SITE SCREENING LEVEL ASSESSMENTS FOR PFOA AND THE RELEVANCE OF SOIL SAMPLING

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EXECUTIVE SUMMARY

DuPont's extensive implementation of both media specific assessment modeling tools and comprehensive on-site and off-site soil, surface-water, and groundwater monitoring for perfluorooctanoate[1] at the Washington Works site in West Virginia allowed for compilation of a generalized screening level assessment model. This model identifies the potential migration pathways for PFOA from any PFOA-use site to the environment and identifies key PFOA monitoring points. Identification of complete migration pathways and key monitoring points is necessary for conducting screening level assessments at industrial sites using PFOA.

The extensive investigation at Washington Works provided enough data to thoroughly evaluate the value of modeling tools, media-specific sampling, and monitoring when conducting a PFOA screening level assessment. The data demonstrated that groundwater and surface-water monitoring provide a more realistic assessment of the fate of PFOA in the environment than does soil monitoring. The conclusion was reached that soil sampling is not relevant in conducting PFOA screening level assessments.
This conclusion was based on the following data:

- PFOA has high water solubility.
- PFOA has a high water mobility (3M, 1978) and low soil adsorption capacity [Association of Plastics Manufacturers in Europe (APME), 2003] for multiple soil types.
- PFOA soil results from the Little Hocking Water Association well field and the Washington Works site demonstrate that PFOA in air emissions deposited on ground surfaces will quickly be dissolved by precipitation and be transported in precipitation to surface water or to groundwater.
- Extensive soil sampling was not shown to be relevant in conducting the site-wide PFOA screening level assessment at the Washington Works site because groundwater and surface-water PFOA data provide a more realistic assessment of the fate of PFOA in the environment and because there is no receptor exposure to PFOA-impacted soils.

Other tools, including modeling tools and groundwater and surface-water monitoring, can more effectively and efficiently be used to evaluate PFOA migration pathways, and to predict/measure concentrations in the environment and evaluate overall exposure. The PFOA screening level assessment model, presented here, focuses on identifying the migration pathways for PFOA from any PFOA-use site to the environment and identifying key PFOA monitoring points.

[1]For the purposes of this report, perfluorooctanoate includes the anion of the acid perfluorooctanoate (PFOA).

1.0 INTRODUCTION

Perfluorooctanoate[2] (also known as PFOA, FC-143, or C-8) is used in the manufacture of fluoropolymer products at the DuPont Washington Works site in Washington, West Virginia. During manufacturing activities, PFOA was and is currently discharged to air via stack emissions and to surface water via outfall emissions. In addition, PFOA containing wastewater was once historically managed in a former on-site solid waste management unit (SWMU).

The presence of PFOA in various site environmental media was determined through extensive groundwater, surface-water, and soil sampling at and within two miles of the Washington Works site and in Ohio, across the Ohio River from the Washington Works site. In addition, numerous modeling tools were employed using site-specific data (process, geological, hydrological, analytical, and meteorological) to evaluate the migration pathways of PFOA from the site to the environment, and to predict the concentrations of PFOA in various media, including air and groundwater. These modeling tools were critical to the development of focused monitoring plans that allowed for monitoring of media where potential exposures could occur.

A screening level assessment conceptual model was developed utilizing the results from the extensive site-related modeling and monitoring that was conducted at the DuPont Washington Works site (see Figure 1). This conceptual model describes the migration pathways for PFOA from any PFOA-use site to the environment and identifies key PFOA monitoring points.

Because there have been so many different types of investigations conducted at, and off-site from, the Washington Works site, it is possible to examine the value of each investigation (i.e., media specific sampling) to the overall screening level assessment for PFOA. This report demonstrates that extensive soil sampling and analysis for PFOA is not relevant to conducting PFOA screening level assessments at fluoropolymer manufacturing sites.

The following data support this position:

- PFOA has a high solubility and has a low affinity for soils. When PFOA is deposited onto soil, it is quickly dissolved by precipitation and then migrates to surface water or groundwater. Therefore, surface-water and groundwater monitoring provide a more realistic assessment of the fate of PFOA in the environment.
- Extensive soil concentration data are not needed to develop a screening level model for a site. Other more effective and efficient tools can be used to evaluate PFOA migration pathways and predict/measure concentrations in the environment. These tools include:
  - groundwater and surface-water sampling and monitoring
  - surface-water discharge modeling (e.g., PDM Model)

[2]For the purposes of this report, perfluorooctanoate includes the anion of the acid perfluorooctanoate (PFOA).

- ambient air and deposition modeling (e.g., ISCST3 Model)
- unsaturated soil modeling (e.g., PRZM Model)
- groundwater flow modeling (e.g., MODFLOW Model)

To demonstrate the position that soil sampling is not relevant to site screening level assessments for PFOA, the development of the generalized PFOA site screening level assessment conceptual model will be discussed. In addition, solubility data for PFOA will be summarized, as will the recent results from the Adsorption/Desorption of Ammonium Perfluorooctanoate to Soil [Organization for Economic and Cooperative Development (OECD) 106] study sponsored by the Association of Plastics Manufacturers in Europe (APME, 2003), which indicates that PFOA has a low affinity for soils. Finally, the results of the soil sampling conducted at and near the Washington Works site are presented; these results support the solubility and adsorption/desorption data. (All documents referenced in this report can be found in United States Environmental Protection Agency docket # OPPT-2003-0012 or AR-226.)

Using a portion of the DuPont Washington Works site data set, this report also demonstrates the usefulness of limited soil sampling in delineating impact and evaluating exposure after identification of a release from a SWMU. Limited soil sampling can be useful if the SWMU-release is deemed as a critical source of PFOA and if complete migration pathways to the environment and known receptor exposure exist.

2.0 DATA PRESENTATION

2.1 Development of a Generalized PFOA Screening Level Site Conceptual Model

Extensive PFOA sampling of surface water, groundwater, and soils was conducted at the Washington Works site during a Verification Investigation (VI; DuPont, 1992) and a Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI; DuPont, 1999). Geological and hydrological data were also acquired during these investigations. Additional PFOA data, both on-site and off-site in West Virginia and in Ohio, were generated while conducting activities required by the Multi-media Consent Order (Order No. GWR-2001-019) issued to DuPont in November 2001. The Consent Order also required that air modeling and groundwater modeling (DuPont, 2003a) be conducted for the site. Additional modeling tools were also employed by DuPont to evaluate PFOA at the site, which were eventually verified with field sampling data. A PFOA screening level assessment model was then developed for the Washington Works site by combining the sampling results and the results from the various modeling tools (DuPont, 2003b).

The PFOA screening level assessment model describes the migration pathways for PFOA from the Washington Works site to the environment and identifies key PFOA monitoring points. For Washington Works, the following sources for PFOA, complete migration pathways and key monitoring points, were identified and are listed in the following table.

PFOA Source	Complete Migration Pathway	Key Monitoring Points
stack emissions	air emission to ground surfaces then to groundwater via precipitation air emission to surface water	groundwater (monitoring and production wells) and surface-water bodies (rivers, springs, cisterns, public water supplies)
process wastewater	aqueous discharge through outfalls	surface water (outfall and river)
historic SWMU releases of wastewater and sludge	aqueous discharge to groundwater	groundwater (monitoring wells and production wells)

Soil was not shown to be a key monitoring point for any of the PFOA sources and complete migration pathways identified at the Washington Works site.

Based on the Washington Works model, a generalized PFOA screening level assessment model was developed. This generalized model can be used for any industrial site that uses PFOA to describe the possible migration pathways from the site to the environment and to identify key PFOA monitoring points. Figure 1 shows the generalized PFOA site screening assessment conceptual model. This model shows that there are two main types of releases of PFOA from a site to the environment: air emissions and aqueous discharge.

An air emission migration pathway is possible at any site that has PFOA contained in air emissions. Air emissions can enter ambient air and remain there, or they can be scavenged from ambient air by precipitation and be deposited on the ground surface.

PFOA that is deposited on the ground surface may migrate to a surface-water body via runoff (overland flow). Alternatively, deposited material may enter the subsurface and migrate through the saturated soil zone to groundwater. In either case, the ultimate destination of deposited PFOA is either groundwater or surface water, not soil. This conclusion is based on adsorption/desorption data and was confirmed through field sampling that showed little or no PFOA concentrations in soil. Thus, the appropriate environmental media for monitoring PFOA that has been deposited near a manufacturing facility are surface water and groundwater.

The second type of PFOA release, shown in Figure 1, is direct aqueous discharge. A direct aqueous discharge migration pathway is possible for any site where PFOA discharges as an aqueous medium. Aqueous discharge as a migration pathway can be from various sources. Figure 1 shows two of these sources. One source on this figure is the discharge of wastewater containing PFOA via permitted outfalls into surface-water bodies. For sites having aqueous discharge through permitted outfalls as complete PFOA migration pathway, key monitoring points are the outfalls and possibly surface-water body or bodies into which the outfalls discharge.

The second source is aqueous discharge from landfills or other SWMUs to surface-water bodies through outfalls or to soil or through unsaturated soil to groundwater. Key monitoring points for sites with releases from on-site SWMU as a complete migration pathway include groundwater (both upgradient and downgradient of the SWMU) and/or surface-water bodies. If data for an industrial site being evaluated for PFOA showed that a SWMU release to soil had occurred and there is receptor exposure to PFOA-impacted soil, then limited soil sampling can also be very useful in delineating the aerial extent of the impact and in evaluating exposure point concentration.

2.2 Laboratory Studies of PFOA and Field Sample Verification

Analysis of laboratory data on the solubility and adsorption/desorption behavior of PFOA in soils and of the extensive soil PFOA data set for Washington Works has lead to the conclusion that in general, PFOA has a low affinity for soils. In the following subsections, summaries of the laboratory studies conducted by APME (2003) and 3M (1978) and results obtained are provided, as is the field soil data from Washington Works that validated these laboratory results.

Because of the low affinity that PFOA has for soils and the availability of other modeling tools and monitoring that can be used to evaluate PFOA migration pathways and concentrations in the environment, it can be concluded that soil sampling is not relevant to the development of PFOA site conceptual models for industrial sites that use PFOA. Limited soil sampling can be useful in evaluating releases from SWMUs only where receptor exposure to the soil is known or likely. In Section 2.2.4, a portion of the Washington Works PFOA soil data set is presented that shows an example of the importance of limited soil sampling, although, in the case of the Washington Works site, receptor exposure to impacted soils is not occurring.

2.2.1 The Behavior of PFOA in Water

PFOA is a fluoropolymer polymerization aid (PFA). PFAs are members of a class of commercially available perfluoroalkyl carboxylate surfactants used to suspend and emulsify some fluoropolymers during manufacture and industrial use. PFOA is the most commonly used PFA in the production of many fluoropolymers and fluoroelastomers (Fluoropolymer Manufacturers Group, 2003).

The solubility of PFAs varies greatly with counter ion, chain structure or length, and temperature (Fluoropolymer Manufacturers Group, 2001; 2003). The water solubility of PFAs changes with counter ion. For example, perfluorononanoate acid exhibited a room temperature solubility of less than 0.2%. At the same temperature, the sodium salt of perfluorononanoate acid showed about 2% solubility, while the solubility of ammonium perfluorononanoate, the ammonium salt of the perfluorononanoate acid, was reported to be about 18% (Fluoropolymer Manufacturers Group, 2001).

The water solubility of PFAs also decreases with an increasing chain length of the carbon molecule. At 25 °C, PFAs with chain structures C1 to C6 are miscible in water in all proportions while PFAs with chain structures C8 to C10 are only slightly soluble (Brace, 1962). The solubility of PFOA, which has a C8 chain structure, is reported to be about 50% at room temperature whereas the solubility of ammonium perfluorononanoate, which has a C9 chain structure, is reported to be about 18% at room temperature (Fluoroploymer Manufacturers Group, 2001).

Water solubility of PFAs also increases with increasing temperature (Shinoda et. al., 1972). For example, the solubility of ammonium perfluorononanoate, which is about 18% at room temperature, rose to between 40 to 50% at 50 °C (Fluoropolymer Manufacturers Group, 2001).

Specific value for the water solubility of PFOA is reported to be greater than 1,000 mg PFOA/liter by Kissa (1994) and is reported to be greater than 10% (mass/volume) at 23°C by 3M (2001).

In summary, PFOA is considered to have a high water solubility. Because of the high water solubility, PFOA in the environment tends to be mobilized easily. PFOA that is transported by way of air emissions and deposited on ground surfaces is likely remobilized rapidly following precipitation events and migrates with precipitation. Precipitation containing dissolved PFOA migrates to surface-water bodies as runoff or downward, ultimately reaching the water table (groundwater).

2.2.2 Adsorption/Desorption of Ammonium Perfluorooctanoate to Soil

A PFOA adsorption/desorption study was sponsored by the Association of Plastics Manufactures in Europe (APME) and was conducted by the Corporate Center for Engineering Research, Central Research and Development, E. I. du Pont de Nemours and Company (APME, 2003). The study was conducted in compliance with the United States Environmental Protection Agency (USEPA), Title 40 Code of Federal Regulations Part 160 (effective October 16, 1989), and TSCA Title 40 Code of Federal Regulations Part 792, which are consistent with the OECD Principles of Good Laboratory Practice (OECD, 1998). The OECD 106 Guidelines for the Testing of Chemicals; Adsorption-

Desportion Using a Batch Equilibrium Method (OECD, 2000) were followed in the study.

The purpose of this study was to test the adsorption behavior of PFOA in four soil samples (Drummer, Hidalgo, Cape Fear, and Keyport) and one activated sludge sample (Wilmington Sludge) and to calculate a sorption value that can be used to predict partitioning of PFOA in the environment. Four soils and one sludge were selected for this study to evaluate the adsorption/desorption behavior in a variety of soil types. The soil types included in this study were silt clay loam (Drummer), sandy clay loam (Hidalgo), sandy loam (Cape Fear and Wilmington Sludge) and loam (Keyport).

The study of PFOA in soil was evaluated in two phases. Phase 1 involved screening studies to determine the optimal testing conditions and included an evaluation of the chemical and physical properties of the four soils and the sludge used in the study. Phase 2 utilized a batch equilibrium soil slurry method to evaluate the linear and Freundlich adsorption isotherm parameters and to evaluate desorption of PFOA.

The results showed that there was a strong linear correlation between the fraction of organic carbon and the average distribution coefficient values determined for PFOA on the soils evaluated. There was also a strong inverse relationship between the fraction of organic carbon and the total percent desorption for three of the soils tested. Desorption results were variable for the fourth soil (Hidalgo) and the sludge. These results indicate the following:

- Most soil types with low to medium organic carbon content displayed very low adsorption capacity.
- A high organic content soil/sludge also displayed a low adsorption coefficient as a function of organic content (K_{oc}).
- Water effectively desorbs PFOA.

The results of the APME study (2003) agree with the conclusions of a 1978 PFOA adsorption-desorption study conducted by the 3M Company (3M, 1978). In the 3M study, the K_{oc} for PFOA in a sandy loam soil was determined. Based on the results obtained, 3M concluded "the study substance is expected to exhibit high mobility in the kind of soil tested."

Figure 2 presents the K_{oc}'s for PFOA on the four soils and sludge sample as determined in the APME (2003) study, the K_{oc}'s for PFOA on the soil as determined by the 3M (1978) study, and the K_{oc}'s for methylene chloride (high solubility) and naphthalene (low solubility). This comparison shows that the adsorption coefficient of PFOA onto the soils and sludge is around that of methylene chloride, but significantly lower than the adsorption of coefficient of naphthalene.

From the results of this adsorption/desorption study, DuPont concluded that PFOA has a low affinity for adsorption onto soils.

2.2.3 Little Hocking Water Association Investigation Results

The Little Hocking Water Association well field is located close to the DuPont Washington Works facility across the Ohio River in Ohio. Groundwater sampled in 2002 from a test well in the Little Hocking well field, TW-4, showed a PFOA concentration range of 12.3 to 37.1 ug/L. In August 2002, DuPont conducted a field investigation of the Little Hocking Water Association well field in order to delineate PFOA concentrations in soil and groundwater near TW-4. DuPont had previously submitted summary reports to the Ohio Environmental Protection Agency documenting off-site investigation activities near the Washington Works facility (DuPont, 2002a; 2002b; 2002c; and 2002d). These reports assessed media-specific PFOA transport from the facility and concluded that migration of air emissions is the only probable transport mechanism for PFOA found in groundwater at the Little Hocking Water Association well field. Because the predominant wind direction at the Washington Works site is towards the north, air emissions containing PFOA have most likely been migrating over the Little Hocking well field for many years.

The field investigation of the Little Hocking Water Association well field focused on delineating depth-specific PFOA concentrations in soil and groundwater near TW-4 (DuPont, 2003c). In total, 22 soil samples, including one duplicate, were sampled from two temporary borings near TW-4. Figure 3 presents graphically the concentrations of PFOA measured in the two temporary borings. All soil results are below the C-8 Assessment of Toxicity Team (CATT)-established human health protective screening criteria for PFOA in soil of 240 mg/kg or 240,000 ug/kg (WVDEP, 2002). This figure shows that in both borings, the highest concentrations (110 ug/kg and 170 ug/kg) measured were in the surface samples and that PFOA concentrations decrease with depth. Samples from both borings also show low concentrations of PFOA below the water table, less than 18.0 ug/kg in NW-1 and all Non Quantifiables (NQs) in SW-1.

The observation of very low concentrations of PFOA in soils that have had many years of PFOA containing air emissions deposited on them supports the following migration pathway: PFOA from the DuPont facility is transported via air emissions by wind and is deposited on the Little Hocking well field surface soils. Any precipitation that lands on the surface soil and percolates downward through the soil dissolves the PFOA because of the high solubility of PFOA. The dissolved PFOA then migrates in the precipitation downward through the unsaturated zone towards the top of the water table. (Dissolved PFOA in precipitation may also migrate to surface-water bodies through overland flow. However, no surface-water bodies exist in the Little Hocking well field.) Overall, the very low concentrations of PFOA measured in the soils support the high solubility reported for PFOA and support that PFOA does not readily adsorb to soil. The observation of higher PFOA concentrations in the surface soils than at greater depth is likely the result of an extended period of low precipitation. Sampling at Little Hocking was conducted following a six-week period of below normal precipitation.

In summary, the Little Hocking soil results support that the ultimate destination of PFOA deposited on ground surfaces is either groundwater (or surface water), not soil. Therefore, groundwater and surface-water PFOA data provide a more realistic assessment of the fate of PFOA in the environment than do soil PFOA data.

2.2.4 Washington Works RFI Soil Sampling Results

During the RFI (DuPont, 1999), over 230 soil samples were collected (including duplicates) and analyzed for PFOA. Surface samples (0 to 2 feet in depth) and deep samples [up to 70 feet below ground surface (BGS)] were collected. At the Washington Works site, there are two sources from which PFOA is being or has been released into soil: (1) historic and current air emissions and (2) historic releases from SWMUs containing PFOA-bearing wastewater and sludge. For this evaluation, the soil PFOA data are divided into two categories based on PFOA source. These data were intentionally categorized to differentiate between SWMU impacts to soils and air-emission impacts to soil. Soil PFOA data related to air emissions is presented first and soil PFOA data related to SWMU releases follows.

Soil Sampling for the Evaluation of Air Emission Migration Pathways

Figure 4 presents the RFI soil data, excluding soil samples collected from within the former anaerobic digestion ponds SWMU area. Figure 4 is a bar graph showing the number of samples versus PFOA concentration. Note that the PFOA concentration axis is not linear. Also provided on each bar is the percent of the samples falling into each concentration range. For example, 70.5% had PFOA concentrations of less than 20 ug/kg, whereas only 5.1% had concentration above 100 ug/kg. Also provided in Figure 2 are the total number of samples, the minimum concentration, and the maximum concentration. Table 1 provides the data used in Figure 4.

Figure 4 and Table 1 show that none of the 211 samples collected and analyzed have PFOA concentrations greater than the CATT-established human health protective screening criteria for PFOA in soil of 240 mg/kg or 240,000 ug/kg (WVDEP, 2002). Of these 211 samples, only 11 samples, or 5.3%, have PFOA concentrations greater than 100 ug/kg. Given that the air emissions containing PFOA have been emitted from Washington Works for many years, one might expect to measure much higher concentrations of PFOA. However, these data support the air emission migration pathway presented with the Little Hocking soil data in the previous section. In this migration pathway, any precipitation that lands on the surface soil and percolates downward through the soil dissolves the PFOA deposited by air emissions because of the high solubility of PFOA. The dissolved PFOA then migrates in the precipitation downward through the unsaturated zone towards the top of the water table. In addition, these results support the results of the APME (2003) and 3M (1978) adsorption/desorption studies and DuPont's conclusion that PFOA has a low affinity for adsorption onto soils.

If PFOA were to have a high affinity to soil, then the concentrations of PFOA observed in surface soil should be higher than was actually observed because of the many years of air emission deposition. Of the 211 soil samples shown in Figure 4, 50 are surface soils collected from 0 to 2 feet BGS. Figure 5 and Table 2 provides a closer look at the PFOA concentrations measured in the 50 surface soil samples analyzed.

Only two of the 50 samples had PFOA concentrations greater than 90 ug/kg. U04-SB01 had 140 ug/kg, and V04-SB01 had 600 ug/kg. A concentration of 140 ug/kg could be the result of air emission deposition and is in line with results from the Little Hocking Water Association. The 600 ug/kg concentration appears to be significantly higher than the

concentration range observed for air emission deposition and could be an anomalous result. However, in general, these surface soil PFOA data again support the air emission migration pathway presented in the discussion of the Little Hocking soil data. These results also support the APME (2003) and 3M (1978) adsorption/desorption studies and DuPont's conclusion that PFOA has a low affinity for adsorption onto soils.

In summary, the low PFOA concentrations measured at Washington Works, in both surface and subsurface soils support that the ultimate destination of PFOA deposited on ground surfaces is either groundwater (or surface water), not soil. Therefore, groundwater and surface-water PFOA data provide a more realistic assessment of the fate of PFOA in the environment than do soil PFOA data.

Soil Sampling for the Evaluation of SWMU Release Migration Pathways

The former anaerobic digestion ponds were a series of three ponds located on the riverbank at the Washington Works site. Wastewater and sludges containing PFOA were managed in these ponds. These ponds were constructed with natural clay and bentonite clay bottoms that were designed to impede water infiltration. However, when the ponds were active, PFOA-containing water likely infiltrated downward into the underlying clay soils.

Figure 6 presents the PFOA results for ADP SWMU-impacted soil samples (DuPont, 1999). Table 3 provides the PFOA data used in Figure 6. Figure 6 indicates that unlike Figures 4 and 5, the SWMU-impacted soils have a much higher range of PFOA concentrations, likely reflecting the higher concentrations of PFOA contained within the wastewater and sludge.

For the Washington Works site, PFOA concentrations measured in these soils do not exceed the CATT-established human health protective screening criteria for PFOA in soil of 240 mg/kg or 240,000 ug/kg (WVDEP, 2002) and there are no current receptors to the soil near the former ADP SWMU. However, if a site being evaluated for PFOA showed that a SWMU release had occurred based on historical data and groundwater results and that there was receptor exposure to impacted soil, then limited soil sampling may be very useful in delineating aerial extent of impact and in evaluating exposure point concentration. Using the PFOA concentrations in soil, surveyed location information and carefully documented sample depth data, vertical and horizontal area of impacted-soils could be delineated if required. In addition, maximum exposure point concentrations could be determined, and average exposure point concentration could then be calculated using surface soil results alone or could be calculated for specific depths if needed.

3.0 SUMMARY

DuPont's extensive implementation of both media specific assessment modeling tools and comprehensive on-site and off-site soil, surface-water, and groundwater monitoring for PFOA at the Washington Works site allowed for compilation of a generalized screening level assessment model (see Figure 1). This model identifies the potential migration pathways for PFOA from any PFOA-use site to the environment and identifies potential key PFOA monitoring points. Identification of complete migration pathways and key monitoring points is necessary for conducting screening level assessments at industrial sites using PFOA.

The extensive investigation at Washington Works provided enough data to thoroughly evaluate the value of modeling tools, media-specific sampling, and monitoring when conducting a PFOA screening level assessment. The data demonstrated that surface-water and groundwater monitoring provide a more realistic assessment of the fate of PFOA in the environment than does soil monitoring. The conclusion was reached that soil sampling is not relevant in conducting PFOA screening level assessments. This conclusion was based on the following data:

- Physical and chemical properties of PFOA result in a high water solubility.
- Soil adsorption/desorption studies conducted by 3M (1978) and APME (2003), according to established protocols, concluded that PFOA has a high water mobility and low soil adsorption capacity, respectively, for multiple soil types.
- Actual soil sampling and analysis data from several investigation locations at and near Washington Works demonstrate that PFOA in air emission deposited on ground surfaces will quickly be dissolved by precipitation and be transported via precipitation to surface water or to groundwater.
- Extensive soil sampling was not shown to be relevant in conducting the site-wide PFOA screening level assessment at the Washington Works site because groundwater and surface-water PFOA data provide a more realistic assessment of the fate of PFOA in the environment and because there is no receptor exposure to PFOA-impacted soils. However, if a site being evaluated for PFOA showed that SWMU release had occurred based on historical data and groundwater results and that there was receptor exposure to impacted soil, then limited soil sampling may be very useful in delineating aerial extent of impact and in evaluating exposure point concentration.

Other tools, including modeling tools and groundwater and surface-water monitoring, can more effectively and efficiently be used to evaluate PFOA migration pathways, and to predict/measure concentrations in the environment and evaluate overall exposure. The PFOA screening level assessment model, presented here, focuses on identifying the migration pathways for PFOA from any PFOA-use site to the environment and identifying key PFOA monitoring points.

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Table 1
Washington Works RFI Soil PFOA Results

Sample Name	Sample Date	Top of Sample (ft BGS)	Bottom of Sample (ft BGS)	PFOA Concentration	UNITS
AA04-SB01	8/20/1998	0	2	6	ug/kg
AA04-SB01	8/20/1998	6	8	32	ug/kg
AA04-SB01	8/20/1998	14	16	12	ug/kg
AA04-SB01	8/20/1998	30	32	6	ug/kg
AA05-SB01	9/23/1998	0	2	13.5	ug/kg
AA05-SB01	9/23/1998	4	6	20	ug/kg
AA05-SB01	9/23/1998	8	10	39	ug/kg
AA05-SB01	9/23/1998	16	18	10.5	ug/kg
AA05-SB01	9/23/1998	20	22	20	ug/kg
AA05-SB01	9/23/1998	40	42	11	ug/kg
AA05-SB01	9/23/1998	60	62	12	ug/kg
AA06-SB01	9/2/1998	0	2	12	ug/kg
AA06-SB01	9/2/1998	6	8	140	ug/kg
AA06-SB01	9/2/1998	14	16	51	ug/kg
AA06-SB01	9/2/1998	20	22	5.5	ug/kg
AA06-SB01	9/2/1998	40	42	5.5	ug/kg
AA06-SB01	9/2/1998	64	66	5.5	ug/kg
AA07-SB01	9/16/1998	0	2	12.5	ug/kg
AA07-SB02	9/27/1998	0	2	82	ug/kg
AA07-SB02	9/27/1998	4	6	91	ug/kg
AA08-SB01	9/27/1998	0	2	32	ug/kg
AA08-SB01	9/27/1998	4	6	6	ug/kg
AA08-SB02	9/27/1998	0	2	6	ug/kg
AB06-SB01	9/1/1998	4	6	12	ug/kg
AB06-SB01	9/1/1998	10	12	11	ug/kg
AB06-SB01	9/1/1998	18	20	10.5	ug/kg
AB06-SB01	9/1/1998	40	42	6	ug/kg
AB06-SB01	9/1/1998	58	60	34	ug/kg
AB06-SB02	9/8/1998	2	4	6	ug/kg
AB06-SB02	9/8/1998	10	12	17	ug/kg
AB06-SB02	9/8/1998	18	20	5.5	ug/kg
AB06-SB02	9/8/1998	40	42	5	ug/kg
AB06-SB02	9/8/1998	62	64	6	ug/kg
AB07-SB02	9/4/1998	0	2	6	ug/kg
AB07-SB02	9/4/1998	4	6	6	ug/kg
AB07-SB02	9/4/1998	10	12	36	ug/kg
AB07-SB02	9/4/1998	14	16	59	ug/kg
AB07-SB02	9/4/1998	20	22	5.5	ug/kg
AB07-SB02	9/4/1998	40	42	10.5	ug/kg
AB08-SB02	9/27/1998	0	2	18.5	ug/kg
AB08-SB02	9/27/1998	4	6	6	ug/kg
AC04-SB01	8/21/1998	0	2	11	ug/kg
AC04-SB01	8/21/1998	10	12	18	ug/kg
AC04-SB01	8/21/1998	20	22	6.5	ug/kg
AC04-SB01	8/21/1998	28	30	6	ug/kg
AC06-SB03	8/31/1998	0	2	5	ug/kg
AC06-SB03	8/31/1998	6	8	55	ug/kg
AC06-SB03	8/31/1998	12	14	12	ug/kg
AC06-SB03	8/31/1998	34	36	5.5	ug/kg

Table 1
Washington Works RFI Soil PFOA Results

Sample Name	Sample Date	Top of Sample (ft. BGS)	Bottom of Sample (ft. BGS)	PFOA Concentration	UNITS
AC06-SB03	8/31/1998	48	50	16	ug/kg
AC06-SB03	8/31/1998	62	64	5.5	ug/kg
AC06-SB04	9/1/1998	0	2	15	ug/kg
AC06-SB04	9/1/1998	6	8	63	ug/kg
AC06-SB04	9/1/1998	14	16	11	ug/kg
AC06-SB04	9/1/1998	34	36	10.5	ug/kg
AC06-SB04	9/1/1998	54	56	5	ug/kg
AC06-SB04	9/1/1998	62	64	6	ug/kg
AC06-SB05	9/9/1998	0	2	5.5	ug/kg
AC06-SB05	9/9/1998	6	8	6	ug/kg
AC06-SB05	9/9/1998	12	14	5.5	ug/kg
AC06-SB05	9/9/1998	18	20	5.5	ug/kg
AC06-SB05	9/9/1998	40	42	5	ug/kg
AC06-SB05	9/9/1998	62	64	6	ug/kg
AC07-SB02	9/9/1998	0	2	39	ug/kg
AC07-SB02	9/9/1998	18	20	6	ug/kg
AC07-SB02	9/10/1998	62	64	5	ug/kg
AC07-SB03	9/14/1998	0	2	64	ug/kg
AC07-SB03	9/14/1998	4	6	6	ug/kg
AC07-SB03	9/14/1998	8	10	11.5	ug/kg
AC07-SB03	9/14/1998	14	16	18	ug/kg
AC07-SB03	9/14/1998	20	22	5.5	ug/kg
AC07-SB03	9/15/1998	40	42	5	ug/kg
AC07-SB03	9/15/1998	64	66	6.5	ug/kg
AC07-SB04	9/14/1998	0	2	29	ug/kg
AC07-SB04	9/14/1998	4	6	6.5	ug/kg
AC07-SB04	9/14/1998	10	12	13	ug/kg
AC07-SB04	9/14/1998	14	16	6	ug/kg
AC07-SB04	9/14/1998	20	22	6	ug/kg
AC07-SB04	9/14/1998	40	42	5	ug/kg
AC07-SB04	9/14/1998	60	62	5.5	ug/kg
AC08-SB01	9/27/1998	0	2	10.5	ug/kg
AC08-SB01	9/27/1998	4	6	17.5	ug/kg
AC08-SB01	9/27/1998	8	10	12.5	ug/kg
AC08-SB01	9/27/1998	14	16	5.5	ug/kg
AC08-SB01	9/27/1998	20	22	11.5	ug/kg
AC08-SB01	9/27/1998	40	42	5	ug/kg
AC08-SB01	9/27/1998	58	60	12.5	ug/kg
AC08-SB02	8/24/1998	0	2	53	ug/kg
AC08-SB02	8/24/1998	10	12	6	ug/kg
AC08-SB02	8/24/1998	20	22	5	ug/kg
AC08-SB02	8/24/1998	30	32	5	ug/kg
AC08-SB02	8/24/1998	40	42	5.5	ug/kg
AC08-SB02	8/24/1998	50	52	5.5	ug/kg
AC08-SB02	8/24/1998	56	58	5.5	ug/kg
AE05-SB02	8/22/1998	0	2	22	ug/kg
AE05-SB02	8/22/1998	10	12	6.5	ug/kg
AE05-SB02	8/22/1998	22	24	5.5	ug/kg
AE05-SB02	8/22/1998	34	36	5	ug/kg

Table 1
Washington Works RFI Soil PFOA Results

Sample Name	Sample Date	Top of Sample (ft BGS)	Bottom of Sample (ft BGS)	PFOA Concentration	UNITS
AE05-SB02	8/22/1998	48	50	5	ug/kg
AE05-SB02	8/22/1998	58	60	6	ug/kg
AE11-SB01	10/6/1998	0	2	24	ug/kg
AF05-SB01	8/22/1998	0	2	11	ug/kg
AF05-SB01	8/22/1998	10	12	6.5	ug/kg
AF05-SB01	8/22/1998	20	22	6	ug/kg
AF05-SB01	8/22/1998	30	32	12	ug/kg
AH05-SB01	10/14/1998	0	2	40	ug/kg
AH05-SB01	10/14/1998	4	6	34	ug/kg
AI06-SB01	8/23/1998	0	2	14	ug/kg
AI06-SB01	8/23/1998	18	20	5.5	ug/kg
AI06-SB01	8/23/1998	36	38	5.5	ug/kg
AI06-SB01	8/23/1998	48	50	5	ug/kg
AI06-SB01	8/23/1998	60	62	5.5	ug/kg
AI10-SB01	10/14/1998	0	2	6.5	ug/kg
AP10-SB01	10/14/1998	0	2	12	ug/kg
E13-SB01	10/7/1998	0	2	37	ug/kg
G17-SB01	10/8/1998	0	2	6	ug/kg
G17-SB01	10/8/1998	64	66	16	ug/kg
K04-SB01	10/12/1998	0	2	35	ug/kg
K04-SB01	10/12/1998	12	14	33	ug/kg
L04-SB01	10/12/1998	0	2	17.5	ug/kg
L04-SB01	10/12/1998	8	10	12	ug/kg
L06-SB01	9/25/1998	0	2	11	ug/kg
L06-SB01	9/25/1998	10	12	280	ug/kg
L06-SB01	9/25/1998	22	24	150	ug/kg
L06-SB01	9/25/1998	66	68	39	ug/kg
M04-SB02	10/10/1998	0	2	55	ug/kg
M04-SB02	10/10/1998	8	10	12.5	ug/kg
M04-SB02	10/10/1998	14	16	26	ug/kg
M04-SB03	10/10/1998	0	2	12	ug/kg
M04-SB03	10/10/1998	6	8	6	ug/kg
M04-SB03	10/10/1998	14	16	12	ug/kg
M04-SB04	10/12/1998	0	2	81	ug/kg
M04-SB04	10/12/1998	10	12	34	ug/kg
M04-SB05	10/12/1998	2	4	86	ug/kg
M04-SB05	10/12/1998	6	8	45	ug/kg
M04-SB05	10/12/1998	12	14	43	ug/kg
M06-SB02	9/28/1998	2	4	44	ug/kg
M06-SB02	9/28/1998	8	10	32	ug/kg
M06-SB02	9/29/1998	20	22	5.5	ug/kg
M06-SB02	9/29/1998	40	42	11	ug/kg
M06-SB02	9/29/1998	66	68	36	ug/kg
N04-SB01	10/12/1998	0	2	12.5	ug/kg
N04-SB01	10/12/1998	12	14	12.5	ug/kg
N04-SB02	10/9/1998	0	2	79	ug/kg
N04-SB02	10/9/1998	8	10	6	ug/kg
N04-SB02	10/9/1998	14	16	220	ug/kg
N05-SBO1	9/28/1998	2	4	5.5	ug/kg

Table 1
Washington Works RFI Soil PFOA Results

Sample Name	Sample Date	Top of Sample (ft BGS)	Bottom of Sample (ft BGS)	PFOA Concentration	UNITS
N05-SBO1	9/28/1998	8	10	110	ug/kg
N05-SBO1	9/28/1998	20	22	1800	ug/kg
N05-SBO1	9/28/1998	40	42	1200	ug/kg
N05-SBO1	9/28/1998	70	72	580	ug/kg
N20-SB01	10/14/1998	0	2	11	ug/kg
O04-SB02	10/11/1998	0	2	34	ug/kg
O04-SB02	10/11/1998	6	8	10	ug/kg
O04-SB02	10/11/1998	14	16	28	ug/kg
O04-SB03	10/12/1998	0	2	32	ug/kg
O04-SB03	10/12/1998	10	12	6	ug/kg
O04-SB03	10/12/1998	14	16	24	ug/kg
P14-SB01	10/14/1998	0	2	52	ug/kg
T04-SB01	10/10/1998	0	2	60	ug/kg
T04-SB01	10/10/1998	10	12	6	ug/kg
T04-SB01	10/10/1998	16	18	54	ug/kg
T14-SB01	10/5/1998	0	2	11.5	ug/kg
U04-SB01	9/30/1998	0	2	140	ug/kg
U04-SB01	9/30/1998	4	6	95	ug/kg
U04-SB01	9/30/1998	16	18	6.5	ug/kg
V04-SB01	9/29/1998	0	2	600	ug/kg
V04-SB01	9/29/1998	4	6	7	ug/kg
V04-SB01	9/29/1998	4	6	170	ug/kg
V04-SB01	9/29/1998	18	20	13.5	ug/kg
Y04-SB01	8/20/1998	0	2	22	ug/kg
Y04-SB01	8/20/1998	10	12	12	ug/kg
Y04-SB01	8/20/1998	18	20	6.5	ug/kg
Y04-SB01	8/20/1998	30	32	12	ug/kg
Y07-SB01	9/22/1998	0	2	5.5	ug/kg
Y07-SB01	9/22/1998	4	6	5.5	ug/kg
Y07-SB01	9/22/1998	8	10	6.5	ug/kg
Y07-SB01	9/22/1998	14	16	78	ug/kg
Y07-SB01	9/22/1998	22	24	11	ug/kg
Y07-SB01	9/22/1998	40	42	5.5	ug/kg
Y07-SB01	9/22/1998	62	64	6	ug/kg
Y14-SB01	10/5/1998	0	2	29	ug/kg
Z06-SB02	9/22/1998	2	4	6	ug/kg
Z06-SB02	9/22/1998	8	10	23	ug/kg
Z06-SB02	9/22/1998	14	16	5	ug/kg
Z06-SB02	9/22/1998	20	22	6	ug/kg
Z06-SB02	9/22/1998	40	42	5.5	ug/kg
Z06-SB02	9/22/1998	62	64	5.5	ug/kg
Z06-SB03	9/15/1998	0	2	13	ug/kg
Z06-SB03	9/15/1998	4	6	10.5	ug/kg
Z06-SB03	9/15/1998	10	12	11	ug/kg
Z06-SB03	9/15/1998	14	16	10.5	ug/kg
Z06-SB03	9/15/1998	20	22	10.5	ug/kg
Z06-SB03	9/15/1998	40	42	5	ug/kg
Z06-SB03	9/15/1998	60	62	12	ug/kg
Z06-SB04	9/11/1998	0	2	13	ug/kg

Table 1
Washington Works RFI Soil PFOA Results

Sample Name	Sample Date	Top of Sample (ft. BGS)	Bottom of Sample (ft. BGS)	PFOA Concentration	UNITS
Z06-SB04	9/11/1998	10	12	59	ug/kg
Z06-SB04	9/11/1998	20	22	5.5	ug/kg
Z06-SB04	9/11/1998	40	42	5	ug/kg
Z06-SB04	9/11/1998	64	66	11	ug/kg
Z07-SB01	9/10/1998	0	2	11	ug/kg
Z07-SB01	9/10/1998	10	12	12	ug/kg
Z07-SB01	9/10/1998	20	22	5	ug/kg
Z07-SB01	9/11/1998	62	64	5.5	ug/kg
Z09-SB01	9/3/1998	2	4	34	ug/kg
Z09-SB01	9/3/1998	8	10	6	ug/kg
Z09-SB01	9/3/1998	14	16	6	ug/kg
Z09-SB01	9/3/1998	20	22	5.5	ug/kg
Z09-SB01	9/3/1998	40	42	6.5	ug/kg
Z09-SB01	9/3/1998	60	62	12	ug/kg
Z11-SB01	10/5/1998	0	2	54	ug/kg

Table 2
Washington Works RFI Surface Soil PFOA Results

Sample Name	Sample Date	Top of Sample (ft. BGS)	Bottom of Sample (ft. BGS)	PFOA Concentration	UNITS
AA04-SB01	8/20/1998	0	2	6	ug/kg
AA05-SB01	9/23/1998	0	2	13.5	ug/kg
AA06-SB01	9/2/1998	0	2	12	ug/kg
AA07-SB01	9/16/1998	0	2	12.5	ug/kg
AA07-SB02	9/27/1998	0	2	82	ug/kg
AA08-SB01	9/27/1998	0	2	32	ug/kg
AA08-SB02	9/27/1998	0	2	6	ug/kg
AB07-SB02	9/4/1998	0	2	6	ug/kg
AB08-SB02	9/27/1998	0	2	18.5	ug/kg
AC04-SB01	8/21/1998	0	2	11	ug/kg
AC06-SB03	8/31/1998	0	2	5	ug/kg
AC06-SB04	9/1/1998	0	2	15	ug/kg
AC06-SB05	9/9/1998	0	2	5.5	ug/kg
AC07-SB02	9/9/1998	0	2	39	ug/kg
AC07-SB03	9/14/1998	0	2	64	ug/kg
AC07-SB04	9/14/1998	0	2	29	ug/kg
AC08-SB01	9/27/1998	0	2	10.5	ug/kg
AC08-SB02	8/24/1998	0	2	53	ug/kg
AE05-SB02	8/22/1998	0	2	22	ug/kg
AE11-SB01	10/6/1998	0	2	24	ug/kg
AF05-SB01	8/22/1998	0	2	11	ug/kg
AH05-SB01	10/14/1998	0	2	40	ug/kg
AI06-SB01	8/23/1998	0	2	14	ug/kg
AI10-SB01	10/14/1998	0	2	6.5	ug/kg
AP10-SB01	10/14/1998	0	2	12	ug/kg
E13-SB01	10/7/1998	0	2	37	ug/kg
G17-SB01	10/8/1998	0	2	6	ug/kg
K04-SB01	10/12/1998	0	2	35	ug/kg
L04-SB01	10/12/1998	0	2	17.5	ug/kg
L06-SB01	9/25/1998	0	2	11	ug/kg
M04-SB02	10/10/1998	0	2	55	ug/kg
M04-SB03	10/10/1998	0	2	12	ug/kg
M04-SB04	10/12/1998	0	2	81	ug/kg
N04-SB01	10/12/1998	0	2	12.5	ug/kg
N04-SB02	10/9/1998	0	2	79	ug/kg
N20-SB01	10/14/1998	0	2	11	ug/kg
O04-SB02	10/11/1998	0	2	34	ug/kg
O04-SB03	10/12/1998	0	2	32	ug/kg
P14-SB01	10/14/1998	0	2	52	ug/kg
T04-SB01	10/10/1998	0	2	60	ug/kg
T14-SB01	10/5/1998	0	2	11.5	ug/kg
U04-SB01	9/30/1998	0	2	140	ug/kg
V04-SB01	9/29/1998	0	2	600	ug/kg
Y04-SB01	8/20/1998	0	2	22	ug/kg
Y07-SB01	9/22/1998	0	2	5.5	ug/kg
Y14-SB01	10/5/1998	0	2	29	ug/kg
Z06-SB03	9/15/1998	0	2	13	ug/kg
Z06-SB04	9/11/1998	0	2	13	ug/kg
Z07-SB01	9/10/1998	0	2	11	ug/kg
Z11-SB01	10/5/1998	0	2	54	ug/kg

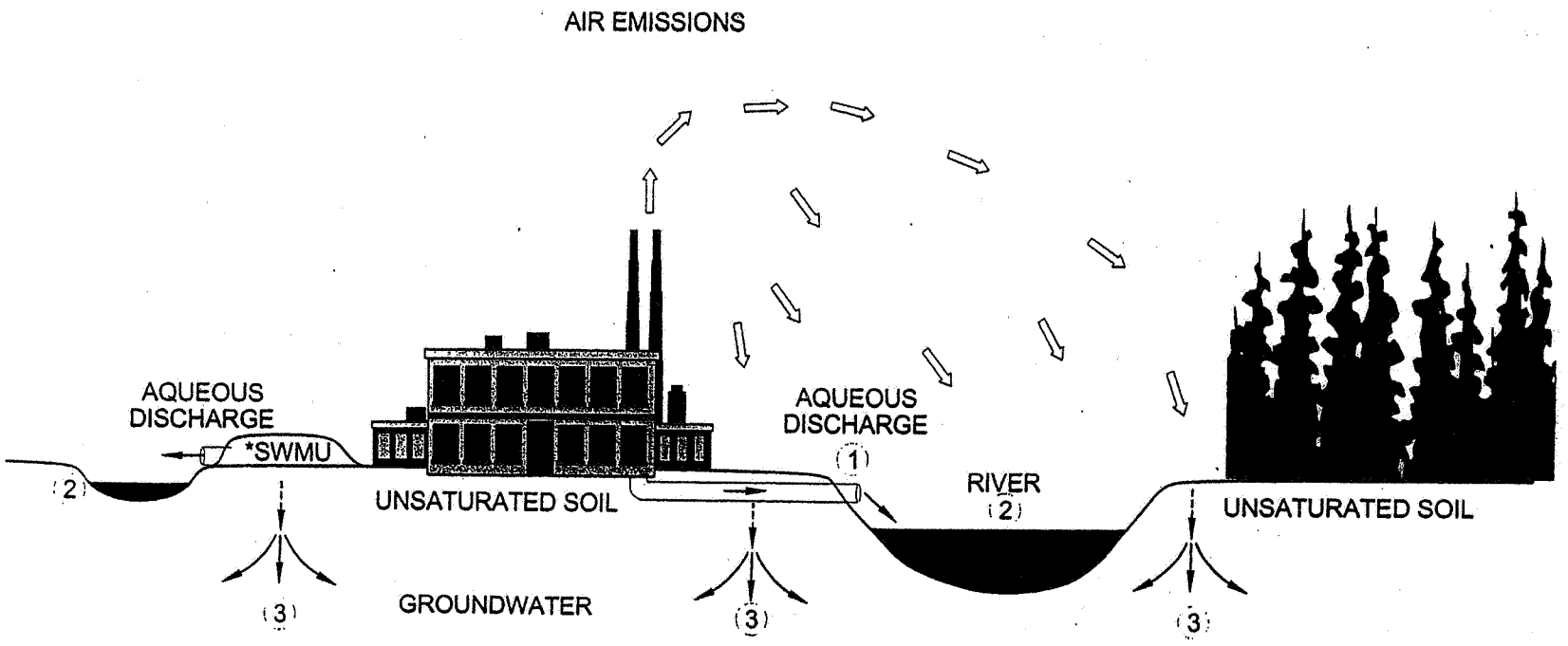
Table 3
Washington Works RFI ADP SWMU Soil PFOA Results

Sample Name	Sample Date	Top of Sample (ft. BGS)	Bottom of Sample (ft. BGS)	PFOA Concentration	UNITS
P04-SB02	10/9/1998	0	2	50	ug/kg
P04-SB02	10/9/1998	14	16	10000	ug/kg
P04-SB02	10/9/1998	8	10	11000	ug/kg
P05-SB02	9/24/1998	22	24	10.5	ug/kg
P05-SB02	9/24/1998	42	44	10.5	ug/kg
P05-SB02	9/24/1998	2	4	20	ug/kg
P05-SB02	9/24/1998	68	70	1000	ug/kg
Q04-SB03	10/11/1998	0	2	170	ug/kg
Q04-SB03	10/11/1998	8	10	48000	ug/kg
R04-SB02	10/9/1998	10	12	7900	ug/kg
R04-SB02	10/9/1998	0	2	9500	ug/kg
R04-SB02	10/9/1998	18	20	11000	ug/kg
S04-SB02	10/11/1998	0	2	1100	ug/kg
S04-SB02	10/11/1998	18	20	11000	ug/kg
S04-SB02	10/11/1998	8	10	44000	ug/kg
S05-SB02	9/26/1998	40	42	5	ug/kg
S05-SB02	9/26/1998	2	4	28	ug/kg
S05-SB02	9/26/1998	10	12	140	ug/kg
S05-SB02	9/26/1998	66	68	2400	ug/kg

FIGURES

FIGURES

Figure 1
PFOA Screening Level Assessment Model



EXP001479

*SWMU = SOLID WASTE MANAGEMENT UNIT

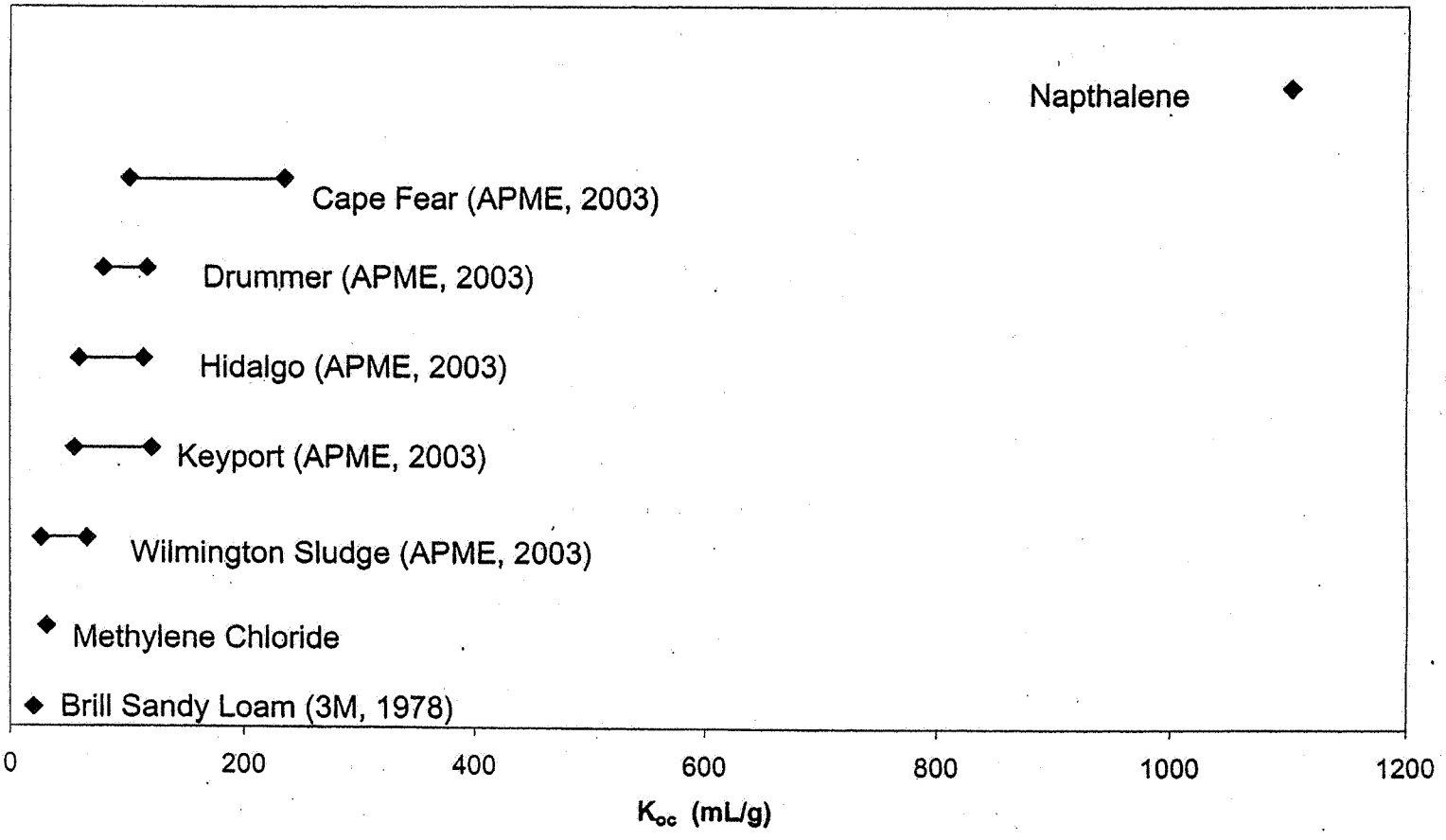
POTENTIAL SCREENING LEVEL ASSESSMENT MONITORING POINTS

(1) FACILITY AQUEOUS DISCHARGE (OUTFALLS)

(2) SURFACE WATER (RIVERS, PONDS, STREAMS ETC.)

(3) GROUNDWATER (MONITORING WELLS, PRODUCTION WELLS ETC.)

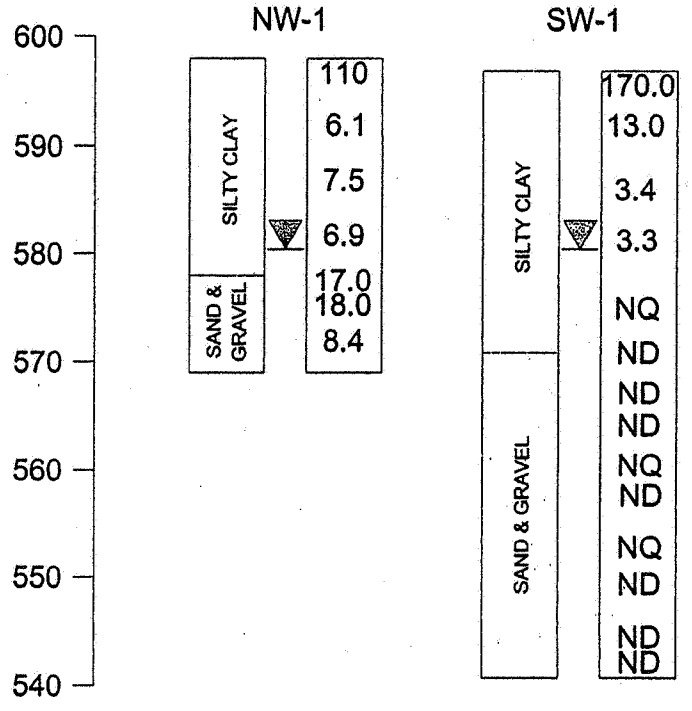
Figure 2
Comparison of K_{oc}'s for PFOA and Other Chemicals



EXP001480

Figure 3
Little Hocking Water Association Well Field Soil PFOA Results

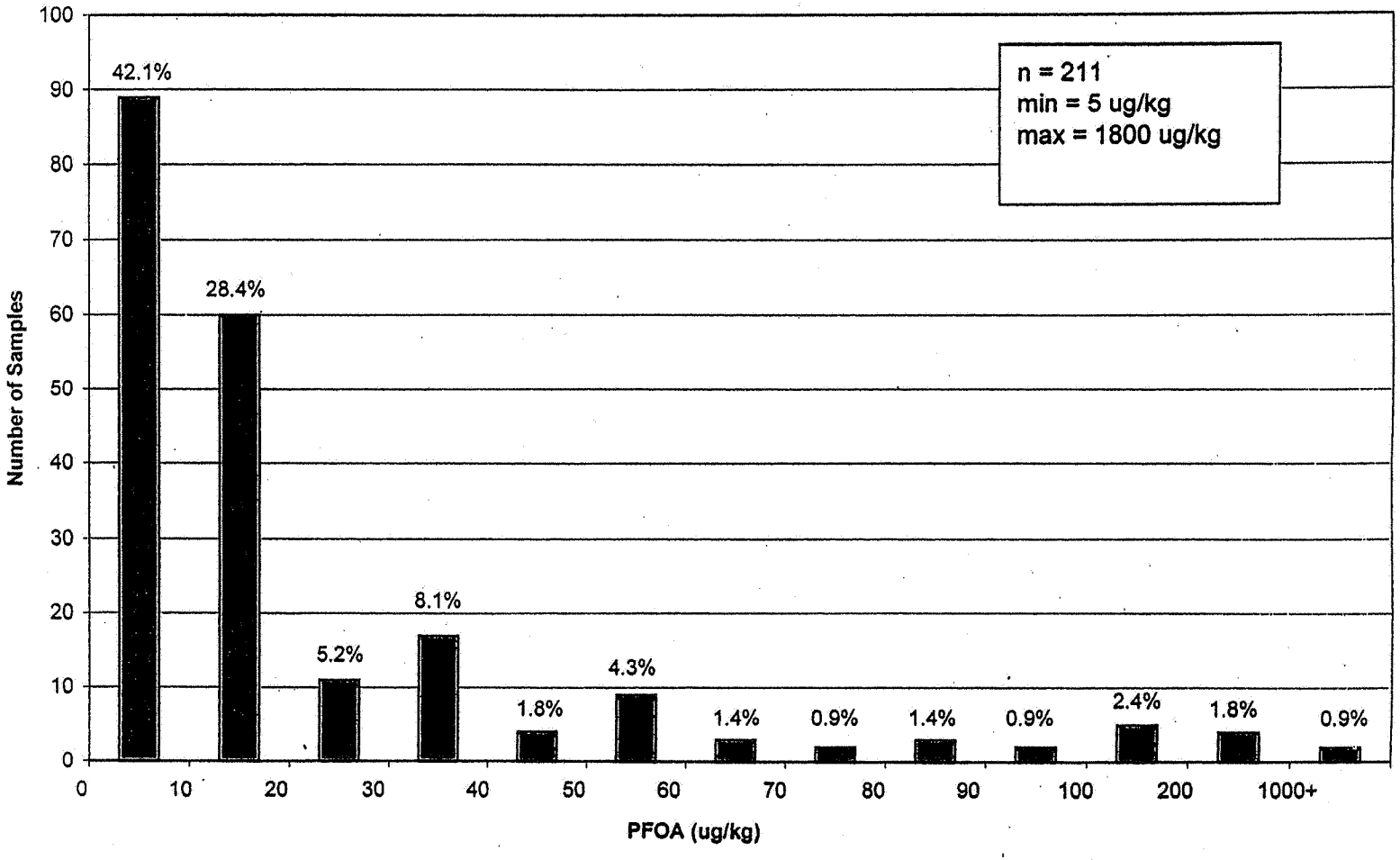
CATT = 240,000 ug/kg



Note: Collected after 6 weeks of below normal precipitation

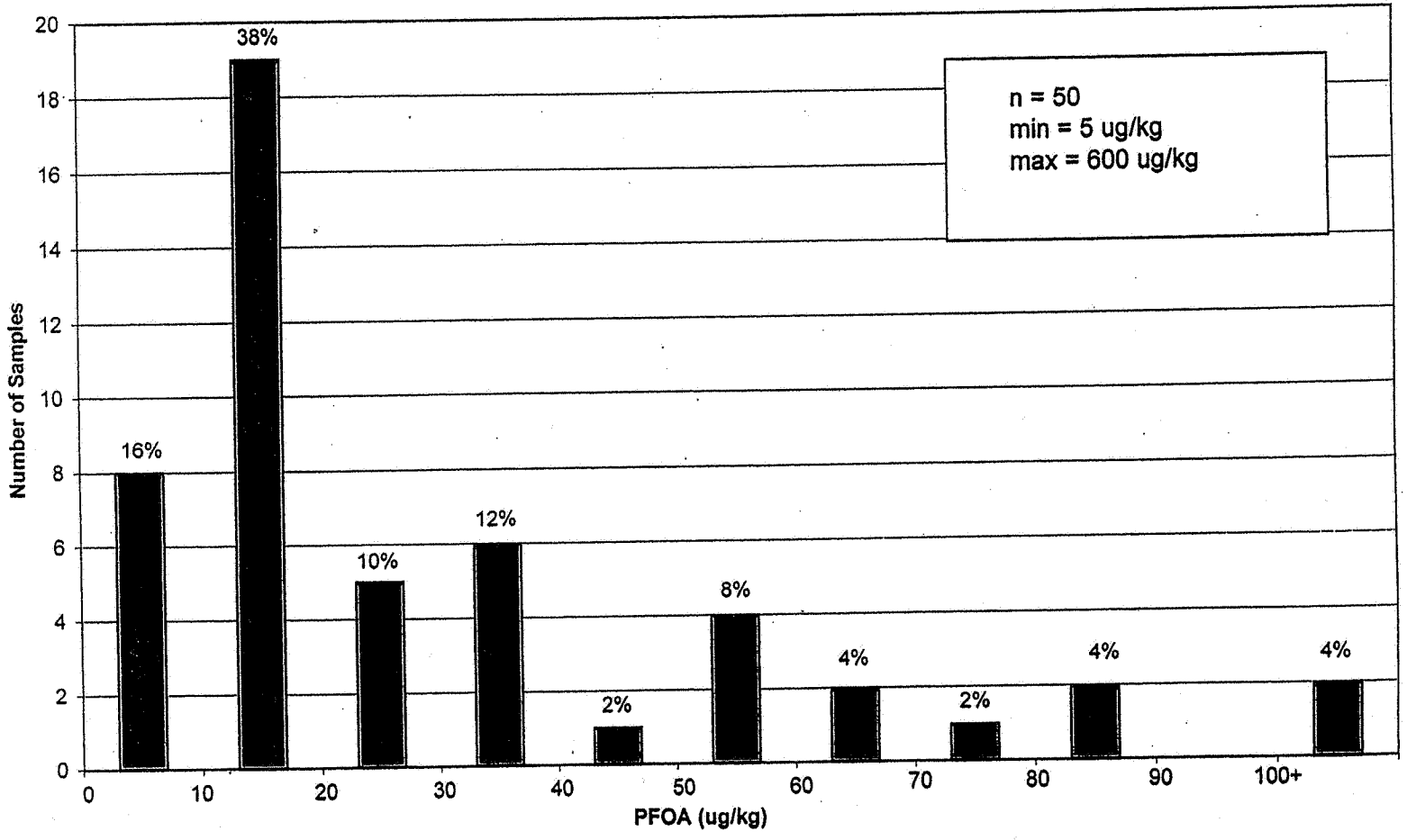
EXP001481

Figure 4
Washington Works RFI Soil PFOA Results



EXP001482

Figure 5
Washington Works RFI Surface Soil (0-2 feet) PFOA Results



EXP001483

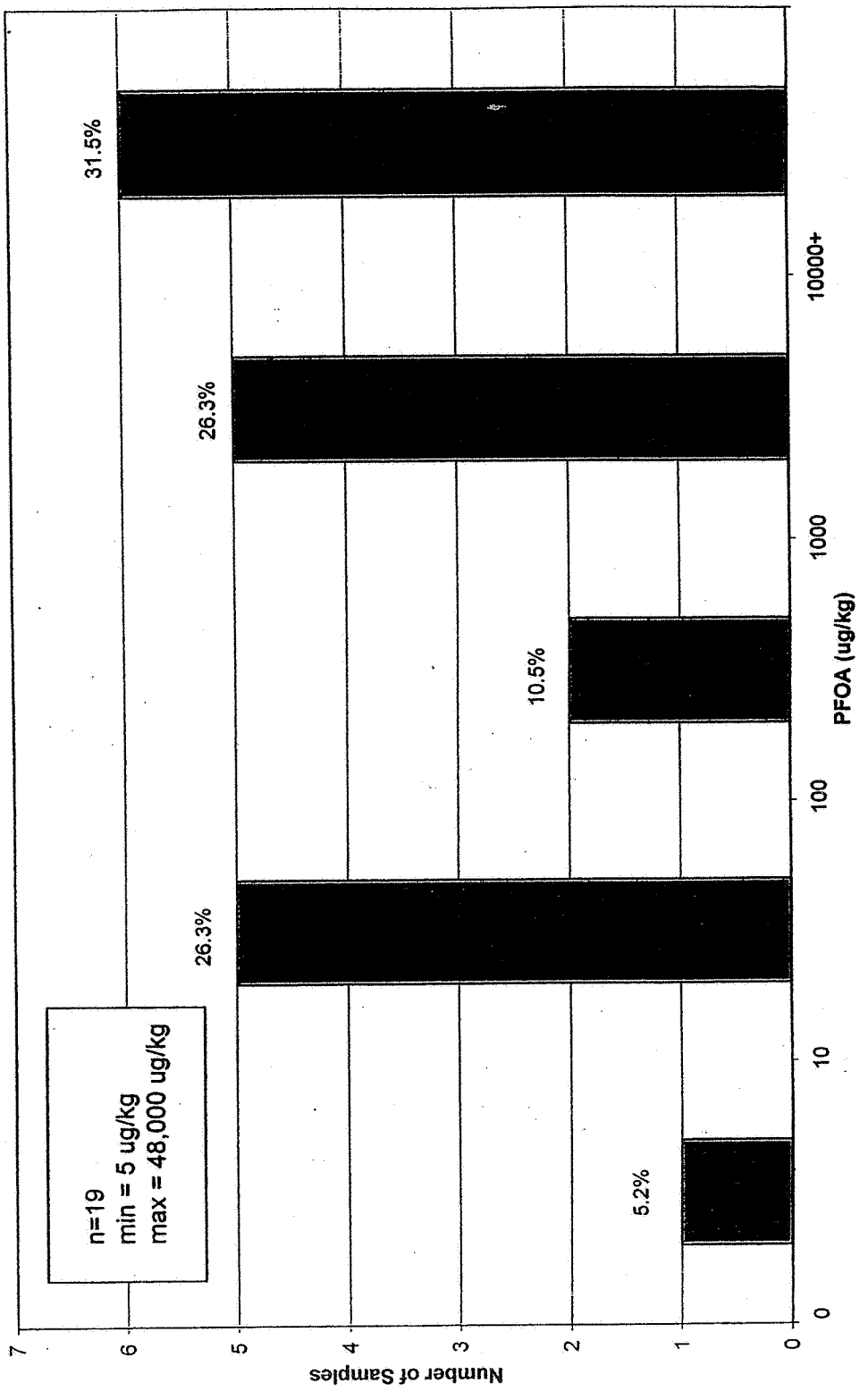


Figure 6
Washington Works RFI APD SWMU Soil Results

EXP001484