner: DECKER APARTMENTS

Well Address:	Owner Address:
DECKER APTS #1,2475 S. COMMERCE	PO BOX 455 WALLED LAKE, MI 48390

Drilling Method: Cable Tool
Well Depth: 60.00 ft. **Well Use:** Type I public
Well Type: Replacement **Date Completed:** 12/1/2004

Casing Type: Steel - unknown **Height:**
Casing Joint: Threaded & coupled
Casing Fitting: Drive shoe

Diameter: 4.00 in. to 56.00 ft. depth

Borehole:

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: **HP:** 1.00
Manufacturer: Fairbanks-Morse **Pump Type:** Submersible
Model Number: FB100 **Pump Capacity:** 22 GPM
Drop Pipe Length: 42.00 ft. **Pump Voltage:**
Drop Pipe Diameter: **Drilling Record ID:**
Draw Down Seal Used: No

Pressure Tank Installed: Yes
Pressure Tank Type: Diaphragm/bladder
Manufacturer: Well-Mate
Model Number: WM25 (2) **Tank Capacity:** 173.0 Gallons
Pressure Relief Valve Installed: No

Static Water Level: 18.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Plunger
Pumping level 56.00 ft. after 2.00 hrs. at 55 GPM

Formation Description	Thickness	Depth to Bottom
Topsoil W/Sand	10.00	10.00
Brown Sand Water Bearing	20.00	30.00
Gray Clay Soft	14.00	44.00
Gray Sand	6.00	50.00
Sand Water Bearing	10.00	60.00

Screen Installed: Yes **Filter Packed:** No
Screen Diameter: 3.00 in. **Blank:** 1.00 ft. Above
Screen Material Type: Stainless steel-wire wrapped

Slot	Length	Set Between
10.00	4.00 ft.	56.00 ft. and 60.00 ft.

Fittings: Neoprene packer

Well Grouted: Yes **Grouting Method:** Unknown

Grouting Material	Bags	Additives	Depth
Bentonite dry granular	3.00	None	0.00 ft. to 56.00 ft.

Wellhead Completion: Pitless adapter

Geology Remarks:

Nearest Source of Possible Contamination:

Type	Distance	Direction
Septic tank	100 ft.	West

Drilling Machine Operator Name:
Employment: Unknown

Abandoned Well Plugged: Yes

Contractor Type: Water Well Drilling Contractor **Reg No:** 63-2147
Business Name: JOE CURRY WELL DRILLING
Business Address:

Casing Diameter: 4 in. **Casing Removed:** No
Plugging Material: Bentonite chips/pellets
No. of Bags: 5.50 **Well Depth:** 54 ft.

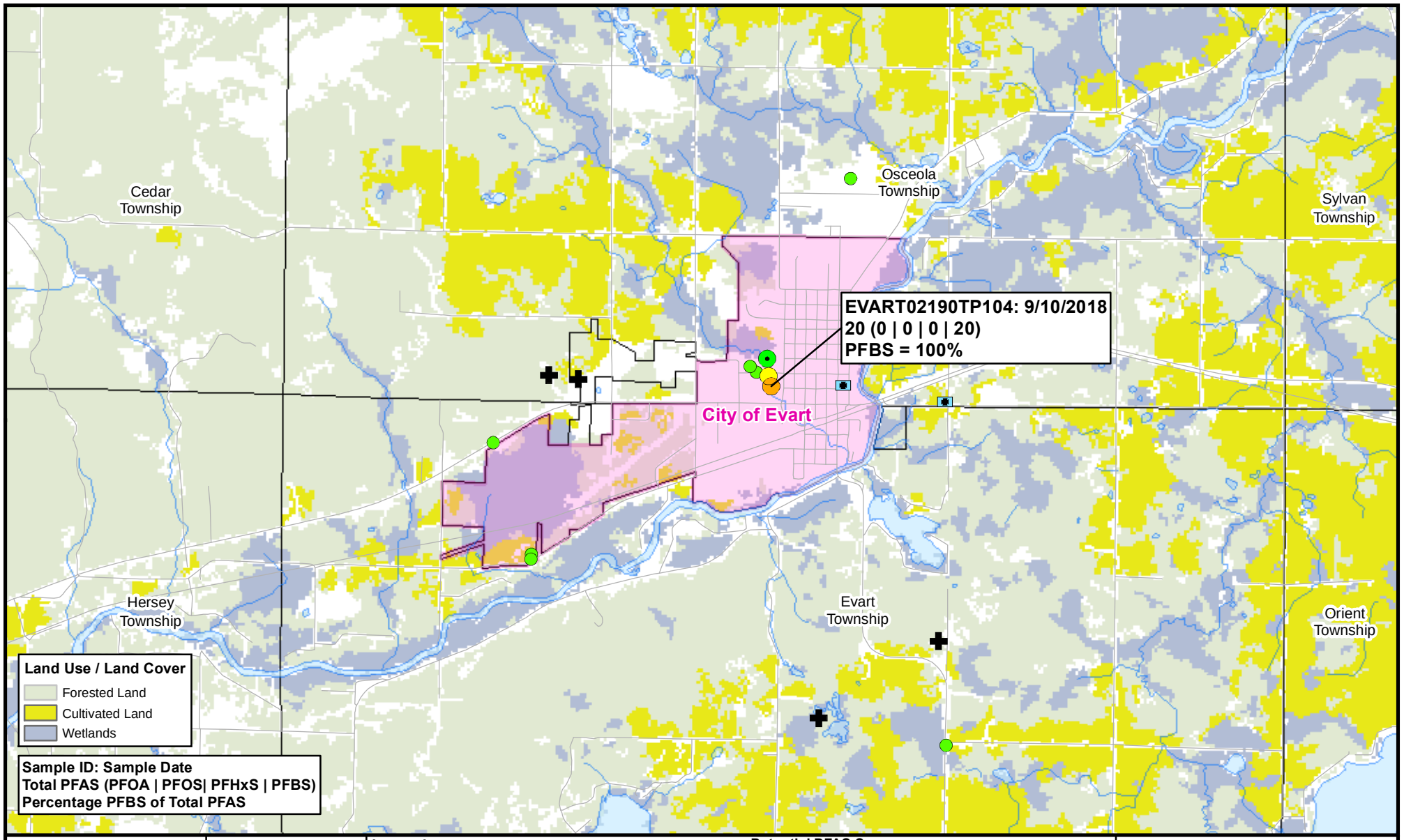
Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks: TEMPORARY WELL OK BY DEQ VIA LAURA VERONA. EMERGENCY DRILL NO WATER. ORIGINAL PUMP AND PRESSURE TANKS HAVE BEEN REPLACED ON 3/22/2007. NO INFORMATION ON NEW PUMP.

Other Remarks:



DEQ

Drawn:	JS	5/14/2019
Approved:		5/14/2019
Project #:		

FIGURE 22
CITY OF EVART

OSCEOLA COUNTY, MI

Source: ESRI USA Topo Maps

G:\GrandRapids\DCS\GIS\ArcMap_GeoDB_Projects\ENV\GIS_Data\GIS\MDEQ CWS\MXD\PFBS_Evaluation\PFAS_Detects\Figure22_City_Of_Evart_Osceola.mxd

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID: 67180833303

Tax No:	Permit No:	County: Osceola	Township: Osceola

Well ID: 67000001700

Elevation: 1008.85 ft.
Latitude: 43.90208
Longitude: -85.26768
Method of Collection: GPS Std Positioning Svc SA Off

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
18N 08W	33		2190	EVART WELL #4

Distance and Direction from Road Intersection:
WSSN# 02190

Well Owner: CITY OF EVART

Well Address:
EVART WELL #4
EVART, MI 49631

Owner Address:
EVART, MI 49631

Drilling Method: Unknown
Well Depth: 60.00 ft. **Well Use:** Type I public
Well Type: New **Date Completed:**

Casing Type: Unknown **Height:** 0.00 ft. below grade
Casing Joint: Unknown
Casing Fitting: None

Diameter:

Borehole:

Pump Installed: No
Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 999.99 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown
Pumping level 0.00 ft. after 0.00 hrs. at 750 GPM

Screen Installed: Yes **Filter Packed:** No
Screen Diameter: 0.00 in. **Blank:** 0.00 ft. Above
Screen Material Type:

Slot	Length	Set Between
40.00	20.00 ft.	40.00 ft. and 60.00 ft.

Fittings: None

Formation Description	Thickness	Depth to Bottom
Topsoil	4.00	4.00
Sand Wet/Moist	4.00	8.00
Gray Clay	7.00	15.00
Gray Clay & Gravel	1.00	16.00
Sand & Gravel Wet/Moist	14.00	30.00
Sand & Gravel Water Bearing	30.00	60.00

Well Grouted: Yes **Grouting Method:** Unknown

Grouting Material	Bags	Additives	Depth
Unknown	0.00	None	0.00 ft. to 0.00 ft.

Wellhead Completion: Unknown

Geology Remarks:

Nearest Source of Possible Contamination:

Type	Distance	Direction
None		

Drilling Machine Operator Name:
Employment: Unknown

Contractor Type: Unknown **Reg No:**
Business Name:
Business Address:

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks: ORIGINAL WELLID# WAS 33004; WELL RECORD WAS INCOMPLETE
Other Remarks:

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID: 67180833305

Tax No:	Permit No:	County: Osceola			Township: Osceola	
		Town/Range: 18N 08W	Section: 33	Well Status:	WSSN: 2190	Source ID/Well No: EVART WELL #2A

Well ID: 67000001702

Elevation: 1008.85 ft.
Latitude: 43.90374
Longitude: -85.26881
Method of Collection: GPS Std Positioning Svc SA Off

Distance and Direction from Road Intersection: WSSN# 02190

Well Owner: CITY OF EVART

Well Address: EVART WELL #2A, EVART, MI 49631

Owner Address: EVART, MI 49631

Drilling Method: Rotary
Well Depth: 53.00 ft. **Well Use:** Type I public
Well Type: New **Date Completed:** 11/10/1965

Casing Type: Unknown **Height:** 0.00 ft. below grade
Casing Joint: Unknown
Casing Fitting: None

Diameter: 26.00 in. to 30.00 ft. depth

Borehole:

Pump Installed: No
Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 16.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown
Pumping level 44.00 ft. after 6.00 hrs. at 602 GPM

Screen Installed: No **Intake:** Unknown

Formation Description	Thickness	Depth to Bottom
Sand	5.00	5.00
Gravel & Sand	5.00	10.00
Gravel	10.00	20.00
Gravel	10.00	30.00
Gravel	7.00	37.00
Sand & Gravel Fine	5.00	42.00
Sand & Gravel Fine	5.00	47.00
Sand Fine	2.00	49.00
Sand Fine	4.00	53.00

Well Grouted: Yes **Grouting Method:** Unknown

Grouting Material	Bags	Additives	Depth
Unknown	0.00	None	0.00 ft. to 0.00 ft.

Geology Remarks:

Wellhead Completion: Unknown

Nearest Source of Possible Contamination:

Type	Distance	Direction
None		

Drilling Machine Operator Name:
Employment: Unknown

Contractor Type: Unknown **Reg No:**
Business Name:
Business Address:

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks: ORIGINAL WELLID# WAS 33006; LOG CONATINED LITHOLOGY ONLY; CLAY BEGINS AT 53 FT.
Other Remarks:

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID: 67180833302

Tax No:	Permit No:	County: Osceola	Township: Osceola

Well ID: 67000001699

Elevation: 1008.85 ft.
Latitude: 43.90378
Longitude: -85.26979
Method of Collection: GPS Std Positioning Svc SA Off

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
18N 08W	33		2190	EVART WELL #3A

Distance and Direction from Road Intersection:
WSSN# 02190

Well Owner: CITY OF EVART

Well Address:
EVART WELL #3A
EVART, MI 49631

Owner Address:
EVART, MI 49631

Drilling Method: Other
Well Depth: 46.00 ft. **Well Use:** Type I public
Well Type: Replacement **Date Completed:** 6/22/1959

Casing Type: Unknown **Height:** 0.00 ft. below grade
Casing Joint: Unknown
Casing Fitting: None

Diameter:

Borehole:

Pump Installed: No
Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 13.67 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown
Pumping level 31.00 ft. after 4.00 hrs. at 450 GPM

Screen Installed: No **Intake:** Unknown

Formation Description	Thickness	Depth to Bottom
Sand	8.00	8.00
Gravel & Boulders Coarse	24.00	32.00
Sand Coarse	3.00	35.00
Gravel & Boulders	8.00	43.00
Clay W/Boulders	3.00	46.00

Well Grouted: Yes **Grouting Method:** Unknown

Grouting Material	Bags	Additives	Depth
Unknown	0.00	None	0.00 ft. to 0.00 ft.

Geology Remarks:

Wellhead Completion: Unknown

Nearest Source of Possible Contamination:

Type	Distance	Direction
None		

Drilling Machine Operator Name:
Employment: Unknown

Contractor Type: Unknown **Reg No:**
Business Name:
Business Address:

Abandoned Well Plugged: No
Reason Not Plugged:

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks: ORIGINAL WELLID# WAS 33003; DRILLED BY REVERSE CIRC.; DRILLER: CARWILE

Other Remarks: Drilling Method:Drilling Method unknown

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No:	Permit No:	County: Osceola	Township: Osceola

Well ID: 67000001684

Elevation: 1024 ft.
Latitude: 43.90421
Longitude: -85.26834
Method of Collection: GPS Std Positioning Svc SA Off

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
18N 08W	33	Active	2190	well 6

Distance and Direction from Road Intersection:

Well Owner: CITY OF EVART

Well Address:
5TH ST. & CEDAR ST.
EVART, MI 49631

Owner Address:
EVART, MI 49631

Drilling Method: Rotary
Well Depth: 57.50 ft. **Well Use:** Type I public
Well Type: Replacement **Date Completed:** 9/19/1963
Casing Type: Unknown **Height:** 0.00 ft. below grade
Casing Joint: Unknown
Casing Fitting: None

Diameter: 30.00 in. to 0.00 ft. depth
16.00 in. to 0.00 ft. depth

Borehole:

Pump Installed: No
Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 13.50 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown

Formation Description	Thickness	Depth to Bottom
Sand & Gravel W/Boulders	12.00	12.00
Sand & Gravel Wet/Moist W/Boulders	43.00	55.00
Gray Clay	3.00	58.00

Screen Installed: No **Intake:** Unknown

Well Grouted: Yes **Grouting Method:** Unknown

Grouting Material	Bags	Additives	Depth
Unknown	0.00	None	

Wellhead Completion: Unknown

Geology Remarks:

Nearest Source of Possible Contamination:

Type	Distance	Direction
Unknown		

Drilling Machine Operator Name:
Employment: Unknown

Contractor Type: Unknown **Reg No:**
Business Name:
Business Address:

Abandoned Well Plugged: No
Reason Not Plugged: Unknown

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks: LAYNE-NORTHERN WELL LOG. PUMPED 700 G.P.M. @41'PTL. HOLE STOPPED IN GRAY CLAY AT 57 1/2 FEET.

Other Remarks:

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID: 67180833301

Tax No:	Permit No:	County: Osceola	Township: Osceola

Well ID: 67000001698

Elevation: 1008.85 ft.
Latitude: 43.902946
Longitude: -85.267594
Method of Collection: GPS Std Positioning Svc SA Off

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
18N 08W	33		2190	EVART WELL #1

Distance and Direction from Road Intersection:
WSSN# 02190

Well Owner: CITY OF EVART

Well Address:
EVART WELL #1
EVART, MI 49631

Owner Address:
EVART, MI 49631

Drilling Method: Unknown
Well Depth: 0.00 ft. **Well Use:** Type I public
Well Type: Replacement **Date Completed:**

Casing Type: Unknown **Height:** 0.00 ft. below grade
Casing Joint: Unknown
Casing Fitting: None

Diameter:

Borehole:

Pump Installed: No
Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 999.99 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown

Screen Installed: No **Intake:** Unknown

Formation Description	Thickness	Depth to Bottom
No Lithology Information	0.00	0.00

Well Grouted: Yes **Grouting Method:** Unknown

Grouting Material	Bags	Additives	Depth
Unknown	0.00	None	0.00 ft. to 0.00 ft.

Wellhead Completion: Unknown

Geology Remarks:

Nearest Source of Possible Contamination:

Type	Distance	Direction
None		

Abandoned Well Plugged: No
Reason Not Plugged:

Drilling Machine Operator Name:
Employment: Unknown

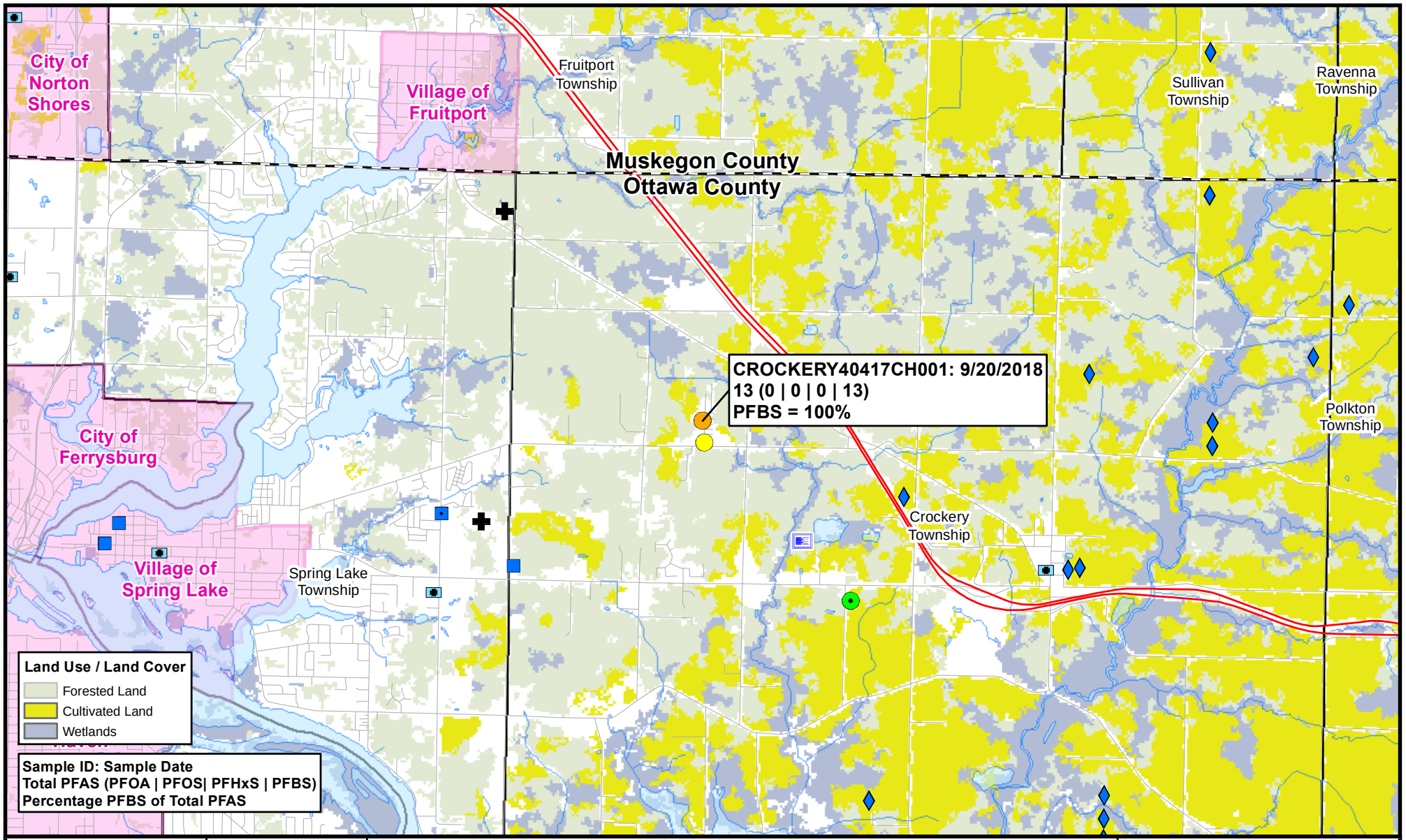
Contractor Type: Unknown **Reg No:**
Business Name:
Business Address:

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks: ORIGINAL WELLID# WAS 33001; NO WELL LOG AVAILABLE
Other Remarks:



Drawn: JS 3/7/2019

Approved: 3/7/2019

Project #:

FIGURE 14
CROCKERY MOBILE HOME PARK

OTTAWA COUNTY, MI

LULC Data provided by USGS

G:\GrandRapids\DCS\GIS\ArcMap_GeoDB_Projects\ENV\GIS_Data\GIS\MDEQ CWS\MXD\PFBS_Evaluation\PFAS_Detects\Figure14_Crockery_MHP_Ottawa.mxd

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No:	Permit No:	County: Ottawa	Township: Crockery

Well ID: 70000007725

Elevation: 614 ft.
Latitude: 43.09071
Longitude: -86.11839
Method of Collection: GPS Std Positioning Svc SA Off

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
08N 15W	8	Active	40417	4

Distance and Direction from Road Intersection:
EAST ON STATE RD FROM 144TH 1/2 MILE

Well Owner: CROCKERY MHP

Well Address:
13251 STATE RD
NUNICA, MI 49448

Owner Address:
13251 STATE RD
NUNICA, MI 49448

Drilling Method: Cable Tool
Well Depth: 42.00 ft. **Well Use:** Type I public
Well Type: New **Date Completed:** 6/7/1997

Casing Type: Steel - unknown **Height:**
Casing Joint: Threaded & coupled
Casing Fitting: Drive shoe

Diameter: 6.00 in. to 33.00 ft. depth

Borehole: 6.00 in. to 42.00 ft. depth

Pump Installed: No
Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 6.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown

Formation Description	Thickness	Depth to Bottom
Sand	6.00	6.00
Sand W/Stones Water Bearing	36.00	42.00

Screen Installed: Yes **Filter Packed:** No
Screen Diameter: 5.00 in. **Blank:** 1.40 ft. Above
Screen Material Type: Stainless steel-slotted

Slot	Length	Set Between
10.00	9.00 ft.	33.00 ft. and 42.00 ft.

Fittings: Neoprene packer

Well Grouted: Yes **Grouting Method:** Unknown

Grouting Material	Bags	Additives	Depth
Bentonite dry granular	4.00	Unknown	0.00 ft. to 33.00 ft.

Wellhead Completion: Pitless adapter

Geology Remarks:

Nearest Source of Possible Contamination:

Type	Distance	Direction
Septic tank	100 ft.	

Drilling Machine Operator Name: DARYLD GRABE
Employment: Unknown

Contractor Type: Water Well Drilling Contractor **Reg No:** 61-2074
Business Name: GONYON WELL DRILLING
Business Address:

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks:
Other Remarks:

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Wellogic

Import ID:

Tax No:	Permit No:	County: Ottawa	Township: Crockery

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
08N 15W	8	Active	40417	3

Well ID: 70000007724

Elevation: 614 ft.
Latitude: 43.09083
Longitude: -86.11834
Method of Collection: GPS Std Positioning Svc SA Off

Distance and Direction from Road Intersection:

Well Owner: CROCKERY MHP

Well Address:
13251 STATE RD
NUNICA, MI 49448

Owner Address:
13251 STATE RD
NUNICA, MI 49448

Drilling Method: Cable Tool
Well Depth: 40.00 ft. **Well Use:** Type I public
Well Type: New **Date Completed:** 9/19/1989

Casing Type: Steel - unknown **Height:**
Casing Joint: Threaded & coupled
Casing Fitting: None

Diameter: 6.00 in. to 30.00 ft. depth

Borehole:

Pump Installed: No
Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 8.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown

Screen Installed: Yes **Filter Packed:** No
Screen Diameter: 6.00 in. **Blank:**
Screen Material Type: Stainless steel-slotted

Slot	Length	Set Between
12.00	10.00 ft.	30.00 ft. and 40.00 ft.

Fittings: Neoprene packer

Well Grouted: Yes **Grouting Method:** Unknown

Grouting Material	Bags	Additives	Depth
Neat cement/bentonite	8.00	Unknown	5.00 ft. to 25.00 ft.

Wellhead Completion: Pitless adapter

Formation Description	Thickness	Depth to Bottom
Black Topsoil	1.00	1.00
Sand Dry	5.00	6.00
Gray Sand Medium	2.00	8.00
Red Sand Fine To Medium Wet/Moist	4.00	12.00
Brown Sand Wet/Moist	5.00	17.00
Sand & Gravel Wet/Moist	7.00	24.00
Sand Coarse Water Bearing	6.00	30.00
Sand & Gravel Medium Wet/Moist	4.00	34.00
Silt & Gravel Water Bearing	3.00	37.00
Sand Medium Wet/Moist	4.00	41.00
Gray Sand & Clay Fine Water Bearing	2.00	43.00

Geology Remarks:

Nearest Source of Possible Contamination:

Type	Distance	Direction
Unknown		

Drilling Machine Operator Name:
Employment: Unknown

Contractor Type: Water Well Drilling Contractor **Reg No:** 61-0246
Business Name: RIEGLER WATER WELL DRILLING
Business Address:

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks:
Other Remarks:

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No:	Permit No:	County: Ottawa	Township: Crockery

Well ID: 70000002199

Elevation: 630 ft.
Latitude: 43.09122
Longitude: -86.1182
Method of Collection: GPS Std Positioning Svc SA Off

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
08N 15W	8	Active	40417	2

Distance and Direction from Road Intersection:

Well Owner: CROCKERY MOBILE HOME PARK

Well Address:
CROCKERY MHP WELL #2
NUNICA, MI 49448

Owner Address:
1920 PINE CT
GRAND HAVEN, MI 49417

Drilling Method: Cable Tool
Well Depth: 45.00 ft. **Well Use:** Type I public
Well Type: Replacement **Date Completed:** 11/21/1972

Casing Type: Unknown **Height:**
Casing Joint: Threaded & coupled
Casing Fitting: None

Diameter: 6.00 in. to 35.00 ft. depth

Borehole:

Pump Installed: No
Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 5.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown

Screen Installed: Yes **Filter Packed:** No
Screen Diameter: 5.60 in. **Blank:** 0.00 ft. Above
Screen Material Type: Unknown

Slot	Length	Set Between
0.00	10.00 ft.	35.00 ft. and 45.00 ft.

Fittings: None

Formation Description	Thickness	Depth to Bottom
Sand Dry	5.00	5.00
Sand Coarse Water Bearing	29.00	34.00
Clay	1.00	35.00
Sand Medium Water Bearing	10.00	45.00
Blue Clay	35.00	80.00

Well Grouted: No

Geology Remarks:

Wellhead Completion: Other, 12 inches above grade

Nearest Source of Possible Contamination:

Type	Distance	Direction
Septic tank	100 ft.	North

Abandoned Well Plugged: No
Reason Not Plugged: Unknown

Drilling Machine Operator Name:
Employment: Unknown

Contractor Type: Unknown **Reg No:** 64-0471
Business Name:
Business Address:

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks:

Other Remarks: Wellhead Completion:12 inch Above Grade

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No:	Permit No:	County: Ottawa	Township: Crockery

Well ID: 70000007723

Elevation:

Latitude: 43.08894

Longitude: -86.1178

Method of Collection: GPS Std Positioning Svc SA Off

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
08N 15W	8	Active	40417	1

Distance and Direction from Road Intersection:
130' NORTH OF STATE RD

Well Owner: CROCKERY MHP

Well Address:	Owner Address:
1 ARROWHEAD NONICA, MI 49448	1 ARROWHEAD NONICA, MI 49448

Drilling Method: Cable Tool
Well Depth: 30.00 ft. **Well Use:** Type I public
Well Type: New **Date Completed:** 10/12/1966

Casing Type: Steel - unknown **Height:**
Casing Joint: Unknown
Casing Fitting: Unknown

Diameter: 4.00 in. to

Borehole:

Pump Installed: No
Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 7.60 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown
Pumping level 18.00 ft. after 1.00 hrs. at 35 GPM

Screen Installed: Yes **Filter Packed:** No
Screen Diameter: in. **Blank:**
Screen Material Type: Stainless steel-slotted
Slot **Length** **Set Between**
0.00 ft.

Fittings: Neoprene packer

Formation Description	Thickness	Depth to Bottom
Sand	15.00	15.00
Sand Water Bearing	15.00	30.00

Well Grouted: No

Geology Remarks:

Wellhead Completion: Pitless adapter

Nearest Source of Possible Contamination:
Type **Distance** **Direction**
Unknown

Drilling Machine Operator Name:
Employment: Unknown

Contractor Type: Unknown **Reg No:**
Business Name: HAMILTON SUPPLY
Business Address:

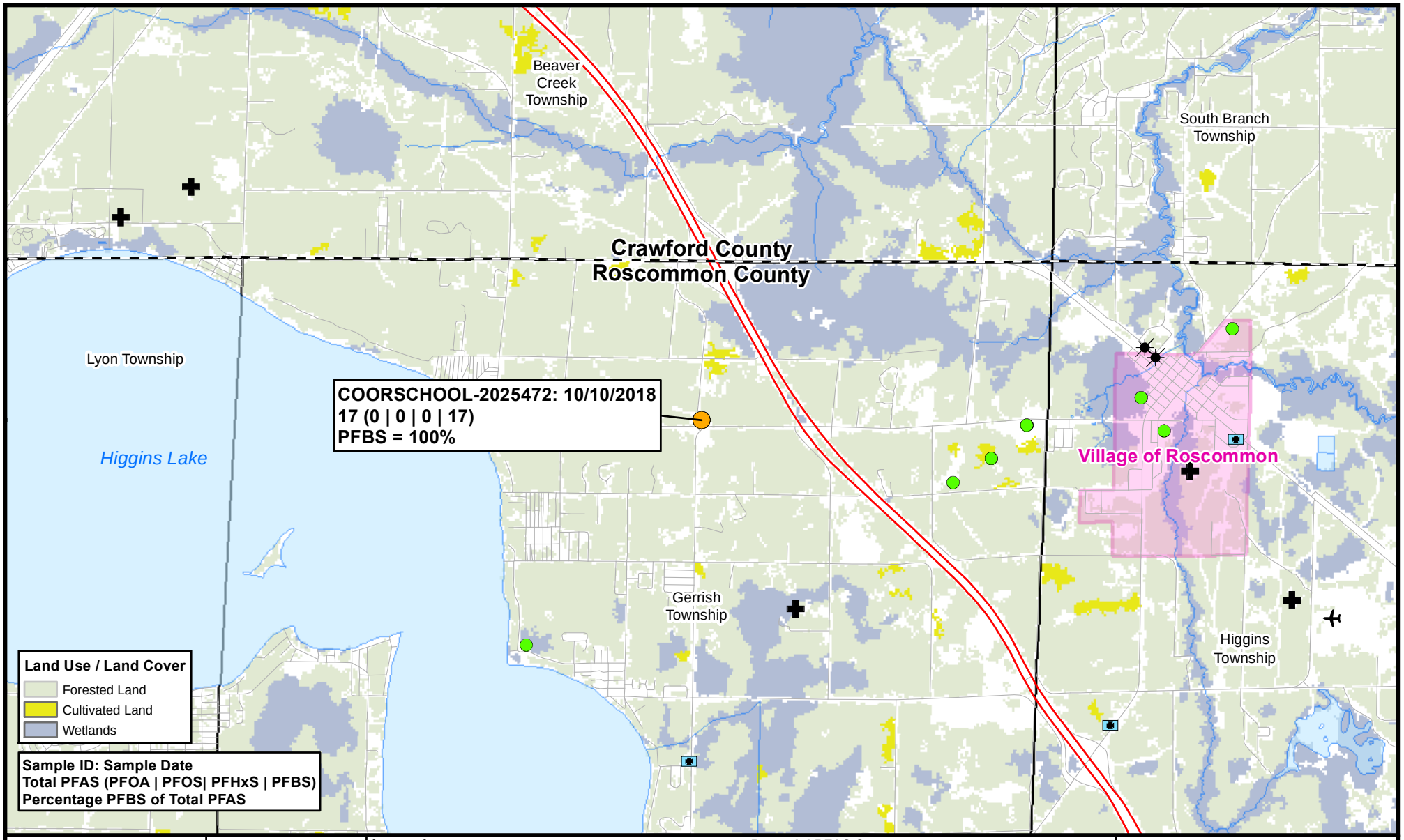
Water Well Contractor's Certification

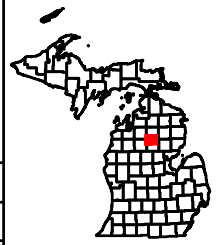
This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks:

Other Remarks:





Legend

PFBS > 50% of Total PFAS

Total PFAS (ppt)

- >0 - 10
- >10 - 50
- >50 - 100
- >100 - 200
- >200

- PFAS Non-Detect
- PFAS Detection; PFBS < 50% of Total PFAS
- Village / City Boundary
- Township Boundary
- County Boundary

Potential PFAS Sources

- Petroleum Bulk Stations
- Petroleum Terminals
- Military Sites
- Airports
- Paints & Allied Products
- Electroplaters
- Plating and Polishing Sites
- Active Accepting Landfills
- Historic Landfills
- Superfund Sites
- Biosolids Field
- Fire Station
- WWTP

0 0.5 1 2 Miles

N

Drawn:	JS	3/7/2019
Approved:		3/7/2019
Project #:		

FIGURE 11
C.O.O.R. SCHOOL

ROSCOMMON COUNTY, MI

LULC Data provided by USGS

G:\GrandRapids\DCS\GIS\ArcMap_GeoDB_Projects\ENV\GIS_Data\GIS\MDEQ CWS\MXD\PFBS_Evaluation\PFAS_Detects\Figure11_COOR_School_Roscommon.mxd

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID: 72240303402

Tax No:	Permit No:	County: Roscommon	Township: Gerrish

Well ID: 72000000509

Elevation: 1350 ft.
Latitude: 44.4942201764
Longitude: -84.6627013642
Method of Collection: GPS Differential (DGPS)

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
24N 03W	3	Active	2025472	001

Distance and Direction from Road Intersection:
WSSN 20254-72 #1

Well Owner: C.O.O.R.

Well Address:
COUNTY ROAD 100
ROSCOMMON, MI 48653

Owner Address:
COUNTY ROAD 100
ROSCOMMON, MI 48653

Drilling Method: Cable Tool
Well Depth: 230.00 ft. **Well Use:** Type II public
Well Type: Replacement **Date Completed:** 5/21/1977

Casing Type: Unknown **Height:**
Casing Joint: Threaded & coupled
Casing Fitting: Drive shoe

Diameter: 4.00 in. to 225.00 ft. depth

Borehole:

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: **HP:**
Manufacturer: F.E. Myers **Pump Type:** Submersible
Model Number: J5035 **Pump Capacity:** 0 GPM
Drop Pipe Length: 218.00 ft. **Pump Voltage:**
Drop Pipe Diameter: **Drilling Record ID:**
Draw Down Seal Used: No

Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 190.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown

Formation Description	Thickness	Depth to Bottom
Sand & Gravel	190.00	190.00
Sand & Gravel Water Bearing	40.00	230.00

Screen Installed: Yes **Filter Packed:** No
Screen Diameter: 4.00 in. **Blank:** 0.00 ft. Above
Screen Material Type:

Slot	Length	Set Between
12.00	5.00 ft.	225.00 ft. and 230.00 ft.

Fittings: Neoprene packer

Well Grouted: Yes **Grouting Method:** Unknown

Grouting Material	Bags	Additives	Depth
Other	0.00	None	0.00 ft. to 190.00 ft.

Wellhead Completion: Pitless adapter, 12 inches above grade

Geology Remarks:

Nearest Source of Possible Contamination:

Type	Distance	Direction
Septic tank	300 ft.	South

Abandoned Well Plugged: No
Reason Not Plugged:

Drilling Machine Operator Name: HALLIS R. CARLSON
Employment: Unknown

Contractor Type: Unknown **Reg No:** 20-1608
Business Name:
Business Address:

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks: S
Other Remarks: Grouting Material 1:Listed as other in Wellkey, Pump Manufacturer:RAPIDAYTON

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID: 72240303403

Tax No:	Permit No:	County: Roscommon	Township: Gerrish

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
24N 03W	3	Active	2025472	002

Well ID: 72000000510

Elevation: 1299 ft.
Latitude: 44.49427
Longitude: -84.66274
Method of Collection: GPS Std Positioning Svc SA Off

Distance and Direction from Road Intersection:
WSSN 20254-72 #2

Well Owner: C.O.O.R.I.S.D.

Well Address:
11051 NORTH CUT ROAD
ROSCOMMON, MI 48653

Owner Address:
11051 NORTH CUT ROAD
ROSCOMMON, MI 48653

Drilling Method: Cable Tool
Well Depth: 234.00 ft. **Well Use:** Type II public
Well Type: New **Date Completed:** 12/10/1992

Casing Type: Steel - black **Height:**
Casing Joint: Threaded & coupled
Casing Fitting: Drive shoe

Diameter: 4.00 in. to 226.00 ft. depth

Borehole:

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: **HP:**
Manufacturer: **Pump Type:** Submersible
Model Number: RAPIDAYTON **Pump Capacity:** 35 GPM
Drop Pipe Length: 218.00 ft. **Pump Voltage:**
Drop Pipe Diameter: **Drilling Record ID:**
Draw Down Seal Used: No

Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 185.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown
Pumping level 200.00 ft. after 1.00 hrs. at 45 GPM
Pumping level 220.00 ft. after 1.00 hrs. at 50 GPM

Formation Description	Thickness	Depth to Bottom
Sand & Gravel	20.00	20.00
Gravel & Stones	80.00	100.00
Sand & Gravel	50.00	150.00
Sand	30.00	180.00
Sand & Gravel	15.00	195.00
Tan Clay	4.00	199.00
Sand Coarse	35.00	234.00

Screen Installed: Yes **Filter Packed:** No
Screen Diameter: 3.00 in. **Blank:** 3.00 ft. Above
Screen Material Type:

Slot	Length	Set Between
10.00	8.00 ft.	226.00 ft. and 234.00 ft.

Fittings: Neoprene packer

Well Grouted: Yes **Grouting Method:** Unknown

Grouting Material	Bags	Additives	Depth
Other	0.00	None	0.00 ft. to 0.00 ft.

Wellhead Completion: Pitless adapter, 12 inches above grade

Geology Remarks:

Nearest Source of Possible Contamination:

Type	Distance	Direction
Septic tank	173 ft.	South

Drilling Machine Operator Name: JOSEPH A. LYONS
Employment: Unknown

Contractor Type: Unknown **Reg No:** 72-1671
Business Name:
Business Address:

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks: S
Other Remarks: Grouting Material 1:Listed as other in Wellkey, Pump Manufacturer:MYERS

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No:	Permit No: 11 72 02	County: Roscommon	Township: Gerrish

Well ID: 72000005486

Elevation:

Latitude: 44.49484

Longitude: -84.663806

Method of Collection: Interpolation-Map

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
24N 03W	3	Active	2028172	002

Distance and Direction from Road Intersection:
Located at the top of Pioneer Hill, NW corner of Cut Rd. and Sunset.

Well Owner: COOR ISD

Well Address:	Owner Address:
11051 N. Cut Rd. Roscommon, MI 48653	11051 N. Cut Rd. Roscommon, MI 48653

Drilling Method: Rotary
Well Depth: 283.00 ft. **Well Use:** Type II public
Well Type: Replacement **Date Completed:** 6/25/2011

Casing Type: PVC plastic **Height:** 1.00 ft. above grade
Casing Joint: Solvent welded/glued
Casing Fitting: None

Diameter: 5.00 in. to 193.00 ft. depth SDR: 21.00
5.00 in. to 273.00 ft. depth SDR: 17.00

Borehole: 5.00 in. to 283.00 ft. depth

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: 6/25/2011 **HP:** 2.00
Manufacturer: Goulds **Pump Type:** Submersible
Model Number: 25GS20 **Pump Capacity:** 25 GPM
Drop Pipe Length: 262.00 ft. **Pump Voltage:** 230
Drop Pipe Diameter: 1.25 in. **Drilling Record ID:**
Draw Down Seal Used: No

Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 190.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Air
1.00 hrs. at 25 GPM

Screen Installed: Yes **Filter Packed:** Yes
Screen Diameter: 5.00 in. **Blank:**
Screen Material Type: Stainless steel-slotted

Slot	Length	Set Between
10.00	10.00 ft.	273.00 ft. and 283.00 ft.

Fittings: None

Formation Description	Thickness	Depth to Bottom
Sand	18.00	18.00
Sand & Gravel	60.00	78.00
Sand	102.00	180.00
Gray Clay	2.00	182.00
Sand & Gravel	13.00	195.00
Sand	38.00	233.00
Gray Clay	2.00	235.00
Sand	48.00	283.00

Well Grouted: Yes **Grouting Method:** Grout pipe outside casing

Grouting Material	Bags	Additives	Depth
Bentonite slurry	14.00	None	0.00 ft. to 269.00 ft.

Geology Remarks:

Wellhead Completion: 12 inches above grade

Nearest Source of Possible Contamination:

Type	Distance	Direction
Septic tank	75 ft.	North

Drilling Machine Operator Name: Tom Jordan
Employment: Employee

Contractor Type: Water Well Drilling Contractor **Reg No:** 72-2106
Business Name: Jordan Well Drilling
Business Address: 247a Nellsville Rd, Houghton Lake, MI, 48629

Abandoned Well Plugged: Yes

Latitude: 44.49489 **Longitude:** -84.663868
Casing Diameter: 4 in. **Casing Removed:** No
Plugging Material: Bentonite chips/pellets
No. of Bags: 29.00 **Well Depth:** 220 ft.

Water Well Contractor's Certification

This well/pump was constructed under my supervision and I hereby certify that the work complies with Part 127 Act 368 PA 1978 and the well code.

Signature of Registered Contractor **Date**

General Remarks:

Other Remarks:

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID: 72240312403

Tax No:	Permit No:	County: Roscommon	Township: Gerrish

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
24N 03W	12	Active	2019172	001

Well ID: 72000000516

Elevation: 1151 ft.
Latitude: 44.493726091
Longitude: -84.6150568388
Method of Collection: GPS Differential (DGPS)

Distance and Direction from Road Intersection:
WSSN 20191-72 WELL #1

Well Owner: GERRISH-HIGGINS ELEMENTARY SCH

Well Address:
COUNTY ROAD 100
ROSCOMMON, MI 48653

Owner Address:
ROSCOMMON, MI 48653

Drilling Method: Rotary
Well Depth: 116.00 ft. **Well Use:** Type II public
Well Type: Replacement **Date Completed:** 9/27/1972

Casing Type: Unknown **Height:** 5.00 ft. above grade
Casing Joint: Threaded & coupled
Casing Fitting: Drive shoe

Diameter: 6.00 in. to 103.00 ft. depth
5.00 in. to 116.00 ft. depth

Borehole:

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: **HP:**
Manufacturer: Red Jacket **Pump Type:** Submersible
Model Number: 5001-13fc **Pump Capacity:** 50 GPM
Drop Pipe Length: 76.00 ft. **Pump Voltage:**
Drop Pipe Diameter: **Drilling Record ID:**
Draw Down Seal Used: No

Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 6.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown
Pumping level 16.00 ft. after 2.00 hrs. at 60 GPM
Pumping level 22.00 ft. after 8.00 hrs. at 72 GPM

Formation Description	Thickness	Depth to Bottom
Sand	86.00	86.00
Clay	5.00	91.00
Sand	25.00	116.00

Screen Installed: Yes **Filter Packed:** No
Screen Diameter: 5.00 in. **Blank:** 0.00 ft. Above
Screen Material Type:

Slot	Length	Set Between
7.00	10.00 ft.	103.00 ft. and 113.00 ft.

Fittings: Neoprene packer

Well Grouted: Yes **Grouting Method:** Unknown

Grouting Material	Bags	Additives	Depth
Other	0.00	None	0.00 ft. to 0.00 ft.

Wellhead Completion: Pitless adapter, Other, 12 inches above grade

Geology Remarks:

Nearest Source of Possible Contamination:

Type	Distance	Direction
Unknown	0 ft.	

Abandoned Well Plugged: No
Reason Not Plugged:

Drilling Machine Operator Name: NORMAN K. SIMMONS
Employment: Unknown

Contractor Type: Unknown **Reg No:** 65-0033
Business Name:
Business Address:

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks:
Other Remarks: Grouting Material 1:Listed as other in Wellkey

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID: 72240312404

Tax No:	Permit No:	County: Roscommon	Township: Gerrish

Well ID: 72000000517

Elevation: 1148 ft.
Latitude: 44.4937917381
Longitude: -84.6142034759
Method of Collection: GPS Differential (DGPS)

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
24N 03W	12	Active	2019172	002

Distance and Direction from Road Intersection: WSSN 20191-72 WELL #2

Well Owner: GERRISH-HIGGINS SCHOOL DI

Well Address:	Owner Address:
175 SUNSET BLVD. ROSCOMMON, MI 48653	814 LAKE STREET ROSCOMMON, MI 48653

Drilling Method: Rotary
Well Depth: 128.00 ft. **Well Use:** Type II public
Well Type: Replacement **Date Completed:** 5/6/1998

Casing Type: PVC plastic **Height:**
Casing Joint: Unknown
Casing Fitting: None

Diameter: 5.00 in. to 112.00 ft. depth

Borehole: 8.00 in. to 128.00 ft. depth

Static Water Level: 4.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown
Pumping level 13.00 ft. after 2.00 hrs. at 70 GPM

Screen Installed: Yes **Filter Packed:** No
Screen Diameter: 3.00 in. **Blank:** 0.00 ft. Above
Screen Material Type:

Slot	Length	Set Between
12.00	16.00 ft.	112.00 ft. and 128.00 ft.

Fittings: Neoprene packer

Well Grouted: Yes **Grouting Method:** Unknown

Grouting Material	Bags	Additives	Depth
Other	0.00	None	0.00 ft. to 105.00 ft.

Wellhead Completion: Pitless adapter, Other, 12 inches above grade

Nearest Source of Possible Contamination:

Type	Distance	Direction
Unknown	110 ft.	South

Abandoned Well Plugged: Yes

Casing Removed:

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: **HP:**
Manufacturer: Red Jacket **Pump Type:** Submersible
Model Number: 200CWI **Pump Capacity:** 50 GPM
Drop Pipe Length: 76.00 ft. **Pump Voltage:**
Drop Pipe Diameter: **Drilling Record ID:**
Draw Down Seal Used: No

Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Formation Description	Thickness	Depth to Bottom
Yellow Sand W/Silt	24.00	24.00
Brown Clay	5.00	29.00
Gravel & Cobbles Coarse	24.00	53.00
Brown Clay	6.00	59.00
Lithology Unknown	15.00	74.00
Brown Clay	3.00	77.00
Brown Clay & Gravel Coarse	19.00	96.00
Gray Clay	4.00	100.00
Lithology Unknown	8.00	108.00
Gravel & Sand Coarse	20.00	128.00

Geology Remarks:

Drilling Machine Operator Name: DAN SENTELL
Employment: Unknown

Contractor Type: Unknown **Reg No:** 72-0131
Business Name:
Business Address:

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks:
Other Remarks: Grouting Material 1:Listed as other in Wellkey, Pump Manufacturer:MORLEY

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID: 72240312402

Tax No:	Permit No:	County: Roscommon	Township: Gerrish

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
24N 03W	12	Active	2029172	001

Well ID: 72000000515

Elevation: 1205 ft.
Latitude: 44.4902427085
Longitude: -84.6194816679
Method of Collection: GPS Differential (DGPS)

Distance and Direction from Road Intersection:
WSSN 20291-72/WELL #1

Well Owner: GERRISH-HIGGINS MIDDLE SCHOOL

Well Address:
814 Lake St.
ROSCOMMON, MI 48653

Owner Address:
P.O. Box 825
ROSCOMMON, MI 48653

Drilling Method: Rotary
Well Depth: 185.00 ft. **Well Use:** Type II public
Well Type: New **Date Completed:** 5/26/1992

Casing Type: Steel - black **Height:** 1.50 ft. above grade
Casing Joint: Threaded & coupled
Casing Fitting: Drive shoe

Diameter: 6.00 in. to 150.00 ft. depth

Borehole: 10.00 in. to 165.00 ft. depth

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: **HP:**
Manufacturer: Red Jacket **Pump Type:** Submersible
Model Number: 1006G54-4H **Pump Capacity:** 200 GPM
Drop Pipe Length: 126.00 ft. **Pump Voltage:**
Drop Pipe Diameter: **Drilling Record ID:**
Draw Down Seal Used: No

Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 52.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown
Pumping level 72.00 ft. after 5.00 hrs. at 200 GPM

Screen Installed: Yes **Filter Packed:** No
Screen Diameter: 5.00 in. **Blank:** 4.00 ft. Above
Screen Material Type:

Slot	Length	Set Between
10.00	20.00 ft.	165.00 ft. and 185.00 ft.

Fittings: None

Formation Description	Thickness	Depth to Bottom
Sand & Gravel	60.00	60.00
Clay & Gravel	7.00	67.00
Sand & Gravel	31.00	98.00
Clay & Gravel	4.00	102.00
Sand & Gravel	38.00	140.00
Sand Fine	23.00	163.00
Sand Coarse	12.00	175.00
Sand Fine To Medium	10.00	185.00

Well Grouted: Yes **Grouting Method:** Unknown

Grouting Material	Bags	Additives	Depth
Other	0.00	None	5.00 ft. to 150.00 ft.

Wellhead Completion: Pitless adapter, Other, 12 inches above grade

Geology Remarks:

Nearest Source of Possible Contamination:

Type	Distance	Direction
Lagoon	800 ft.	Northeast

Drilling Machine Operator Name: RUSSELL HEHIR
Employment: Unknown

Contractor Type: Unknown **Reg No:** 68-1619
Business Name:
Business Address:

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks: WELL #1 - SOUTH WELL
Other Remarks: Grouting Material 1:Listed as other in Wellkey

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID: 72240312401

Tax No:	Permit No:	County: Roscommon	Township: Gerrish

Well ID: 72000000514

Elevation: 1205 ft.
Latitude: 44.490215518
Longitude: -84.6197124433
Method of Collection: GPS Differential (DGPS)

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
24N 03W	12	Active	2029172	002

Distance and Direction from Road Intersection:
WSSN 20291-72/WELL #2

Well Owner: GERRISH-HIGGINS MIDDLE SCHOOL

Well Address:
299H WEST SUNSET DR.
ROSCOMMON, MI 48653

Owner Address:
299H WEST SUNSET DR.
ROSCOMMON, MI 48653

Drilling Method: Rotary
Well Depth: 189.00 ft. **Well Use:** Type II public
Well Type: New **Date Completed:** 6/2/1992

Casing Type: Steel - black **Height:** 1.50 ft. above grade
Casing Joint: Threaded & coupled
Casing Fitting: Drive shoe

Diameter: 6.00 in. to 150.00 ft. depth

Borehole: 10.00 in. to 169.00 ft. depth

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: **HP:**
Manufacturer: Red Jacket **Pump Type:** Submersible
Model Number: 1006F544HB **Pump Capacity:** 200 GPM
Drop Pipe Length: 126.00 ft. **Pump Voltage:**
Drop Pipe Diameter: **Drilling Record ID:**
Draw Down Seal Used: No

Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 53.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown
Pumping level 73.00 ft. after 5.00 hrs. at 200 GPM

Screen Installed: Yes **Filter Packed:** No
Screen Diameter: 5.00 in. **Blank:** 3.00 ft. Above
Screen Material Type:

Slot	Length	Set Between
10.00	20.00 ft.	169.00 ft. and 189.00 ft.

Fittings: None

Formation Description	Thickness	Depth to Bottom
Sand & Gravel	60.00	60.00
Clay & Gravel	6.00	66.00
Sand & Gravel	30.00	96.00
Clay & Gravel	2.00	98.00
Sand & Gravel	40.00	138.00
Sand Fine	30.00	168.00
Lithology Unknown	11.00	179.00
Sand Fine	10.00	189.00

Well Grouted: Yes **Grouting Method:** Unknown

Grouting Material	Bags	Additives	Depth
Other	0.00	None	5.00 ft. to 150.00 ft.

Geology Remarks:

Wellhead Completion: Pitless adapter, Other, 12 inches above grade

Nearest Source of Possible Contamination:

Type	Distance	Direction
Lagoon	800 ft.	Northeast

Drilling Machine Operator Name: RUSSELL HEHIR
Employment: Unknown

Contractor Type: Unknown **Reg No:** 68-1619
Business Name:
Business Address:

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks: WELL #2 - NORTH WELL
Other Remarks: Grouting Material 1:Listed as other in Wellkey

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No:	Permit No:	County: Roscommon	Township: Gerrish

Well ID: 72000002269

Elevation: 1198 ft.
Latitude: 44.48765
Longitude: -84.62507
Method of Collection: GPS Std Positioning Svc SA Off

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
24N 03W	12	Active	2014672	001

Distance and Direction from Road Intersection:

Well Owner: ROSCOMMON HIGH SCHOOL

Well Address:	Owner Address:
10600 OAKWOOD ROSCOMMON, MI 48653	10600 OAKWOOD ROSCOMMON, MI 48653

Drilling Method: Unknown
Well Depth: ft. **Well Use:** Type II public
Well Type: Unknown **Date Completed:**

Casing Type: Unknown **Height:**
Casing Joint: Unknown
Casing Fitting: Unknown

Diameter:

Borehole:

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: **HP:**
Manufacturer: **Pump Type:** Submersible
Model Number: **Pump Capacity:**
Drop Pipe Length: 0.00 ft. **Pump Voltage:**
Drop Pipe Diameter: **Drilling Record ID:**
Draw Down Seal Used: No

Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: Below Grade
Well Yield Test: **Yield Test Method:** Unknown

Screen Installed: No **Intake:** Unknown

Well Grouted: No

Wellhead Completion: Unknown, Other

Formation Description	Thickness	Depth to Bottom
No Log	1.00	1.00

Geology Remarks:

Nearest Source of Possible Contamination:

Type	Distance	Direction
Unknown		

Abandoned Well Plugged: No

Reason Not Plugged:

Drilling Machine Operator Name:
Employment: Unknown

Contractor Type: Unknown **Reg No:**
Business Name:
Business Address:

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks: NO WELL LOG
Other Remarks:

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No: 72 004 012 008 0020	**Permit No:** 13-72-01	**County:** Roscommon		**Township:** Gerrish
		Town/Range: 24N 03W	**Section:** 12	**Well Status:** Active
		WSSN: 2014672	**Source ID/Well No:** 003	

Well ID: 72000005836

Elevation:

Latitude: 44.48765

Longitude: -84.62517

Method of Collection: GPS Std Positioning Svc SA Off

Distance and Direction from Road Intersection:
10600 Oakwood

Well Owner: Roscommon High School

Well Address:	**Owner Address:**
10600 Oakwood Roscommon, MI 48653	10600 Oakwood Roscommon, MI 48653

Drilling Method: Rotary
Well Depth: 148.00 ft. **Well Use:** Type II public
Well Type: Replacement **Date Completed:** 3/5/2013

Casing Type: PVC plastic **Height:** 1.00 ft. above grade
Casing Joint: Solvent welded/glued
Casing Fitting: None

Diameter: 6.90 in. to 138.00 ft. depth SDR: 21.00

Borehole: 8.75 in. to 148.00 ft. depth

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: 3/5/2013 **HP:** 10.00
Manufacturer: Goulds **Pump Type:** Submersible
Model Number: L8510 **Pump Capacity:** 85 GPM
Drop Pipe Length: 105.00 ft. **Pump Voltage:** 460
Drop Pipe Diameter: 3.00 in. **Drilling Record ID:**
Draw Down Seal Used: No **LQW Reg. No:** 20146-72

Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 40.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Air
Pumping level 138.00 ft. after 1.00 hrs. at 100 GPM

Formation Description	Thickness	Depth to Bottom
Sand & Gravel	74.00	74.00
Brown Clay & Gravel Sandy	35.00	109.00
Sand & Gravel	39.00	148.00

Screen Installed: Yes **Filter Packed:** Yes
Screen Diameter: 5.00 in. **Blank:** 1.00 ft. Above
Screen Material Type: Stainless steel-wire wrapped

Slot	Length	Set Between
12.00	10.00 ft.	138.00 ft. and 148.00 ft.

Fittings: Neoprene packer

Well Grouted: Yes **Grouting Method:** Grout pipe outside casing

Grouting Material	Bags	Additives	Depth
Bentonite slurry	10.00	None	0.00 ft. to 138.00 ft.

Wellhead Completion: Pitless adapter, 12 inches above grade

Geology Remarks:

Nearest Source of Possible Contamination:

Type	Distance	Direction
Storm sewer	35 ft.	North

Abandoned Well Plugged: Yes

Casing Diameter: 6 in. **Casing Removed:** No
Plugging Material: Bentonite slurry
No. of Bags: 13.00 **Well Depth:** 140 ft.

Drilling Machine Operator Name: Jeremy Gioannini
Employment: Employee
Pump Installer: Floyd Meir

Contractor Type: Water Well Drilling Contractor **Reg No:** 26-2248
Business Name: Thayer Well Drilling Inc
Business Address: 4298 Raymond Road, Beaverton, MI, 48612

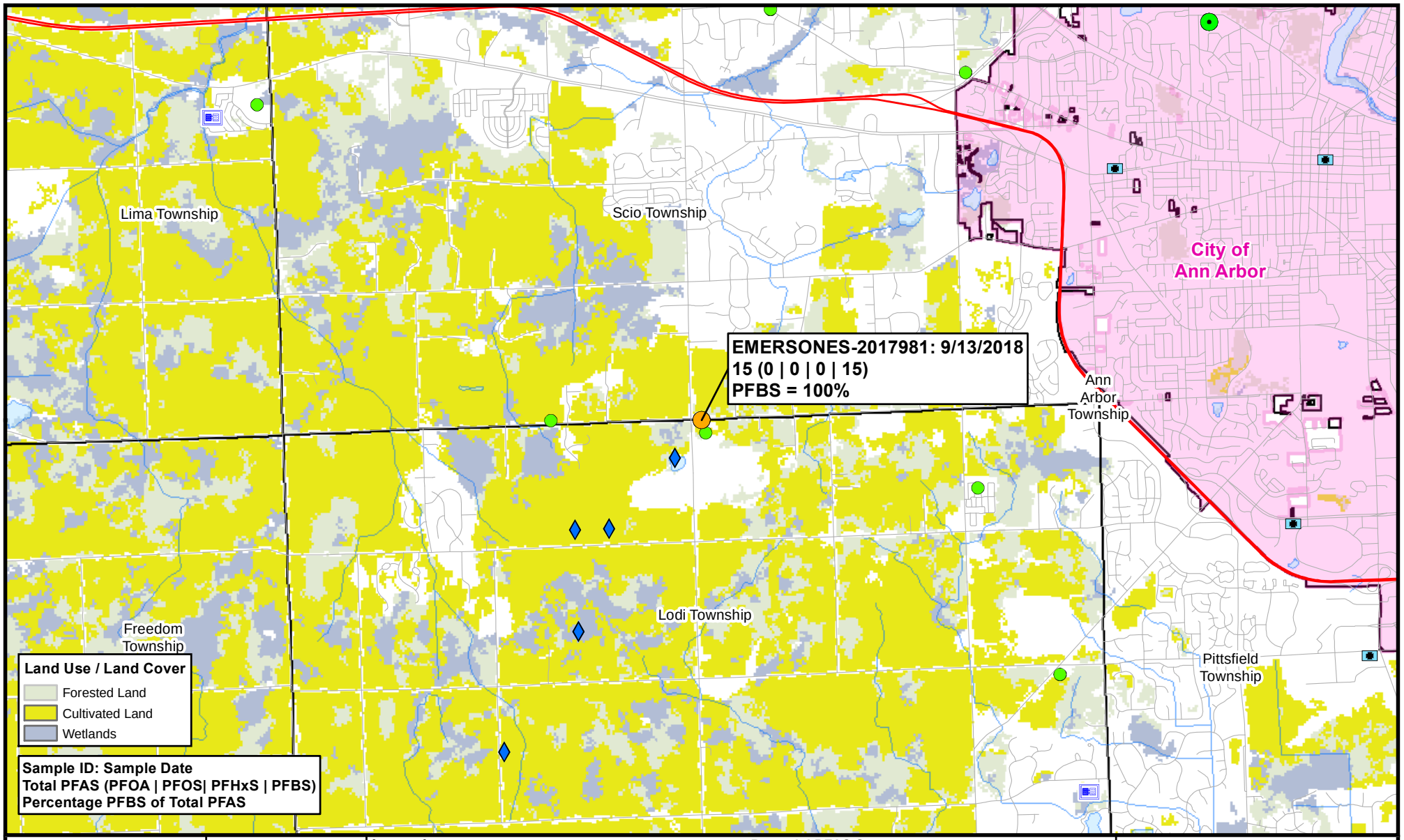
Water Well Contractor's Certification

This well/pump was constructed under my supervision and I hereby certify that the work complies with Part 127 Act 368 PA 1978 and the well code.

Signature of Registered Contractor **Date**

General Remarks:

Other Remarks:



DEQ

Drawn:	JS	3/7/2019
Approved:		3/7/2019
Project #:		

Legend

PFBS > 50% of Total PFAS

Total PFAS (ppt)

- >0 - 10
- >10 - 50
- >50 - 100
- >100 - 200
- >200

- PFAS Non-Detect
- PFAS Detection; PFBS < 50% of Total PFAS
- Village / City Boundary
- Township Boundary
- County Boundary

Potential PFAS Sources

- Petroleum Bulk Stations
- Petroleum Terminals
- Military Sites
- Airports
- Paints & Allied Products
- Electroplaters
- Plating and Polishing Sites
- Active Accepting Landfills
- Historic Landfills
- Superfund Sites
- Biosolids Field
- Fire Station
- WWTP

0 0.5 1 2 Miles

N

FIGURE 20
EMERSON SCHOOL - ELEMENTARY

WASHTENAW COUNTY, MI

Source: ESRI USA Topo Maps

G:\GrandRapids\DCS\GIS\ArcMap_GeoDB_Projects\ENV\GIS_Data\GIS\MDEQ CWS\MXD\PFBS_Evaluation\PFAS_Detects\Figure20_Emerson_Elementary_Washtenaw.mxd

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Wellogic

Import ID:

Tax No: 811303200003	**Permit No:**	**County:** Washtenaw		**Township:** Lodi
		Town/Range: 03S 05E	**Section:** 3	**Well Status:** Plugged	**WSSN:** 2017981	**Source ID/Well No:** 001

Well ID: 81000006032

Elevation: 997 ft.
Latitude: 42.25414
Longitude: -83.8364
Method of Collection: GPS Std Positioning Svc SA Off

Distance and Direction from Road Intersection:

Well Owner: EMERSON ELEMENTARY SCHOOL

Well Address:
5425 SCIO CHURCH RD
ANN ARBOR, MI 48103

Owner Address:
5425 SCIO CHURCH RD
ANN ARBOR, MI 48103

Drilling Method: Rotary
Well Depth: 151.00 ft. **Well Use:** Type II public
Well Type: Replacement **Date Completed:** 6/23/1983

Casing Type: Unknown **Height:**
Casing Joint: Threaded & coupled
Casing Fitting: Drive shoe

Diameter: 4.00 in. to 145.00 ft. depth

Borehole: 6.75 in. to 141.00 ft. depth

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: **HP:**
Manufacturer: Unknown **Pump Type:** Submersible
Model Number: **Pump Capacity:**
Drop Pipe Length: **Pump Voltage:**
Drop Pipe Diameter: **Drilling Record ID:**
Draw Down Seal Used: No

Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 113.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown
Pumping level 115.00 ft. after 2.00 hrs. at 25 GPM

Formation Description	Thickness	Depth to Bottom
Yellow Clay	18.00	18.00
Yellow Clay Sandy	2.00	20.00
Gravel	107.00	127.00
Gray Clay	11.00	138.00
Gravel Medium	11.00	149.00
Gray Clay	2.00	151.00

Screen Installed: Yes **Filter Packed:** No
Screen Diameter: 3.75 in. **Blank:** 1.00 ft. Above
Screen Material Type: Unknown

Slot	Length	Set Between
30.00	4.00 ft.	145.00 ft. and 149.00 ft.

Fittings: Neoprene packer

Well Grouted: Yes **Grouting Method:** Unknown

Grouting Material	Bags	Additives	Depth
Bentonite slurry	0.00	None	

Geology Remarks:

Wellhead Completion: Pitless adapter

Nearest Source of Possible Contamination:

Type	Distance	Direction
Septic tank	100 ft.	Southwest

Drilling Machine Operator Name:
Employment: Unknown

Contractor Type: Unknown **Reg No:** 81-0524
Business Name:
Business Address:

Abandoned Well Plugged: No
Reason Not Plugged: Unknown

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks: ORIGINAL WELLID# WAS 03005; ALSO 03301. LI 17-83.
Other Remarks:

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No:	Permit No: WEL2005-00273	County: Washtenaw	Township: Lodi

Well ID: 81000016482

Elevation:

Latitude: 42.254535

Longitude: -83.836307

Method of Collection: Interpolation-Map

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
03S 05E	3	Active	2017981	002

Distance and Direction from Road Intersection:
EAST OF ZEEB ROAD

Well Owner: EMERSON SCHOOL

Well Address:
5425 Scio Church Rd
ANN ARBOR, MI 48103

Owner Address:
5425 SCIO CHURCH
ANN ARBOR, MI 48103

Drilling Method: Rotary
Well Depth: 171.00 ft. **Well Use:** Type II public
Well Type: New **Date Completed:** 8/16/2005

Casing Type: PVC plastic **Height:** 1.00 ft. above grade
Casing Joint: Solvent welded/glued
Casing Fitting: None

Diameter: 6.00 in. to 150.00 ft. depth

Borehole: 10.00 in. to 175.00 ft. depth

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: 9/30/2005 **HP:** 10.00
Manufacturer: Berkeley **Pump Type:** Submersible
Model Number: 6TP125-10 **Pump Capacity:** 130 GPM
Drop Pipe Length: 135.00 ft. **Pump Voltage:**
Drop Pipe Diameter: 3.00 in. **Drilling Record ID:**
Draw Down Seal Used: No

Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 132.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Test pump
Pumping level 141.00 ft. after 6.00 hrs. at 130 GPM

Formation Description	Thickness	Depth to Bottom
Brown Clay	17.00	17.00
Gray Clay	11.00	28.00
Sand & Gravel	113.00	141.00
Gray Clay	7.00	148.00
Sand Water Bearing	23.00	171.00
Gray Clay	4.00	175.00

Screen Installed: Yes **Filter Packed:** Yes
Screen Diameter: 6.00 in. **Blank:**
Screen Material Type: Stainless steel-wire wrapped

Slot	Length	Set Between
20.00	20.00 ft.	151.00 ft. and 171.00 ft.

Fittings: None

Well Grouted: Yes **Grouting Method:** Grout pipe outside casing

Grouting Material	Bags	Additives	Depth
Bentonite slurry	15.00	None	0.00 ft. to 149.00 ft.

Wellhead Completion: Pitless adapter, 12 inches above grade

Geology Remarks:

Nearest Source of Possible Contamination:

Type	Distance	Direction
Drainfield/Dry well	700 ft.	Southwest
None		

Drilling Machine Operator Name: STEVE WHEELER
Employment: Employee

Contractor Type: Water Well Drilling Contractor **Reg No:** 81-2215
Business Name: Ann Arbor Well Drilling, Inc.
Business Address: Box 163, Dexter, MI, 48130

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks: SCREEN SLOT: 5' OF 20, 5' OF 18, 10' OF 15#

Other Remarks:

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No: 811303200003	**Permit No:**	**County:** Washtenaw		**Township:** Lodi
		Town/Range: 03S 05E	**Section:** 3	**Well Status:** Active	**WSSN:** 2037281	**Source ID/Well No:** 001

Well ID: 81000006033

Elevation: 997 ft.
Latitude: 42.25317
Longitude: -83.83568
Method of Collection: GPS Std Positioning Svc SA Off

Distance and Direction from Road Intersection:

Well Owner: EMERSON SCHOOL

Well Address:	**Owner Address:**
5425 SCIO CHURCH ANN ARBOR, MI 48103	5425 SCIO CHURCH ANN ARBOR, MI 48103

Drilling Method: Rotary
Well Depth: 152.00 ft. **Well Use:** Type II public
Well Type: New **Date Completed:** 8/27/1991

Casing Type: PVC plastic **Height:**
Casing Joint: Welded
Casing Fitting: Drive shoe

Diameter: 5.00 in. to 144.00 ft. depth
4.00 in. to 152.00 ft. depth

Borehole:

Pump Installed: Yes **Pump Installation Only:** No
Pump Installation Date: **HP:**
Manufacturer: Unknown **Pump Type:** Submersible
Model Number: **Pump Capacity:**
Drop Pipe Length: **Pump Voltage:**
Drop Pipe Diameter: **Drilling Record ID:**
Draw Down Seal Used: No

Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 110.00 ft. Below Grade
Well Yield Test: **Yield Test Method:** Unknown
Pumping level 110.00 ft. after 2.00 hrs. at 30 GPM

Formation Description	Thickness	Depth to Bottom
Brown Sand & Clay	7.00	7.00
Sand	2.00	9.00
Brown Clay	22.00	31.00
Sand & Gravel	79.00	110.00
Sand Wet/Moist	42.00	152.00

Screen Installed: Yes **Filter Packed:** No
Screen Diameter: 4.00 in. **Blank:** 0.00 ft. Above
Screen Material Type: Unknown

Slot	Length	Set Between
20.00	8.00 ft.	144.00 ft. and 152.00 ft.

Fittings: Neoprene packer

Well Grouted: Yes **Grouting Method:** Unknown

Grouting Material	Bags	Additives	Depth
Bentonite slurry	0.00	None	0.00 ft. to 110.00 ft.

Wellhead Completion: Pitless adapter, 12 inches above grade

Geology Remarks:

Nearest Source of Possible Contamination:

Type	Distance	Direction
Septic tank	200 ft.	West-Northwest

Drilling Machine Operator Name: ANN ARBOR DRILLING
Employment: Unknown

Contractor Type: Unknown **Reg No:** 81-1290
Business Name:
Business Address:

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor **Date**

General Remarks:
Other Remarks:

AECOM

About AECOM

AECOM is built to deliver a better world. We design, build, finance and operate infrastructure assets for governments, businesses and organizations in more than 150 countries. As a fully integrated firm, we connect knowledge and experience across our global network of experts to help clients solve their most complex challenges. From high-performance buildings and infrastructure, to resilient communities and environments, to stable and secure nations, our work is transformative, differentiated and vital. A Fortune 500 firm, AECOM had revenue of approximately $17.4 billion during fiscal year 2016. See how we deliver what others can only imagine at aecom.com and @AECOM.