

**STATE OF MINNESOTA DISTRICT COURT FOR THE
COUNTY OF HENNEPIN FOURTH JUDICIAL DISTRICT**

CIVIL ACTION NO. 27-CV-10-28862

STATE OF MINNESOTA, *et al.* v. 3M COMPANY

**EXPERT REPORT OF
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**PREPARED ON BEHALF OF
PLAINTIFF STATE OF MINNESOTA**

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1. INTRODUCTION

1.1 Scope of Report

I have been asked by counsel to review the site information and associated documents concerning the disposal of liquid and residual solid wastes containing perfluorocarbon compounds (“PFCs”) generated by 3M Company at their Cottage Grove facility. These wastes were disposed of at the Cottage Grove facility, the Oakdale disposal site, the Woodbury disposal site, and the Washington County Landfill located in Washington County, Minnesota. Specifically, I was asked to address the following topics:

- What 3M knew or should have known regarding the contamination of groundwater by 3M’s PFC-containing wastes at its four waste disposal sites and when 3M knew or should have known it; and
- Whether 3M exercised reasonable care when disposing of its PFC-containing wastes at its four disposal sites and allowing releases from those disposal sites to continue.

I have reviewed the reports, documents, deposition transcripts, and various other materials provided by counsel and gathered independently and offer my professional opinions in this report. A list of the materials I have reviewed is contained in Attachment 1 to this report. The types of documents that I have reviewed, including patents, scientific publications, 3M’s reports and internal communications, 3M’s communications with regulatory agencies and the public, are those that would reasonably be relied upon in the preparation of an expert report.

As more fully detailed in the body of this report, I offer the following professional opinions to a reasonable degree of scientific certainty:

1. By the early 1950s, 3M knew or should have known that pollutants from landfilled industrial wastes would reach the groundwater beneath its disposal sites and would pose a potential threat of harm to human health and the environment and harm the State’s natural resources. By the early 1960s, 3M knew that groundwater beneath at least two of its disposal sites was contaminated with industrial organic chemicals, which were components of its waste.
2. 3M failed to exercise reasonable care in connection with its disposal of PFCs and PFC-containing wastes because it disposed of them without regard for harm to human health and the environment. Further, 3M failed to exercise reasonable care by failing to prevent the continued release of PFCs into the groundwater and the Mississippi River after they were disposed of at 3M’s Minnesota sites.

1.2 Personal Background and Qualifications

From 1970 through 2001, I was employed as a Professor of Soil and Crop Sciences in the Soil and Crop Sciences Department, Texas A&M University, College Station, Texas. I currently serve as Professor Emeritus in the Soil and Crop Sciences Department, Texas A&M University, College Station, Texas. In 1990, I received a joint appointment to the faculty in Toxicology at Texas A&M University, where I supervised the research of masters degree and doctoral candidates in the field of toxicology. My educational background includes a Bachelor of Science degree in Agronomy from Delaware Valley College (1962), Masters of Science degree in Agronomy/Plant Physiology from Cornell University (1964), and Doctor of Philosophy degree from University of Nebraska (1969). My résumé is presented as Attachment 2, and includes a complete list of my publications.

While a member of the faculty at Texas A&M University, I conducted extensive research including numerous research projects for the U.S. Environmental Protection Agency ("USEPA") and the National Institute of Health ("NIH") on the fate and transport of contaminants, including pathways of exposure and toxicity of hazardous substances to receptors in the environment. As a result of these research efforts, I have authored or co-authored over 190 peer-reviewed, scientific publications, including numerous articles dealing with the disposal and treatment of waste materials, including Resource Conservation and Recovery Act ("RCRA") hazardous wastes and Comprehensive Environmental Response, Compensation, and Liability Act ("CERCLA") hazardous substances contained therein and the problems arising therefrom. Additionally, I have authored or co-authored over 35 publications which deal with risk assessment or toxicity of hazardous substances in the environment. I have conducted research in a national center funded by the USEPA to study the fate of hazardous substances in the environment.

The research I conducted on the mobility of organic liquids through clay landfill liners was instrumental in the incorporation of the prohibition of land disposal of liquid wastes in the Hazardous and Solid Waste Amendments in 1984 (P.L. 98-616, 1984). Extensive research that I conducted on landfill liners was instrumental in the development and implementation of regulations which now require that both hazardous and municipal landfills must be lined and all leachate must be collected and removed for treatment. I authored the USEPA guidance document on the land treatment of hazardous wastes, and portions of the USEPA guidance document on the design of landfill liners. I authored a publication for USEPA where I surveyed the characteristics of the hazardous wastes generated by industry based on the SIC code of the industry.

During my tenure at Texas A&M University, I taught courses in Soil Physics which included topics on the movement of air, water, and other fluids in the soil, and a graduate course on the land disposal of wastes, which included consideration of the principles and practices applicable to the fate, mobility, and clean-up of contaminated sites. Students in these classes included engineers, soil scientists, chemists, and geologists. I have served on hundreds of advanced degree committees in these and related disciplines.

I have served on technical advisory panels to the USEPA, committees of the Office of Technical Assessment, and the National Academy of Science. Significant reports resulting from these committee assignments include, Groundwater and Soil Cleanup, Improving Management of Persistent Contaminants (1999); Ranking Hazardous Waste Sites (1994); Coming Clean,

Superfund Problems Can be Solved (1989); and Superfund Strategy (1985). I was the primary author of a 1983 publication for the USEPA entitled Hazardous Waste Land Treatment. This publication specifically addressed the treatment of hazardous wastes from industrial waste streams to mitigate risk during treatment and eliminate risk to potential receptors.

In 1981, I was appointed to the USEPA Land Treatment Task Force where I served from 1981 through 1985. As part of my assignment with the Task Force, I evaluated the alternatives for land disposal of wastes and the risk associated with the disposal alternatives. While a member of this Task Force, I testified before the U.S. House of Representatives - Science and Technology Committee in November 1982 on the adequacy of USEPA's liquid management system to protect groundwater at hazardous waste landfills, which lead to the passage of the Hazardous and Solid Wastes Amendments of 1984 under the Resource Conservation and Recovery Act.

In 1983 and 1984, I was a member of the Advisory Panel to U.S. Congressional Office of Technology Assessment. This panel was tasked with determining the effectiveness of current USEPA programs to clean up uncontrolled hazardous waste sites. As part of my assignment with this committee, I reviewed and evaluated the toxicity and imposed risk to receptors due to hazardous substances and provided recommendations for improving the efficiency of USEPA programs to mitigate risk at uncontrolled hazardous waste sites.

In 1984, I was a member of the Office of Water Regulations and Standards Committee on Municipal Sludge Landfilling, which was formed to advise USEPA on the pollutants which should be regulated for disposal and the methods or procedures to be used for regulating such pollutants. As part of my work for this committee, I assessed the hazards and risk associated with the hazardous substances contained in municipal sewage sludge and provided recommendations for regulation of metals in sewage sludge based on the degree of risk presented by exposure to these metals.

From 1987 through 1995, I was a member of the Advisory Panel to U.S. Congressional Office of Technology Assessment, which was tasked with assessing the effectiveness of the USEPA in identifying, prioritizing and cleaning up hazardous waste sites. As part of my work for this committee, I evaluated the impacts of exposure from different media and the effectiveness of available technologies to mitigate exposure and risk from hazardous waste sites.

From 1991 through 1994, I served on the National Academy of Sciences Committee on Remedial Action Priorities for Hazardous Waste Sites, where I evaluated the role of risk assessment and mitigation of risk in the decision process for remedial action.

From 1995 through 1998, I served on the National Academy of Sciences, National Research Council Committee on Environmental Technologies Subcommittee on Landfills. As part of my assignment to this committee, I evaluated the risk due to contaminants in soil and groundwater and recommended strategies for the management and control of recalcitrant wastes for the reduction of risk due to these persistent contaminants.

In addition, I have served on numerous USEPA review panels addressing toxicity and risk including the following, among others:

- USEPA Panel to Review the Acceptability of Landfill Disposal of Sewage Sludge (1984);
- USEPA Panel to Write a Protocol for Mutagenicity Sample Preparation (1984);
- USEPA Hazardous Waste Center Review Panel (1988); and
- USEPA Review for Risk Assessment for Petroleum Industry Hazardous Waste Listing Determination (1995).

I am personally familiar with the definition of “hazardous substance” as defined in § 101(14) of the Comprehensive Environmental Response, Compensation, and Liability Act (“CERCLA”) and under the statutes and regulations incorporated by reference into that section. A hazardous substance under CERCLA is defined in 42 U.S.C. § 9601 (14), invoking the EPA designations under 42 U.S.C. §§ 3001 and 9602, among other statutes. Included in the definition of a CERCLA hazardous substance are certain hazardous wastes which are either listed in 40 C.F.R. § 261, Subpart D or have certain identified characteristics as described in 40 C.F.R. § 261, Subpart C.

Further, I have studied and am familiar with industrial, commercial, and residential wastes, and the landfills that eventually contain such waste. I have researched the risks associated with leachate from landfills containing these wastes. I have also investigated the partitioning, biodegradation, mobility, volatilization, solubility and reactivity of organic compounds found in leachate from landfills and the resulting fate and transport in both surface water and groundwater. I have reviewed numerous remedial plans and proposed remedies pertaining to landfills containing industrial, commercial, and residential wastes. I have also served as a reviewer of toxicological profiles of hazardous substances for the Agency for Toxic Substances and Disease Registry (“ATSDR”).

I have been a consultant in the field of environmental science and engineering for the past 37 years. I founded K. W. Brown and Associates, Inc., and served as President from 1980 until 1991. I was employed as a Principal Consultant with K. W. Brown Environmental Services from 1991 until 1999 and with SI Group, LP from 2000 to 2008. From January 2009 through March 2011, I was employed as a Principal Consultant with TTI Environmental Consultants. I have been employed as an independent consultant since April 2011.

Through these years of consulting, numerous private and public clients have employed me. My expertise has been utilized for site assessments, data review and interpretation, waste management activities, the study of fate and transport of contaminants in the environment, the movement of contaminants in groundwater, the design and implementation of remedial actions for recalcitrant organic compounds, and other related environmental matters. I have also reviewed and interpreted a large quantity of analytical data for soils and groundwater, as well as borings logs, field logs, technical reports, and other information related to the environmental conditions of a site.

As a consultant, I have evaluated or analyzed numerous waste disposal and landfill sites including the following: Laurel Park Landfill, Beacon Heights Landfill, Lone Pine Landfill, Ft.

Bend County Landfill, Oak Grove Landfill, East Bethel Landfill, Dickson County Landfill, and Sinton Landfill, among others. In addition, I have also worked on the following Superfund sites: Hardage Criner, Love Canal Landfill, Lowrey Landfill, Montana Pole, National Gypsum, Riley Tar, Sharon Steel, Helen Kramer Landfill, Sikes' Pits, Metal Bank of America, Tar Creek, Babylon Landfill, and the West Dallas Lead Site.

1.3 Prior Expert Testimony

I have qualified and given testimony as an expert witness in civil cases in federal and state courts, regulatory hearings, and enforcement actions pertaining to hazardous wastes, organic chemical contamination, and the fate and transport of organic chemicals and other contaminants in environmental media, as well as exposure and risk, among other issues. I have offered opinions related to these topics at several Superfund sites. A list of cases in which I have testified as an expert at trial or by deposition since January 1, 2013 is presented in Attachment 3.

1.4 Compensation

I am being compensated at customary rates for work on this case. My hourly rate of compensation is \$300 per hour for non-testimony time and \$350 per hour for testimony time. My compensation in no way depends on the outcome of this litigation or the substance of my opinions.

1.5 Exhibits and Reservations of Rights

I may use as exhibits any document contained or referred to in this report, or supplements to this report, including but not limited to the appendices; any document needed as foundation for or illustration of my testimony; any document listed as an exhibit or provided in discovery by the Defendant or any other party; any document considered by any the Defendant's or any other party's experts; or any document needed to respond to or to rebut testimony on behalf of the Defendants or any other party. I reserve the right to provide lists of exhibits as permitted by the Minnesota Rules of Civil Procedure and the Scheduling Orders in this case.

I further reserve the right to supplement or modify opinions expressed herein upon which I expect to testify, to add to or modify the bases and reasons for my opinions and supplement the exhibits that I may use at trial for any of the following reasons: (1) to respond to expert reports, including but not limited to rebuttal reports, submitted by the Defendant or any other party; (2) to respond to new information; (3) to respond to information obtained in discovery, including but not limited to depositions and interviews; and (4) as permitted by Minnesota Rules of Civil Procedure.

1.6 Documents and Other Information Considered

This report was developed as a result of discovery of information to which I have been provided access or which I have discovered independently. The opinions I have formed in this case are based on my education and experience described in Section 1.2, as well as documents and other materials listed in Attachment 1.

2. 3M'S FLUOROCHEMICAL PRODUCTION AND DISPOSAL

2.1 Properties of PFCs

Perfluorocarbon compounds, or PFCs, are any chemical in a family of synthetic chemicals that contains a perfluorinated (fully fluorinated) carbon chain consisting of 1 to 16 carbon atoms with a functional end group consisting of at least one double bond.

PFCs do not occur in nature and were developed as a part of the research associated with the Manhattan Project during World War II. PFCs have similar molecular structure as their corresponding hydrocarbon compounds, except with complete replacement of all hydrogen atoms in the hydrocarbon molecule with fluorine. The principal compounds at issue in this suit, perfluorooctane sulfonate (PFOS), perfluorooctanoic acid (PFOA), and perfluorobutanoic acid (PFBA), are PFCs.

From my review of the scientific literature, it is my understanding that many important properties of PFCs were known as a result of the early work by Dr. Joseph Simons, a research fellow at Pennsylvania State University, and numerous 3M researchers. Shortly after the public disclosure of the electrochemical fluorination process during the 114th annual meeting of the American Chemical Society on September 15, 1948, 3M purchased patents from Dr. Simons related to the manufacture of perfluorochemicals (Simons, 1950a). 3M also employed several former graduate students of Dr. Simons to prepare new compounds and develop new markets for these perfluorochemicals (Simons, 1948; Simons, 1949; *Brice*, 1950; *Guenthner* and *Vietor*, 1962; *Bryce*, 1964; *Pearlson*, 1968).¹

Reactivity. Early patent applications and the scientific literature document that the chemical stability of PFCs was well understood before commercial production of PFCs began at the 3M Cottage Grove facility. Dr. Simons' 1948 patent application, for example, noted that PFCs were "non-corrosive, and of little chemical reactivity." PFCs "do not react with any of the metals at ordinary temperatures and react only with the more chemically reactive metals such as sodium, at elevated temperatures" (Simons, 1948). Another patent application filed the following year explained that PFCs do not react with other compounds or reagents due to the sheath of fluorine atoms surrounding the carbon skeleton of the molecule (Simons, 1949). These highly stable PFCs were developed to provide non-reactive solid and liquid chemicals with low surface tensions that could withstand high temperatures and would not react with highly reactive materials such as oxygen (Simons, 1949; *Bryce*, 1964). It is the stability of the carbon-to-fluorine bonds in the PFCs and the lack of attraction for other chemical species that prevent the PFCs from undergoing further chemical reactions or degrading under natural processes in the environment (Simons, 1950b). As *Bryce* recognized, "[t]his chemical stability also extends itself to all types of biological processes; there are no known biological organisms that are able to attack the carbon-fluorine bond in a fluorocarbon" (*Bryce*, 1964).

3M was well aware of these chemical properties of PFCs because *T.J. Brice* and *H.G. Bryce* were 3M employees as well as former graduate students under Joseph Simons, and 3M

¹ All names given in italics are either current or former 3M employees. The discoveries and information developed by these individuals was thus known to 3M.

acquired many of Simons' patents related to fluorochemicals (3M, 2007 [3MA02527087]). 3M's knowledge of this and other basic properties was demonstrated by, among many other things, a 1949 3M sales brochure, which described the chemical and physical properties of PFBA, and a 1963 3M sales brochure on its fluorochemical surfactants, which touted their chemical and thermal stability (3M, 1949 [3M_MN03109500]; 3M, 1963 [3MA01201629]).

Thermal Stability. The thermal stability of PFCs was understood prior to the start of commercial production of PFCs by 3M. In 1947, two researchers from Columbia reported that fluorocarbon compounds did not degrade at temperatures as high as 500° C (932°F), even in the presence of catalytic materials (Grosse and Cady, 1947). Simons' patent application posited that PFCs were thermally stable at temperatures up to 750° C (1382° F) (Simons, 1948; Simons et al., 1949). These PFCs were non-reactive and thermally stable due to the strength and stability of the carbon-to-fluorine bonds (Simons, 1949; *Brice*, 1950). Additional research by 3M expanded the understanding of the thermal stability of these perfluorocarbon compounds. As *Bryce* explained in his 1964 work, fracture of the carbon-to-carbon bonds in the PFCs may take place at temperatures from 600 to 1000° C (1112 to 1832° F) depending on the carbon chain length; the carbon-to-fluorine bond is much stronger and can require temperatures of 1200° C (2192° F) to break (*Bryce*, 1964).

Solubility. As discussed further below, 3M was capable of producing a variety of PFCs at its Cottage Grove facility. From my review of 3M documents, it is my understanding that many of the PFCs produced by 3M, including PFOS, PFOA, and PFBA, in addition to the salts of PFOS, PFOA, and PFBA, would readily dissolve in water. In 3M's 1949 sales brochure, they advertised that PFBA was miscible in water at 20° C. The same brochure indicated that the salts of PFBA are highly soluble, ranging from 42.2 grams to 493 grams per 100 grams of water (3M, 1949 [3M_MN03109500]). In 1962, testing of PFOS-based surfactants indicated that these compounds were very soluble (*Guenthner and Vietor*, 1962). A 1963 brochure on 3M's fluorochemical surfactants confirmed that 3M was aware that many of its fluorochemical surfactants, including PFOS, were soluble in water. That brochure, for example, indicated that the solubility of FC-95 (the potassium salt of PFOS) in water was 2 grams of FC-95 per liter of water (3M, 1963 [3MA01201629]). More broadly, numerous PFCs manufactured by 3M, including fluorocarbon carboxylic acids and fluorocarbon sulfonic acids such as PFOA and PFOS, dissolved when mixed with water (*Bryce*, 1964). 3M knew by 1964 that when dissolved, fluorocarbon carboxylic acids and fluorocarbon sulfonic acids dissociated² to form highly stable perfluorocarboxylate and perfluorosulfonate ions (*Bryce*, 1964). Later studies by 3M on the adsorption and mobility of FC-95 and FC-143 (the ammonium salt of PFOA) in soils indicated very high solubilities and very high mobilities in soils for both compounds (3M, 1978 [3MA10036129]).

Resistance to Degradation. Because of their very limited reactivity and the high thermal stability of the perfluorinated carbon chain, PFCs do not degrade in the environment (*Brice*, 1950). The breaking of a carbon-to-fluorine bond required the input of large amounts of energy

² By dissolving in water, the chemical compounds will dissociate by separating into their component ions (charged particles) in the solution. For acids like PFOA, the ions will include perfluorooctanoate and the hydrogen ion. The released hydrogen ion will increase the acidity and decrease the pH of the solution.

to overcome the attraction of carbon for fluorine. Chemical and physical processes occurring in nature lack sufficient energy to break carbon-to-fluorine bonds and without this input of energy, the carbon-to-fluorine bonds remain intact. “This chemical stability also extends itself to all types of biological processes; there are no known biological organisms that are able to attack the carbon-fluorine bond in a fluorocarbon” (*Bryce*, 1964). From the chemical stability of the carbon-to-fluorine bond, 3M knew that the PFCs were immune to chemical and biological degradation in soils and groundwater. A 1971 internal memo by *H.G. Bryce* stated that “the thesis that there is ‘no natural sink’ for fluorocarbons obviously demands some attention,” meaning that PFCs released to the environment will never degrade (3M, 1971 [3MA02496587]).

In natural environments, PFCs do not undergo degradation of the carbon-to-fluorine bonds of the perfluorinated carbon chain. However, the non-fluorinated, functional group of the PFCs will partially degrade, yielding recalcitrant PFCs such as PFOS, PFOA, and PFBA, which resist further degradation. Basic weathering and degradation reactions, such as hydrolysis,³ occur at the non-fluorinated, functional group end of the molecule, producing the original fluorocarbon compound (*Pearlson*, 1950)—such as PFOS, PFOA, or PFBA—from which other PFCs were made (3M, 1979 [3M_MN00000151]). In this manner, derivative compounds containing the C₇F₁₅– group were converted to PFOA and derivative compounds containing the C₈F₁₇SO₂– group reverted to PFOS (*Bryce*, 1964). In sum, 3M knew that the perfluorinated components of PFCs released to the environment would not degrade the perfluorinated carbon structure, but would remain intact (*Brice*, 1950).

Later 3M research on the biodegradation of its fluorochemical compounds confirmed these results (Bacon, 2017 (pp. 40-48)). A 1976 study, for example, observed no biodegradation of FC-95, the potassium salt of PFOS. 3M judged the result of the study “unsurprising” in light of the fact that “[b]iodegradation of FC 95 is improbable because it is completely fluorinated” (3M, 1976 [3MA01252037]). A 3M report from 1978 likewise summarized a “quite extensive” set of studies of the biodegradability of FM-3422, a compound manufactured from PFOS, and concluded that “FM 3422 is likely to persist in the environment for extended periods unaltered by metabolic attack” (3M, 1978 3MA00717615]). Studies of FC-95 and FC-143 (the ammonium salt of PFOA) conducted in 1978 likewise concluded that those compounds were “likely to persist in the environment for extended periods unaltered by microbial catabolism” (3M, 1978 [3MA10054929]).

³ Typically, *hydrolysis* is a chemical process where a molecule of water is substituted or added at the functional group of the PFC derivative. The addition of water cleaves the non-fluorinated portion of the molecule from the fluorinated carbon tail.

2.2 3M's Production of PFOS, PFOA, PFBA, and Related Compounds

The Electrochemical Fluorination Process. 3M used the Simons electrochemical fluorination (ECF) process to produce PFCs (Simons, 1950a; 3M, 2007 [3MA02527087]). It is my understanding based on my independent review of the available documents that the ECF process consisted of a combination of an electrochemical cell with condensers, a sodium hydroxide reactor and driers for the removal of excess hydrogen fluoride and outlets from the cell for the collection of the liquid, fluorinated carbon-containing product mixtures (Simons, 1950a; Simons, 1950b).

The ECF process created mixtures of a number of fluorinated carbon compounds. This mixture of product compounds required further separation by a process called fractional distillation,⁴ which separated the mixture into distinct “fractions,” each with a distinct boiling point range (Simons et al., 1949). The segregated fractions of fluorocarbon products were collected for direct use in 3M product mixtures, used as building blocks for the production of other fluorinated compounds, or discarded as waste (Dworak, 2012 (p. 190); 3M, 2000 [3MA00001260]).

Production of Various PFCs. By upscaling the electrochemical fluorination process developed by Dr. Simons, the production of fluorocarbon compounds became commercially feasible. Simons and *Brice* wrote that “[t]he first commercial plant for the production of fluorocarbons and their derivatives by the electrochemical process was put into operation near Hastings, Minnesota, in October 1951” (Simons and *Brice*, 1954).

From this point, 3M began its commercial production of fluorocarbons at its Cottage Grove facility near Hastings, Minnesota. In its early years, it operated on a relatively modest scale, producing some 250 pounds of fluorocarbon product per day in 1954 (Simons and *Brice*, 1954). 3M quickly expanded its production to include an entire facility devoted to the production of PFCs within its Chemolite plant. The electrochemical fluorination process for the manufacture of PFOA remained essentially the same at 3M's Cottage Grove plant from the first initial batch produced in the early 1950s through the phase out of production in 2002 (*Dworak*, 2012 (p. 35)).

3M used the ECF process to develop a wide variety of PFCs. Different hydrocarbon compounds containing elements other than carbon or hydrogen were sometimes used as the “feed stock,” or starting materials, to develop PFCs (3M, 2000 [3MA00001260]). Some of these additional hydrocarbon starting materials retained the reactive properties of the original hydrocarbon feed stock after fluorination (Simons, 1949; Simons et al., 1949).⁵ This work was

⁴ Fractional distillation is a chemical separation process where a mixture of different compounds are separated based on the boiling points of the individual compounds in the mixture. This is achieved by repeatedly heating and boiling the mixture of compounds; because the various compounds in the mixture have different boiling points, they physically separate during this heating process.

⁵ In hydrocarbon compounds, an atom other than carbon attached in the skeletal structure is called a heteroatom. Functional groups are groups of two or more, non-carbon containing atoms.

based in part on the research of Dr. Simons at Penn State, demonstrating that organic acids and sulfonyl halides, when used as the starting materials for the fluorination process, produced perfluorinated compounds while retaining their organic functional groups (Simons et al., 1949; *Pearlson*, 1950; Simons and *Brice*, 1954).⁶ This technique was used by 3M to manufacture PFOS, PFOA, PFBA, and related compounds (Simons, 1949; Simons, 1950a; *Scholberg* and *Bryce*, 1955; *Brice* and *Trott*, 1956).

The presence of a heteroatom or a functional group within the hydrocarbon molecule imparts different properties to the substance.

⁶ Organic acids and sulfonyl halides are examples of functional groups that remain unchanged in the chemical structure upon fluorination of the starting materials.

2.3 Composition of 3M's PFC-Containing Waste Streams

From the beginning of the manufacture of PFCs, anyone with a knowledge of the chemistry and the manufacturing processes would have known that the wastes produced from the production of PFCs contained residual perfluorochemicals (3M, 1983 [3M_MN02571703]). 3M employed chemists and engineers who specialized in the production and product development of PFCs including *T.J. Brice, H.G. Bryce, P.W. Trott, R.A. Guenther, M.L. Vietor, H.M. Scholberg, R.I. Coon, D.G. Weiblen* and *W.H. Pearlson*, among others. These chemists and engineers were highly trained, specializing in the manufacturing and production steps needed to separate and isolate the individual products. Therefore, 3M knew that the production wastes contained PFCs. These wastes included processing wastes, such as acid tars and resinous materials, fractionation wastes, waste solvents, solid materials, and off-specification products containing PFCs (3M, 1983 [3M_MN02571703]; 3M, 2000 [3MA00001260]; 3M, 1993 [3MA00206150]).

Varieties of PFC-Containing Wastes

During most of the period considered by this report, 3M did not classify its wastes in terms of their perfluorochemical content. In the 1950s and 1960s, 3M classified its wastes using rudimentary categories such as acid tars; dry scrap, such as paper, pallets, production scrap, and cardboard; wet scrap, such as liquid and semi-solid mixtures and materials contaminated with solvents, resins, waste solvents, and nonpumpable residue (3M, 1963 [3MA00456368]; 3M, 1980 [3MA01248573]). As 3M itself has explained: "The manufacturing process for sulfonated perfluorochemicals is complicated. There are more than 600 intermediate manufacturing steps associated with the production of POSF and POSF-based products. This translates into hundreds of process steps that require venting or that generate wastewater or solid waste" (3M, 2000 [3MA00045043]). POSF is the raw intermediate used to make PFOS (3M, 2000 [3MA00001260]).

By the late 1960's, 3M wastes were separated into three broad categories, namely dry scrap wastes, wet scrap wastes, and extra hazardous wastes (*Lewis et al., 1976*). Hazardous wastes originating from 3M operations would have included dirty solvents from coating operations, mother liquors from chemical reactions, spent cleaning solutions, reject products, and nonmarketable items, as well as other wastes (*Van Noordwyk and Santoro, 1978*).

It is my understanding from my review of 3M documents that wastes containing PFCs from the perfluorochemical manufacturing processes included the following, among others. Furthermore, I concur with the waste streams identified in Dr. Andrews report.

- **hydrofluoric acid tars**, sometimes known as HF tars or acid tars, that resulted from the operation of the electrochemical cell;
- **fractionation bottoms**, or unwanted perfluorochemical by-products or residuals separated from the desired product during the fractionation step of the manufacturing process;

- **cleaning and process wastes** resulting from the cleaning of equipment used in the manufacturing process and from numerous other steps of the manufacturing process;
- **laboratory and pilot-scale testing wastes** including waste chemicals, spent solvents and other solid wastes contaminated with fluorocarbons;
- **fluorochemical inerts**, low boiling point by-products that were removed during the fluorination and distillation processes. Fluorochemical inerts are composed of short perfluorinated or partially-fluorinated carbons chains, either with or without a functional group, and other related by-products;
- **wastewater treatment plant sludge**, including solid waste materials, which settled to the bottom of the wastewater treatment pond (until 1962) or wastewater treatment plant settlement ponds (after 1962); and
- **incinerator ash and incinerator wastewater sludge** produced once the incinerator built at the Cottage Grove facility began operation in 1971.

3M's Knowledge

When assembling its research and production team, 3M hired Ph.D.-level scientists and engineers with hands-on knowledge in the manufacture of fluorochemical compounds. This team worked regularly to optimize the ECF process and improve the efficiency of the stabilization and/or separation of the finished products, as well as designing and synthesizing new materials for additional markets. Because 3M understood the chemistry and engineering underlying electrochemical fluorination and other elements of its manufacturing processes, 3M knew or should have known that the wastes described in this section contained PFCs.

Acid tars. The early patent documents, prepared by Dr. Joseph Simons, disclosed that the formation of acidic tars, resinous residuals containing fluorochemicals, were produced by the ECF process (Simons, 1948; Simons, 1950b). 3M was aware that these tars—often called “acid tars” or “HF tars”—contained PFCs even before it began producing PFCs on a commercial scale (3M, 1983 [3M_MN02571703]; 3M, 2000 [3MA00001260]). Testing conducted in 1963 attempted to increase the recovery of hydrofluoric acid and the recovery of PFC product intermediates by dissolving the residual tars in fuming sulfuric acid, but proved unsuccessful (3M, 1974 [3MA01201775]). The very fact that 3M was trying to recover PFCs from the acid tars clearly demonstrated that they knew that the tars contained PFCs.

Fractionation bottoms. Research results by Dr. Joseph Simons on the ECF process also disclosed that the fluorination process produced a mixture of fluorinated products, which must be separated rather than one specific product (Simons, 1949b; Simons, 1950b). The mixture of products from the electrochemical fluorination process occurred as fluorocarbon compounds of differing carbon chain lengths including fully saturated fluorocarbons and other compounds with incomplete replacement of hydrogen by fluorine (Simons and Brice, 1954). Wastes from these processing steps contained residual PFCs. (3M, 1983 [3M_MN 02571703]; 3M, 2000 [3MA00001260]). A 1981 3M memo indicates that 3M sought to recover additional

fluorocarbons from these wastes, confirming that 3M knew that they contained PFCs (3M, 1981 [3MA00082742]; Dworak, 2012 (p. 172)).

Cleaning wastes and process wastewaters. 3M knew or should have known that cleaning wastes and process wastewaters contained PFCs. Due to the need to fractionate the raw products from the electrochemical fluorination steps and the stabilization/workup needed for the production of specialized perfluorochemicals, water and organic solvents were often used to clean vessels used in the production steps. In his deposition, Mr. Dworak stated, “any solution used to boil out the cell bodies went down the sewer to wastewater treatment and the water used from the pressure blasting went down the sewer to wastewater treatment” as well (Dworak, 2012 (p. 104)). The washwater and these solvents, containing PFCs, were typically drained to the chemical sewer. Likewise, laboratory and pilot-scale testing wastes would have included PFCs as components of their waste streams. These cleaning and processing wastes also contained PFCs (3M, 1983 [3M_MN02571703]; Dworak, 2012 (pp. 104-07, 123-24, 167, 184-85)). Given 3M’s knowledge of the production processes used to manufacture PFCs, 3M knew or should have known that the cleaning wastes and process wastewaters resulting from the PFC manufacturing process would contain PFCs.

Fluorochemical inerts. 3M knew or should have known that fluorochemical inerts contained PFCs. Incompletely fluorinated byproducts were typically collected by 3M from the ECF process for further use as solvents and carriers in subsequent batch processes or as starting materials in the ECF process (3M, 2000 [3MA00001260]). 3M knew or should have known that small amounts of fluorochemical inerts would have been present in the acid tars and distillation bottoms as wastes or would have been partially degraded in the stabilization processes and discharged to the chemical sewer (3M, 2000 [3MA00001260]).

Wastewater treatment plant sludge. PFC-containing wastes were discharged into the chemical sewer from Building 15 at Cottage Grove, where most of the PFCs were manufactured. (Dworak, 2012 (pp. 104-107, 123-124)). From 1971 to 1979, the wastewater treatment plant sludge included solids settled from the incinerator wastewater as well (3M, 1979 [3MA00722981]). Certain PFCs, such as FM-3422 (a PFC made from PFOS) were determined to have relatively large octanol/water partition coefficients and would have preferentially absorbed to the organic solids (3M, 1979 [3M_MN00000151]). Perfluorooctane sulfonyl fluoride (POSF), the precursor to PFOS and its salts, would be “adsorbed by waste treatment sludge and eventually land applied with this sludge” (3M, 1983 [3M_MN02571703, -706]). PFCs with strong affinity for the solid materials would have collected in the sludge of the wastewater pond prior to 1962. Even PFCs with relatively low octanol/water partition coefficients would adsorb to the solids in the wastewater treatment plant system to some degree. After completion of the wastewater treatment system, these partitioning PFCs would have collected in the aeration basins of the wastewater treatment system as wastewater treatment plant sludge (3M, 1966 [3MA00456431]; 3M, 1979 [3M_MN00000151, -160]). In the cases of FC-95 and FC-143, 3M had sufficient information regarding the fate and mobility for each PFC to prepare a schematic diagram showing the partitioning of the compound into the different segments of the environment, namely air, water, and the soil, including partitioning into the solid phase as sludge (3M, 1979 [3M_MN00000745, -748-749]; 3M, 1979 [3MA01410327, -331-334]).

Incinerator ash and sludge. 3M knew from the early work of Dr. Joseph Simons that PFCs were thermally stable and resistant to degradation at high temperatures. Simons, 1950a. In his review of perfluorinated compounds, *H.G. Bryce* presented that the fluorine-to-carbon bond is very stable and can only be broken by heating the PFCs to very high temperatures (*Bryce*, 1964). For example, the compound CF_4 was found to be completely stable at temperatures in excess of 1200°C (2192°F) (*Bryce*, 1964). Dr. *Bryce* was a former graduate student of Joseph Simons and a 3M employee, therefore 3M knew that PFCs would not be completely decomposed at temperatures below that level.

With these benchmarks in mind, 3M incinerated PFC-containing wastes at kiln temperatures as low as 649°C (1100°F) (*Van Noordwyk* and *Santoro*, 1978; *Santoro*, 2017 (pp. 36-37); *Weum*, 2017 (p. 111)). 3M thus knew or should have known that PFCs would not have been completely decomposed in the incinerator and products of incomplete combustion would have remained in the incinerator ash and the incinerator wastewater sludge (3M, 1999 [3MA01412204]). Indeed, analysis from *Eric Reiner* in 2000 indicated that fluorochemicals “are more likely to be incompletely burned than most other organic compounds,” and “[d]egradation of the organofluorine compound could be incomplete if the incinerator doesn’t have a high enough temperature (e.g. perhaps $> 1700^\circ\text{F}$ [925°C])” (3M, 1996 [3M MN04747296, -297]). A 1999 3M white paper on the same subject concluded that “[i]n order to ensure complete destruction, incineration experts at 3M suggest residence times in the combustion chamber greater than 1 second and at a temperature 1700°F (926°C) or greater. If combustion chamber temperatures and retention times drop below certain levels, destruction efficiency can drop off rapidly.”

3M’s own experience with incineration confirmed these conclusions. In March 1984, 3M conducted a trial test burn of the contaminated materials from the Oakdale disposal site. The waste materials consisting of contaminated soils and debris, were fed into the Chemolite incinerator at 3M’s Cottage Grove facility to determine if the incinerator was able to effectively burn the residual waste (3M, 1984 [3MA00382051]). In a June 27, 1984 internal correspondence regarding the Oakdale incinerator ash oil and grease extracts, *Jim Gagnon* stated that one sample of the incinerator ash extracts “had strong absorptions indicative of a fluorochemical. Insufficient material was available for identification of the fluorochemical” (3M, 1984 [3MA00300324]). Analysis of these ash extract samples provided reasonable suspicion for the presence of PFCs in the incinerator ash. Based on this suspicion, 3M should have conducted a more thorough investigation of the incinerator ash, but the 3M documents I have reviewed do not indicate that this was ever done (*Weum*, 2017 (p. 114)).

2.4 3M's Disposal of PFC-Containing Wastes

The wastes produced by PFC-manufacturing processes were disposed of in numerous locations over the years. I understand from my review of 3M documents that waste was disposed of at Cottage Grove, Oakdale, Woodbury, and the Washington County Landfill, as described below, and I concur with the disposal history relating to each site as set forth in the report of Dr. Andrews.

Cottage Grove. 3M disposed of PFC-containing wastes at its Cottage Grove facility beginning no later than 1951, according to remedial investigation reports by a 3M contractor and other 3M documents:

- Various unspecified fluorochemical wastes were burned or landfilled at the site until 1956 (3M, 1981 [3MA00364080]).
- Skimmings from the former wastewater treatment pond were disposed of in area D-5 for at least part of the period from 1948 to 1962 (3M, 1986 [3MA00364082, -096-98]).
- Wastewater from the PFC-manufacturing process flowed via the chemical sewers into the former 3M wastewater treatment pond from at least 1951 to 1962 and afterwards to the 3M wastewater treatment plant (3M, 1986 [3MA00364082, -099]; 3M, 1958 [3MA00456234, -239]; 3M, 2004 [3MA00722658, -689]).
- From 1963 to approximately 1973, acid tars from the electrochemical fluorination process were disposed of in area D-1 (3M, 1986 [3MA00364082, -096]; 3M [3MA01201775]; 3M, 2004 [3MA00722658, -684]; Santoro, 2017 (pp. 31-32)).
- Sludges from 3M's wastewater treatment plant were disposed of in areas D-2 and D-9 from at least 1964 to 1973 and in area D-6 from 1978 to 1980 (3M, 1986 [3MA00364082, -096-97]; 3M, 2007 [3M_MN01483002, -016]; 3M, 1986 [3MA00294816, -818]).
- Incinerator ash was disposed of in area D-6 from 1978 to 1979 (3M, 1978 [3M_MN00052172]; 3M [3MA00276845, -848]).

With the exception of area D-1, which was believed to have been concrete-lined, and area D-6, which was partially bentonite-lined, these disposal areas were not lined or otherwise designed to prevent the infiltration of pollutants into the soil (3M, 1986 [3MA00364082, -096]; 3M [3MA00281033, -035]; 3M, 2004 [3MA00722658, -684]). Even though these two waste disposal areas were supposedly lined, the concrete and bentonite liners were porous materials. The liners had limited conductivity, but the conductivity of liquids through the liners was not zero. Small volumes of water with these dissolved materials would have penetrated the liner materials into the underlying soils.

Elevated levels of PFOS, PFOA, and PFBA were detected at a number of locations at Cottage Grove, including areas D-1, D-2, D-5, D-8, D-9, the area once occupied by the former

wastewater treatment pond, and the East Cove area, where effluent from the former wastewater treatment pond (1955-62) and the current wastewater treatment plant (1962-present) discharged into the Mississippi River (Weston, 2007 [3M_MN01483002] (pp. 4-5 to 4-10, 5-3 to 5-6)).

Oakdale. 3M disposed of acid tars and probably a number of other PFC-containing wastes at the Oakdale disposal site from 1956 to 1960 (3M, 1980 [3MA01248573]). Elevated levels of PFCs were found near the waste disposal trenches and with buried drums at this disposal site. There is no indication that the waste disposal areas were lined or otherwise designed to prevent infiltration of contaminants into the soil and groundwater (3M, 2011 [3M_MN01362671, -685]; Weston, 2007 [3M_MN04969186] (pp. 4-1 to 5-2); Weston, 2008 [3M_MN00116060] (pp. 2-9 to 3-1)).

Woodbury. 3M disposed of acid tars from its Cottage Grove facility at the Woodbury site from 1960 to 1963. From 1960 to 1966, 3M disposed of various industrial wastes at the Woodbury site referred to by 3M as “wet scrap.” These wastes contained PFCs. Although some trenches at the Woodbury disposal site were lined beginning in 1962, observers noted that the clay liners did not prevent the seepage of wastes into the soil. Elevated levels of PFOS, PFOA, and PFBA were detected at the Woodbury site (3M, 2010 [3M_MN00826383]; Weston, 2008 [STATE_07240271] (pp. 4-10 to 4-14); Kiester, 2017 (pp. 26-27)).

Washington County Landfill. 3M disposed of wastes including wastewater treatment plant sludge and incinerator ash from 1971 to 1974, at the Washington County Landfill, which was a former sand and gravel quarry. There is no indication that the disposal locations were lined or otherwise designed to constrain the migration of PFCs into the soil and groundwater. Elevated levels of PFOS, PFOA, and PFBA have been detected at the site (MPCA, 2008 [CHARTIS00009805]).

2.5 Bioaccumulation of PFCs

3M knew and was well aware that PFCs accumulated in humans and animals since the mid-1950s. Early research with PFC derivative compounds demonstrated a strong association between the perfluorocarbon carboxylic acids and proteins. Specifically, PFOA was found to bind and coagulate serum proteins to precipitate these biological compounds from solution (Klevens and Ellenbogen, 1954). Essentially, this means that PFCs would precipitate as solids in the blood and remain in the body, and would likely be collected in the liver.

Further research revealed that longer PFCs would cause greater precipitation of proteins. As described in further research by Klevens, the formation of complexes between PFCs with proteins and polypeptides suggested the interaction between polar groups on the proteins and the PFC compound. As the length of the fluorocarbon chain increased, the greater the activity of the PFC as a protein coagulant (Klevens, 1955). Accordingly, longer-chain PFCs—such as PFOA and PFOS—would be expected to cause greater precipitation of proteins.

Additional work by Nordby and Luck at Stanford University, using PFCs supplied by 3M, demonstrated that human blood proteins and other proteins of the human body were bound to and precipitated by PFCs. These precipitated proteins, which when bound to the PFCs, were filtered from the bloodstream by the kidneys and liver of the individual. Once removed from the bloodstream, the precipitated proteins collected, particularly in the liver, where the PFCs accumulated (Nordby and Luck, 1956). 3M thus knew that PFCs accumulated in living organisms by 1956.

By the early 1970s, clinical trials by Leland Clark and his coworkers at the Children's Hospital Research Foundation found that the straight-chain PFCs were deposited in the liver and remained in the liver for the lifetime of the animal (Clark et al., 1973). As acknowledged in the research publications, the PFCs used in the above cited research were provided to the researchers by 3M. Since the research was published in the open scientific literature, and 3M provided the PFCs, 3M knew or should have known, the results of the research, namely, that PFCs accumulated in living organisms.

3M's own research in the mid- and late-1970s quantified the extent that various PFCs bioaccumulated in various animals, confirming 3M's awareness of this basic fact about PFCs (Purdy, 2017 (rough tr. pp. 35-38)).

- In 1978, 3M researchers reported the uptake and accumulation FM-3422, a PFC compound that metabolizes and releases PFOS. The report concluded that FM-3422 bioaccumulated in channel catfish, with bioconcentration factors in excess of 1,000 for the brain and gastrointestinal tract (3M, 1978 [3MA00326803]).
- Similarly, a 1979 study, citing research in 1975 and 1977, indicated “that fluorochemicals can bioaccumulate in fish in a laboratory environment.” This report determined that fish caught in the Tennessee River near 3M's Decatur, Alabama plant had detectable levels of fluorochemicals. 3M's study concluded that the three fluorochemicals tested bioaccumulated in the gastrointestinal tract, reproductive system, and fat of channel catfish (3M, 1979 [3MA01409559]).

- In a 1978 study, rhesus monkeys were fed subacute doses of FC-143 for 90 days. At the higher dosage levels, the monkeys were adversely affected with no survival in the highest test group and only limited survival in the second highest test group. In all test groups, both genders were found to accumulate FC-143 in the liver (3M, 1978 [3M_MN02343997, -4000, -4001]).
- Similarly, in a 1978 feeding study with FC-95, rhesus monkeys were fed subacute doses for 90 days. After 90 days, all test animals survived except the subjects in the highest test group. In all test cases, FC-95 was found to accumulate in the liver of the test animals (3M, 1978 [3M_MN02343995, -996]).

Beginning in 1976, 3M conducted blood testing of employees to ascertain the levels of PFCs in their workers' blood (3M, 1977 [3M_MN00000479, -481]; 3M, 1977 [3MA10035028, -029]). Blood serum concentrations in the some of the earliest samples were characterized as high in comparison to a Red Cross plasma sample (3M, 1977 [3M_MN00000296]). Later samples that year identified plant personnel with up to 300 times normal levels of PFCs in blood (3M, 1977 [3M_MN00000479, -481]). By June 1976, a 3M analysis of previously exposed laboratory personnel "indicate[d] that organically based fluorine remains in the blood for an indefinite period." (3M, 1977 [3MA10035028, -29]). Later testing and analysis led to the conclusion that many PFCs accumulated in humans with a half-life for elimination of four years or more (3M, 2002 [3M_MN02334814]).

2.6 Toxicity and Ecotoxicity of PFCs

My independent review of the scientific literature and 3M's internal studies indicated that, by the early 1960s, 3M knew that PFOS, PFOA, and PFBA pose a potential harm to human health and pose a significant threat to the environment.

Early literature. A review of scientific literature demonstrated that 3M knew by the early 1960s that PFCs were harmful. In the years following World War II, the scientific literature documented that the replacement of hydrogen with fluorine in organic compounds would produce physiological and even toxic responses in tested subjects. As an example, fluoroacetate was lethal to dogs and lower animals even at very low doses (Peters, 1951; Saunders, 1961; Hodge et al., 1963). The toxic responses due to methylfluoroacetate and other fluorine-substituted compounds were the basis for much of the research on new chemical warfare agents at the Army Chemical Center during World War II (Hodge et al., 1963).

By the early 1960s, the toxic effects of a number of fluorinated compounds were published in the scientific literature:

- Early research by B.C. Saunders demonstrated that a variety of fluorinated compounds exhibited toxic effects. As stated by Saunders, “certain compounds have greatly altered physiological action when hydrogen is replaced by fluorine.” Some of the adverse physiological effects noted from the testing of fluorocarbon compounds include anesthesia, depression, enzyme inhibition, and metabolic effects. Other pharmacological responses reported by Saunders include (1) a blood pressure effect; (2) a membrane transfer of tetraethylammonium derivatives; (3) a depression of adrenal ascorbic acid content; and (4) sympathetic nervous system blockage (Saunders, 1961).
- Writing in 1963, J.M. Hamilton concluded that fluorocarbons “ha[ve] been found to run a complete gamut of toxicity, ranging from entirely innocuous to the quickly lethal” (Hamilton, 1963).
- Similarly, in a 1963 discussion on the biological effects of organic fluorides, for example, Dr. H.C. Hodge explained, “[t]he toxic effects of the organic fluorine compounds are unlike those of inorganic fluoride; in general, the effects are not consequent on the liberation of the fluoride ion. ... [A] variety of biological effects has been noted in experimental animals following acute administration of organofluorine compounds” (Hodge et al., 1963).
- Likewise, Taylor and Kent presented additional results in 1965 demonstrating that the substitution of fluorine in biomolecules can alter the function of those molecules, resulting in various—and in some cases, adverse—physiological effects. They wrote: “Interest has centered mainly around the fact that the hormonal activity of certain steroids, notably corticoids, is often enhanced by the replacement by fluorine of a hydrogen atom. ... It is now clear, however, that a wider range of structural modifications, with retention or enhancement of biological activity, is possible than was previously considered to be the case” (Taylor and Kent, 1965).

From this early scientific literature, it is plainly evident that fluorocarbon compounds hold the potential to produce physiological, and even toxic responses in living organisms.

3M research. Beginning in 1950, 3M's research confirmed the toxicity of many PFCs:

- In 1950, 3M conducted acute toxicity studies of PFBA and concluded that a dose of 804 mg/kg administered orally to rats was lethal to fifty percent of the tested animals by the end of one week. In the same test, LD₅₀ values⁷ of 435 mg/kg and 755 mg/kg, respectively, were determined for the intraperitoneal and intravenous injections of PFBA in mice after 24 hours (3M, 1950 [3MA02497530]).
- In 1954, an acute oral toxicity study of the potassium salt of PFOA on mice found a lethal dose 500 mg/kg. The sodium salt of PFOA was found to have an approximate LD₅₀ value of 400 mg/kg when administered as a single dose to Sprague Dawley rats by feeding tube (3M, 1954 [3MA01828941]).
- In 1956, a feeding study of the lithium salt of PFOS was found to have a lethal concentration of 500 mg/kg when administered as a single dose to rats. A separate 1956 study determined the "minimal lethal dosage" of 260 mg/kg for the intravenous injection of PFOA into mice (3M, 1954 [3MA01828941, -942]).
- In a 1963 sales brochure for its fluorochemical surfactants, 3M described FC-95 (the potassium salt of PFOS) as "moderately toxic," with an acute toxicity of 450 mg/kg in rats. The brochure characterized other PFC surfactants as "slightly toxic to moderately toxic." (3M, 1963 [3MA01201629]).
- In 1966, 3M contracted with Industrial Bio-Test Laboratories, Inc. for the study of the acute oral toxicity in albino rats for two of its PFOS derivative compounds. The two fluorochemicals, L-1931 and L-1932, were found to have acute LD₅₀ values of 2600 mg/kg and 900 mg/kg, respectively, following a single administered dose (3M, 1966 [3MA01789595]; 3M, 1966 [3MA01789592]).

After discovering PFCs in human blood in 1976, 3M launched a more detailed toxicological investigation. By 1978, 3M had conducted numerous studies that confirmed the toxicity of its PFCs, including PFOS and PFOA:

- A 90-day subacute toxicity study, conducted on Rhesus monkeys in 1978, determined that feeding FC-95 at a rate of 4.5 mg/kg/day caused all test animals to die within the first few days of the feeding study. In the highest two test groups, FC-95 was found to substantially bioaccumulate in the livers of test animals post-mortem (3M, 1978 [3M_MN02343995]; 3M, 1978 [3MA10032058, -059-60]).

⁷ The quantity of a compound that is lethal to fifty percent of tested subjects is sometimes listed as the "LD₅₀" for that compound.

- A 90-day subacute toxicity study conducted on Rhesus monkeys in 1978, determined that feeding FC-143 (a salt of PFOA) resulted in death of all test subjects at the feeding rate of 100 mg/kg/day and the death of three out of four test subjects at a feeding rate of 30 mg/kg/day (3M, 1978 [3M_MN02343997]).
- In a 90-day feeding study with FC-95 on rats, all test subjects died prior to termination of the study at dosage levels of 300 mg/kg/day and above (3M, 1992 [3M_MN02252650]).
- In a Range-Finding and Definitive Teratology Study in rabbits, the study results indicated a 56% survival rate for female rabbits fed with 96% lithium perfluorooctanesulfonate, a salt of PFOS, at a rate of 4 mg/kg/day (3M, 1992 [3MA01405447, -448]).

By 1980, at least two tests concluded that certain PFCs were teratogenic, in that these PFCs produced malformations in developing rat fetuses (Butenhoff, 2017 (pp. 142-46)). FM-3422, when given to pregnant rats, caused changes to rat fetuses such as “cleft palate, blood in the kidney parenchyma and sternebrae malformations” (3M, 1981 [3MA00326722]). A salt of PFOS caused “[s]ignificant increases in external and visceral anomalies [in the high dose group] includ[ing] subcutaneous edema, cleft palate, and cryptorchism, as well as “delays in skeletal system ossification” (3M, 1983 [3M_MN02456142]; 3M, 2000 [3MB00023926]).

Further studies confirmed that PFCs also posed a significant danger to aquatic life and the environment. Indeed, 3M even used the known physiological effects of fluorochemical compounds to develop new products from their PFC derivatives (*Guenther and Vietnor*, 1962; *Bryce*, 1964). These new products included microbiocides, compounds that kill microbes, demonstrating obvious toxic effects on living organisms. As observed by *Dr. Bryce* (1964): “Fluorocarbon compounds have shown some interesting microbiocidal activity. As might be expected, the fluorocarbon portion of the molecule is physiologically inert; but by varying the functional group, some compounds have shown to have unusually high activity as bactericides and algicides.”

In 1970, a technical journal published a letter warning of the toxicity of 3M’s Light Water product. The author reported, based on rigorous testing, that the compound’s effects were “highly derogatory to marine life and the entire test program had to be abandoned to avoid severe local stream pollution.” At concentrations as low as 4 ppm, he added, the survival time of the fish tested was less than seven days. At all concentrations tested, the fish exhibited “erratic motion, loss of stability and other visibly odd effects” (3M, 1970 [3M_MN02267863]).

3M’s own testing in the early 1970s confirmed the toxicity of FC-95, a salt of PFOS, to bluegill sunfish (1972), water flea and scud (1973), mummichog, grass shrimp, and fiddler crab (1974), algae (1974), and Atlantic oysters (1974) (3M, 2000 [3M_MN00436402]; 3M, 2000 [3M_MN01656831]; 3M, 2000 [3M_MN00437323]; 3M, 2000 [3M_MN00436466]; 3M, 2000 [3M_MN00437343]). Concerns about the environmental effects of fluorocarbons compelled 3M to initiate the Fate of Fluorochemicals project, which was designed to further understand the environmental impact of perfluorocarbon compounds. Subsequent studies established the toxic

effects of various PFCs on organisms such as the bluegill sunfish by 1979 (3M, 1979 [3M_MN02854547]; 3M, 1979 [3M_MN02854512]; 3M, 1979 [3M_MN02255655, -657]). Additional studies in the late 1970s and early 1980s continued to confirm the impacts of PFCs on the environment (3M, 1979 [3M_MN00000151]; 3M, 1979 [3M_MN00000745]; 3M, 1979 [3MA01410327]). 3M researchers analyzing these findings in 1983 noted that “[i]n the case of fluorochemicals, structure considerations and test results to date give rise to concern for environmental safety. . . . These concerns give rise to legitimate questions about the persistence, accumulation potential, and ecotoxicity of fluorochemicals in the environment” (3M, 1983 [3MA10065465]).

2.7 3M's Unique Awareness of the Environmental and Health Risks of PFCs

Since the acquisition of the patents, 3M developed an extensive, proprietary body of knowledge about PFCs and their properties. It acquired the patents related to the electrochemical fluorination process from Dr. Simons, who subsequently collaborated with 3M employees such as *T.J. Brice*, *H.G. Bryce*, and *W. H. Pearlson*, and conducted additional research with 3M support (Simons et al., 1949).

As demonstrated in the previous subsections of this report, 3M's researchers conducted or commissioned a series of studies on the chemical properties, fate and transport, and toxicological properties of PFCs. Many of these studies were not shared in a timely manner with regulators or other interested parties or used to improve 3M's handling of PFC-containing wastes. 3M's understanding of PFCs eclipsed that of regulators and outside researchers. For example:

- **Properties.** The early work of Simons, *Brice*, and *Bryce*, among others, demonstrates 3M's early mastery of the properties of PFCs. Their publication of chapters in the multivolume *Fluorine Chemistry* and articles in *Scientific American* illustrate that they were at the forefront of this emerging area of research (Simons, 1949; Simons et al., 1949; *Brice*, 1950; *Pearlson*, 1950; Simons and *Brice*, 1954; *Bryce*, 1964).
- **Manufacturing Process and Wastes.** 3M used Simons' electrochemical fluorination process to manufacture PFCs after acquiring the patent from Simons. 3M's Cottage Grove facility, which began the commercial manufacture of PFCs in 1951, was the first of its kind (Simons and *Brice*, 1954). In addition, 3M employed numerous chemists and engineers who specialized in the development and production of PFCs. As a result, 3M had unique knowledge of the process and the wastes it produced, and regulators were dependent to a significant degree on 3M to disclose important facts about the manufacturing process and wastes.
- **Bioaccumulation.** 3M's understanding of the properties of PFCs, together with their in-house research capabilities, gave 3M extensive insight into the question of whether and how PFCs bioaccumulated in living organisms. In addition, at least one of the researchers obtained the PFCs directly from 3M (Nordby and Luck, 1956).
- **Risks to Human Health and the Environment.** Here as well, 3M's extensive resources and in-house research capabilities meant that 3M was better situated than regulators or outside researchers to understand the potentially harmful properties of PFCs. By the 1960s, 3M had accumulated lethal dose data on a variety of PFCs that were likely unknown to regulators and others. Following the environmental testing of its PFCs, 3M had a better grasp of the fate and mobility of PFCs than USEPA or Minnesota regulators (3M, 1979 [3M_MN00000151, -159-160]; 3M, 1979 [3M_MN00000745, -752 -753]; 3M, 1979 [3MA01410327, -333 -336]).
- **Analytical Capabilities.** By the 1970s, 3M had the instrumentation and technical knowledge to rival any public universities and private laboratories. The Central Research Analytical division at 3M, and later the Environmental Laboratory division,

was constantly developing new and better techniques to quantify their products, including PFCs. For example, in 1976, Central Research Analytical isolated and characterized PFOA from the blood of a Chemolite supervisor (3M, 1977 [3MA10035028, -029]). By November 1977, 3M had the capabilities to determine both total fluorine and inorganic fluorine in whole blood, plasma, serum, and liver samples down to concentrations of 0.01 parts per million (3M, 1977 [3MA00016495, -496]). As indicated in the 1978 report on organic fluorine in blood, 3M stated that its laboratory was one of “only three or four other laboratories in the world are currently able to measure organic fluorine in blood plasma or serum” (3M, 1978 [3MA10067017, -019]). By 1979, 3M could quantify PFOS and PFOA at parts-per-billion levels (3M, 1979 [3MA00639014]). Similarly, its testing of wastewater from its Decatur facility in 1980 demonstrates that 3M had an early ability to detect and quantify certain PFCs, such as PFOA, in water at parts-per-billion levels (3M, 1980 [3MA01406743, -744]).

- ***Geology and Hydrology.*** By the 1960s, 3M had a full geology department, which was quite unusual for a manufacturing company that produced consumable goods such as tape and sandpaper. Members of 3M’s geology department had a thorough knowledge of the movement of liquids through porous media, namely soils. From its geology department, 3M understood the infiltration and movement of water into the underlying soils as well as the movement of soluble components in their wastes disposed above these soils (3M, 1960 [3M_MN00000135, -137]). Further, the geology department members had the forethought to install test borings to ascertain the subsurface conditions and to recommend observation wells for reference prior to the disposal of wastes at the Woodbury site (3M, 1960 [3M_MN00001421, -422]; 3M, 1960 [3M_MN00000231, -232]). 3M also had, by the 1960s, a sanitary engineering department with extensive knowledge of the subject (Kiester, 2017 (pp. 96-98)).

Knowing that components of their waste would leach with the infiltrating water, 3M completed three soil borings, in 1962, to study the degree of penetration of its waste chemicals in the underlying soils and groundwater at the Woodbury site. Samples from the borings were analyzed for volatile organic compounds, including ethanol, heptane, acetone and methyl ethyl ketone, which had reached the level of the groundwater in one of the three borings (3M, 1962 [3M_MN00000220]). To my knowledge, this assessment of organic compounds in the groundwater below a disposal site was one of the first of its kind. It wasn’t until years later that scientific publications reported the presence of organic contaminants from landfills had contaminated the groundwater (Brown and Donnelly, 1988).

More broadly, 3M had extensive experience in industrial waste disposal and its potential environmental effects. In 1970, President Nixon appointed Bert Cross, then Chief Executive Officer of 3M, as the chairman of the National Industrial Pollution Control Council. The Council was an advisory body comprised of “industrial leaders” established to provide a mechanism for “business and industry to actively and visibly support the drive to abate pollution from industrial sources.” The appointment of 3M’s chief executive to this important post recognized 3M’s advanced knowledge of how improper waste disposal practices could cause

lasting harm to the environment (Weekly Compilation of Presidential Documents, 1970 (p. 502)). However, as discussed in Section 3.2 and elsewhere in this report, 3M failed to use this knowledge to avoid ongoing harmful waste disposal practices.

3. OPINIONS AND BASIS FOR OPINIONS

3.1 3M's Disposal of PFC-Containing Waste Contaminated the Groundwater

By the early 1950s, 3M knew or should have known that pollutants from landfilled industrial wastes would reach the groundwater beneath its disposal sites and would pose a potential threat of harm to human health and the environment and harm the State's natural resources. By the early 1960s, 3M knew that groundwater beneath at least two of its disposal sites was contaminated with industrial organic chemicals that were components of its waste.

A number of technical investigations and public health crises in the early- to mid-twentieth century made clear that the disposal of wastes by landfilling could lead to the contamination of groundwater. 3M documents show that it was keenly aware of the potential for groundwater pollution, and 3M studies of potential disposal sites reflect an awareness that certain choices could slow the rate of contamination. By the early 1960s, 3M engineers had conclusively demonstrated that landfilled wastes from 3M disposal sites had polluted the groundwater in the East Metro area.

Information Generally Available from Technical Literature and Media Reporting

Long before 3M began producing PFCs and their derivative compounds, Dr. L.A. Richards proved the theory of liquid flow through unsaturated porous media (Richards, 1931). Plainly speaking, liquids will flow downward through the soil under the force of gravity and hydraulic potential. Further, in a presentation before the New York State Sewage Works Association in 1932, A.F. Dappert demonstrated that "chemical pollution can be carried for a long distance through fine sand even when the rate of groundwater flow is fairly slow" (Dappert, 1932).

In applying the work of Richards and others from the U.S. Department of Agriculture, the California State Water Pollution Control Board (SWPCB) commissioned a series of field investigation studies to determine the effects of different forms of waste disposal on groundwater quality.

- In 1952, one such study demonstrated that the infiltration and percolation of precipitation through an incinerator ash dump will leach soluble components from the dump. The soluble components will move with the infiltrating water downward under the force of gravity to the groundwater (SWPCB, 1952).
- A related study demonstrated the following year that wastewater containing soluble chemical compounds, when placed on the soil surface, can infiltrate the surface soil and transport the dissolved chemical compounds to subsurface soils and the groundwater (SWPCB, 1953).
- A 1961 SWPCB study showed that water applied to the surface of a refuse disposal site may infiltrate the fill and cause the leaching and transport of soluble components in the fill downward to reach the groundwater (SWPCB, 1961).

Thus, by the 1950s, widely available scientific and technical literature contained much information related to the movement of soluble compounds from disposed waste through the surrounding soil and into the groundwater. Therefore, 3M—as a sophisticated company with significant scientific resources—knew or should have known that compounds from its landfilled wastes could contaminate the groundwater.

In addition, 3M should have been aware by the 1950s of public health crises arising from the contamination of groundwater. For example, 3M should have been aware of a number of cases of methemoglobinemia attributed to the presence of nitrates in the groundwater. Methemoglobinemia, a very serious condition in young children often referred to as “blue baby syndrome,” results from the ingestion of water containing high concentrations of nitrate. The occurrence of many observed cases of methemoglobinemia during the period from 1947 to 1949 led to national media coverage of the disease, including further investigations conducted by the Minnesota Department of Health in 1951 (Minneapolis Star, 1948; Schmidt, 1956).

The 1951 Minnesota Department of Health study, and at least one more conducted in the decade that followed, indicated the high concentrations of nitrate in the groundwater resulted from the transport of soluble nitrates from agricultural chemicals applied to the surface soils and the disposal of industrial wastes containing nitrogen (Schmidt, 1956; Woodward et al., 1961). The 1951 study showed that domestic water supplies in Renville, Nobles, Rock, and Mower Counties—three counties in southwestern and south central Minnesota in close proximity to 3M’s Minnesota facilities—were impacted by nitrates in the shallow groundwater (Schmidt, 1956). Sampling of shallow groundwater wells demonstrated high concentrations of nitrate due to the infiltration and downward migration of the stable nitrate ion into the groundwater (Schmidt, 1956). Further, a 1959 survey of the water wells in the Village of Coon Rapids indicated that nitrates from sewage treatment had impacted groundwater to the extent that concentrations of nitrates in the groundwater posed a threat to infant health (Woodward et al., 1961).

The fact that these groundwater contamination incidents involved nitrate compounds is particularly significant because nitrate compounds are analogous to PFCs in certain respects relevant to groundwater contamination. Nitrate compounds are highly soluble due in part to the high stability of the nitrate ion in aqueous solution. The nitrate species is analogous to PFOA and PFOS in that each of these compounds exists as highly stable and highly soluble anions in aqueous solution. When dissolved in water, PFCs including the PFC acids and acid derivatives (including PFOS, PFOA, and PFBA), dissociate to form soluble anions. With negative charges, the soluble anions are repelled by the soil particles and flow freely with the water, through both the saturated and unsaturated zone. Therefore, 3M would have been able to logically conclude that the environmental behavior of the PFCs would have been similar to that of nitrates and that PFCs would be leached from the wastes, entering into the soils and groundwater.

3M’s Research and Deliberations

3M’s internal documents from the early 1960s leave no doubt that it was aware of the potential for and actual contamination of groundwater as a result of its waste disposal practices. A review of these documents demonstrates that 3M understood the potential for that

contamination to endanger human health and the environment as well as harm the State's natural resources.

In the early 1960s, for example, 3M's deliberations about the location of a new disposal site reflected an acute awareness of the potential for contaminants to reach the groundwater. In a July 13, 1960 memo from *John A. Brown* of the Geology Department to *Hans Wessel* of the Engineering Department at 3M, discussing the location of the new waste disposal site at Woodbury, *Brown* stated:

From a geological standpoint this area would not be ideal in our opinion; however, from the other merits of this location we feel it should satisfy our demands. If there is a large volume of acid waste dumped, it would be better if the area were immediately underlain by a thick formation of limestone or dolomite. This would help neutralize the acid before getting into the groundwater. . . . Other wet wastes, not neutralized nor deposited within rock or soil pore spaces, will eventually reach the water table and pollute domestic wells (3M, 1960 [3M_MN00000135]).

3M's deliberations thus reflected awareness that—absent special geological conditions—the wastes it landfilled would reach the groundwater. Unfortunately, 3M was not committed to avoiding groundwater contamination caused by its wastes. Instead, as the following quotation from *Brown's* memo indicates, 3M focused on the factors that would determine how quickly pollution would accumulate:

Eventual pollution of adjacent domestic wells will depend on time, geological conditions and rate of wet waste dumping. When waste seepage reaches the water table certain solids by that time may be rendered harmless while others will remain to pollute wells. . . . The other factor, rate of dumping, will hasten or prolong pollution. Degree of pollution will in turn indicate the time when dumping should cease. It may be that other factors will signify a time to abandon the site prior to maximum pollution (3M, 1960 [3M_MN00000135]).

Further memos by *Brown* during this period make clear that although 3M hoped to avoid rapid aquifer pollution, it clearly understood that “eventual pollution” was inevitable and the extent of it would “depend on time, rate, and the care that is exercised in dumping” (3M, 1960 [3M_MN00001421]). This report, as well as relevant deposition testimony from a 3M employee, clearly indicated that 3M knew that the underlying aquifer would, sooner or later, become polluted by dumping the wastes in open trenches (Kiester, 2017 (pp. 24-25)).

Additional 3M documents show that 3M understood that its various disposals of wastes at other sites could contaminate the groundwater. A 1969 3M document, for example, related to the disposal of wastewater treatment plant sludge at Cottage Grove noted that one of the “limitations” associated with landfilling the sludge was that “organic contaminants from the sludge may leach into the ground water at the present dumping site” (3M, 1969 [3MA00456474, -475]). Similarly, in 1970, a 3M “Authority for Expenditure” document sought permission to purchase sludge dewatering equipment in part because “[t]he present method of dumping wet sludge into landfill areas on the site cannot be continued because . . . of the potential pollution

from organic contaminants leaching into the underground water supply” (3M, 1970 [3MA00456507]).

Just as important, 3M had the understanding and resources to confirm whether its wastes were reaching the groundwater beneath Woodbury and the other sites. In July 1960, *Brown* and *R.C. Collins*—recounting a meeting including at least four other 3M employees—stated that the attendees were “again warned of the problem of polluting the underground water and it was recommended that before this site is developed, observations wells into the St. Peter and Jordan formations should be drilled and tested . . . periodically” (3M, 1960 [3M_MN00000231]). A 1962 memo likewise considered the possibility of installing a shallow boring down-slope of the first trench to “see if we are getting any subsurface pollution” (3M, 1961 [3M_MN00000138]). 3M clearly understood that borings or monitoring wells could be used to sample groundwater to analyze it for the presence of contaminants from industrial waste.

3M’s Discovery of Contaminants in Groundwater Beneath Its Disposal Sites

Analytical testing performed by 3M in 1960 and 1962 confirmed that contaminants from its industrial wastes had reached the groundwater beneath two of 3M’s Minnesota disposal sites.

At Cottage Grove, where 3M waste disposal began shortly after 3M built the facility there in 1947, 3M’s “monthly well water sampling program” was expanded in November 1960 to include “pollution indicators such as phenol, fluorides, chlorides, surfactants, etc.” A “main purpose” of the newly expanded “Monthly Water Report” was to “gain the necessary information about the spreading of contamination from local pollution sources to different wells so that sufficient warning can be obtained and adequate measures can be provided in time to assure a continuous supply of good quality process water.” Laboratory services for the effort were furnished by “[t]he analytical section of [3M’s] Central Research” department. Copies of the November 1960 report were apparently provided to at least 39 other 3M employees (3M, 1960, [3M_MN00052163]).

The results of the monthly analysis in November 1960 suggest that its waste disposal practices at Cottage Grove resulted in groundwater contamination at the site, and the author—*Dr. Joseph Ling*—explicitly acknowledges the possibility in his memo. “It has been suspected that Well No. 1 has become contaminated because of the continuous increase of alkalinity and hardness in the well water. It is also suspected that the contamination is coming from the waste disposal pond.” Although the memorandum concludes that “no conclusive statement can be made” at that point regarding the exact cause of the contamination, it does cite a finding of 0.3 ppm of “surfactant as ABS” in Well No. 1 as “positively confirm[ing] that Well No. 1 was definitely polluted” (3M, 1960, [3M_MN00052163, -164]).

Other documents from this period definitively confirm that 3M understood the connection between its waste disposal practices at Cottage Grove and groundwater contamination:

- An August 1960 memorandum by *Allan E. Miller and R.C. Collins* of the 3M Geology Department described efforts to “determine the source of the pollution of the #1 Jordan well.” It noted that “we all felt [the well] is within the sphere of activity of

our Chemolite plant.” The same memo stated that a visit to a site adjacent to “the previous two settling ponds along the Bulrington [sic] railroad tracks” revealed “a spring with an organic smell and appearance oozing from the gravel strata” there (3M, 1960 [3MA00335929]).

- A December 1961 memorandum by a 3M employee acknowledged that the wastewater pond contributed to groundwater contamination at the Cottage Grove site. *H. S. Parkinson*, citing a report by *Dr. Ling* dated July 31, 1961, indicated that “the pond does not remove any BOD and its leakage is a contributing factor to the contamination of the Chemolite well water” (3M, 1961 [3MA00456329]).
- A 3M document entitled “Phase One: Chemolite Waste Disposal Program” from no later than 1963 noted that “[e]vidence . . . indicated that the present waste pond has contaminated a nearby water supply well at our Chemolite plan site. We are convinced that contamination will gradually spread to other wells if no corrective measure is taken soon” (3M, 1962 [3MA00456330, -331]).⁸

Similarly, at Woodbury, 3M detected contamination in the groundwater beneath its disposal site no later than 1962. In spite of the warnings from the Geology Department, waste disposal began in 1960 with the disposal of wet scrap waste from 3M in earthen trenches at the site. In the spring of 1962, 3M conducted an investigation to determine the degree of penetration of contaminants from the disposed waste into the underlying soil. The investigation found that acetone had reached 75 feet below the surface—the level at which groundwater was located. Ethanol, heptane, acetone, ethyl acetate, and methyl ethyl ketone had reached 64 feet below ground surface. *Dr. Ling*, the author of the investigation report concluded that “some of our liquid waste chemicals have reached 75’ below ground within about one year of operation.” He concluded that “[i]t is our opinion the waste disposal problem has reached the point where some immediate action should be taken” (3M, 1962 [3M_MN00000220, -221]).

Other documents from the period of 3M disposals at Woodbury from 1960 to 1966 clearly indicate 3M’s awareness that contaminants from its waste were polluting the groundwater.

- A May 1962 memorandum by *R.C. Collins* stated in connection with an engineering study of the Woodbury dump site that “[i]t is the consensus of the Geology Department in regard to safeguarding the underground water supply of the area, that the company seriously consider the installation of an incinerator or other means, whereby this wet waste material will not have an opportunity to seep into the soil” (3M, 1962 [3M_MN00000380, -381]).
- A July 1963 memorandum by *K.R. Knoblock* regarding waste disposal at Woodbury described visual evidence that clay liners used by 3M in some trenches as a seal to retard seepage did not prevent the infiltration of liquids into the soil. “It appears to

⁸ Certain elements of the document’s text suggest that it was written no later than 1963. For example, the author notes that certain wastewater treatment experiments “will be continued until 1963” (3M, 1962 [3MA00456330, -331]).

the writer that this seal is ineffective,” he wrote. “[A] truck driver pointed out the fact that as soon as the waste was dumped it seeped into the ground” (3M, 1963 [3M_MN00000379]; Kiester, 2017 (pp. 55-56).

- A separate July 1963 memorandum by *M.C. Goldsmith* and *K.R. Knoblock* described the conclusion of a meeting of 3M employees during a visit to the Woodbury site as follows: “Those present concluded that steps must be taken to protect 3M interests and township residents by reducing the danger of ground water pollution by more efficient means of waste disposal” (3M, 1963 [3M_MN00000717]).

In all of these documents, there was no indication that 3M believed the groundwater would not become contaminated. To the contrary, these documents clearly acknowledge that the groundwater would be contaminated. The variety of authors and recipients of these internal correspondences show that this fact was widely understood within 3M.

Finally, given 3M’s awareness of its own PFC manufacturing and disposal practices of large quantities of PFC-containing wastes, 3M’s sampling data from the 1960s should have alerted 3M that PFCs from its PFC-containing wastes were reaching the groundwater. Even if 3M lacked the analytical ability to quantify the presence of specific PFCs, its employees observed two indicators of possible PFC contamination of the groundwater—detections of surfactants and observations of foaming:

- Surfactants were detected in the water beneath Cottage Grove and Woodbury in the 1960s. The November 1960 monthly water report for Cottage Grove, described above, noted detections of “[s]urfactants as ABS” in “Well No. 1,” “Spring,” and “Pond” at levels of 0.3, 1.3, and 1.2 ppm, respectively (3M, 1960 [3M_MN00052163, -168]). Similarly, an April 1969 3M report on the Woodbury water problem found surfactants at the level of 0.07 ppm (3M, 1969 [3MA00335191, -199]).
- At Woodbury, a 1967 investigation of the groundwater revealed the water had a “sweet, antiseptic” odor and “created a noticeable foam.” The foaming of groundwater is an important indication that surfactants, such as 3M’s fluorochemical surfactants, were potentially present. The same report concluded that “[t]he investigative work undertaken in the past eight months indicates that chemicals similar to those placed in the pits [at Woodbury] have been identified approximately 3/4 of a mile in a westerly direction from the waste pits,” at a private well (3M, 1967 [3MA00286007]).

The presence of surfactants and foaming in the groundwater—together with 3M’s knowledge that its wastes contained fluorochemical surfactants—should have alerted 3M to the strong possibility that its PFCs had reached the groundwater. While in isolation these facts would not put one on notice of PFC contamination, 3M was obviously aware that it was manufacturing large quantities of PFCs and disposing of them along with other waste in and around these sites. 3M also knew that PFCs have surfactant qualities and create foam when exposed to water. Given this knowledge, 3M knew or should have known that its PFC-containing wastes were reaching the groundwater.

3.2 3M's Failure to Exercise Reasonable Care When Disposing of Its PFC-Containing Wastes

3M failed to exercise reasonable care in connection with its disposal of PFCs and PFC-containing wastes because it disposed of them without regard for the risk of harm to human health and the environment. Further, 3M failed to exercise reasonable care by failing to prevent the continued release of PFCs into the groundwater and the Mississippi River after they were disposed of at 3M's Minnesota sites.

Counsel has informed me that in Minnesota, companies must exercise reasonable care to adequately prevent or mitigate the harm to others foreseeable from their conduct. Counsel has also informed me that the degree of care required to satisfy that standard depends in part on all of the facts and circumstances, and must be commensurate with all known or reasonably foreseeable dangers.

In my professional opinion, 3M failed to meet the standard of care needed to protect human health and the environment. As the documents discussed in this report indicate, 3M knew or should have foreseen the dangers of its PFC-disposal practices. A producer of such wastes, exercising a reasonable degree of care, would not have disposed of them in the manner that 3M disposed of them. Up to 1974 (and even later, at the Cottage Grove site), 3M disposed of PFC-containing wastes at Minnesota disposal sites despite having sufficient information that PFCs could reach the groundwater, accumulate in the environment, and cause significant harm. After 1974, at which point many of 3M's disposals at the Minnesota sites had ended, 3M did nothing to prevent the continued releases of PFCs into the groundwater from its disposal sites. 3M did not provide full and candid disclosures to regulators of the presence of PFCs in the 3M wastes, nor did 3M disclose the risks posed by its disposal of PFCs.

3M's Disposal of Industrial Waste at the Four Disposal Sites (1947-1974, 1978-1980)

3M repeatedly failed to address the readily foreseeable harms resulting from the disposal of its industrial wastes, including PFC-containing wastes, at Cottage Grove, Oakdale, Woodbury, and the Washington County Landfill from 1947 to about 1974 and at Cottage Grove from 1978 to 1980.

Continued Disposal Despite Observations of Contamination. 3M knew the characteristics of the PFCs that they were manufacturing, including the reactivity, thermal stability, solubility, and resistance to biodegradation while disposals at the Minnesota disposal sites were taking place. From the beginning of production, 3M knew that the wastes generated from the production operations contained PFCs. By the mid-1950s, 3M knew or should have known that PFCs had the potential to bioaccumulate in living organisms. By the early 1970s, 3M knew that PFCs bioaccumulated in living organisms. By the 1960s, 3M knew that the organic components of their wastes had infiltrated into the groundwater. In 1976, PFCs were found in human blood samples and by the late 1970s, PFCs were found to accumulate in Humans. In 1983, 3M conducted a study that demonstrated the teratogenic mutations in mice by PFCs. Following 3M's early knowledge of these characteristics and impacts of PFCs, subsequent studies confirmed the early findings.

Despite this knowledge, 3M continued the disposal of wastes notwithstanding evidence that 3M knew the PFCs in the wastes would leach into and migrate with the groundwater. Further, 3M knew that the PFCs leaching from their wastes would cause harm to human health and the environment. Despite this knowledge, 3M landfilled PFC-containing wastes in Minnesota through 1974 and again from 1978 to 1980. During this period, 3M did not attempt actions to prevent the release and movement of PFCs in the groundwater. In addition, 3M did not adequately notify the regulatory authorities of the presence of PFCs in their wastes.

An example of 3M's failure to exercise reasonable care during this period comes from its conduct at the Woodbury site, where it continued to dispose of its wastes even though it knew or should have known that PFCs could reach the groundwater. Despite the warnings from the Geology Department that wet scrap wastes and waste solvents would reach the groundwater, 3M began waste disposal at the Woodbury disposal site during the winter of 1960. Wet scrap waste and waste solvents along with acid-containing HF tars from 3M were disposed in open trenches at the site. In the spring of 1962, 3M conducted an investigation to determine the degree of penetration of the disposed waste leachate into the underlying soil and concluded that "some of our liquid waste chemicals have reached 75' below ground within about one year of operation" (3M, 1962 [3M_MN00000220]).

As described above, investigations at the Woodbury disposal site in the late 1960s provided more evidence that PFCs had likely migrated to the groundwater beneath the site. A 1967 3M report concluded that "[t]he investigative work undertaken in the past eight months indicates that chemicals similar to those placed in the pits [at Woodbury] have been identified approximately 3/4 of a mile in a westerly direction from the waste pits," at a private well. That investigation of the groundwater revealed "isopropyl ether or a compound similar to it" and observed that the water had a "sweet, antiseptic" odor and "created a noticeable foam" (3M, 1967 [3MA00286007]). The foaming of groundwater is an important indication that surfactants, such as 3M's fluorochemical surfactants, may be present. Despite this evidence, 3M continued to dispose of PFC-containing wastes at the Cottage Grove facility and other waste disposal sites. Further, 3M made no attempt to investigate the PFC contamination in the groundwater, much less remediate the groundwater once it knew the groundwater was likely contaminated with PFCs.

Confronted with strong evidence suggesting that toxic contaminants from its industrial wastes had reached the groundwater, 3M should have—at a minimum—halted further disposals until such time as it could confirm that there was no significant risk to human health or the environment. Its failure to do so disregarded known risks to human health and the environment. 3M continued to landfill its PFC-containing wastes in Minnesota disposal facilities incapable of handling such dangerous wastes until at least 1974, and again from 1978 to 1980. *See* Section 2.4, above.

Throughout this period, 3M continued to receive reports from researchers and other interested parties suggesting that its PFCs were capable of causing toxic effects. For example, a researcher wrote the editor of the *Fire Journal* in 1970 to describe the results of toxicity testing of 3M "Light Water" Film Forming Foam, which contained PFC surfactants. In his letter, the researcher described the testing of hardy fish with aqueous concentrations of "Light Water" ranging from 2.0% (1,250 ppm) to 0.002% (1 ppm) in ten-gallon tanks and reported that the 3M

product was “highly derogatory to marine life.” At concentrations greater than 0.006% (4 ppm), the survival time of the fish was observed to be seven days or less. The researcher concluded that “at all [tested] concentrations (including . . . 1 part per million) erratic motion, loss of stability and other visibly odd effects were present” (3M, 1970 [3M_MN02267863, -864]).

Lack of candor with regulators. During the period from 1947 to 1974, 3M displayed a lack of candor with state regulators and failed to cooperate in good faith with those regulators in matters relating to its waste disposal methods and related risks to human health and the environment. A producer of industrial wastes exercising reasonable care would not have hidden information from regulators, because regulators need sufficient information about waste disposal practices in their jurisdiction to assess environmental risks and prioritize resources for investigation and enforcement.

- 3M developed extensive knowledge of the physical and chemical properties of PFCs that would control the fate and mobility of PFCs in the environment. In addition, 3M developed information regarding the bioaccumulation and toxicity of these compounds during this period, but did not adequately disclose this information to any Minnesota regulator. As a result, regulators were not properly equipped to assess the potential harm to human health and the environment posed by 3M’s waste disposal practices. 3M’s failure to keep regulators effectively informed about the potential for harmful effects of its wastes amounted to a failure to exercise due care.
- 3M disposed of fluorochemical wastes at the Oakdale site from 1956 to 1960, but as discussed more fully below, 3M did not disclose its disposal practices to regulators during this period, even after 3M’s investigations at its other disposal sites revealed extensive groundwater contamination.

3M’s Failure to Address Continued PFC Releases (After 1974)

Failure to Remediate for PFCs in Face of Mounting Evidence of Contamination.

Even after 3M shifted many of its disposals away from the four Minnesota sites, 3M’s failure to address past and continuing releases of PFCs from the disposal sites unreasonably disregarded known dangers to human health and the environment. During this period, as Section 2.6 demonstrates, 3M’s knowledge of the harmful effects of PFCs continued to develop:

- A “Fate of Fluorochemicals” research project undertaken by 3M from 1976 to 1979 studied the effects of four important 3M fluorochemicals on aquatic life and their susceptibility (if any) to degradation by microorganisms, among other things. 3M researchers reviewing these results in 1983 and recommending additional testing concluded that “[i]n the case of fluorochemicals, structure considerations and test results to date give rise to concern for environmental safety. . . . These concerns give rise to legitimate questions about the persistence, accumulation potential, and ecotoxicity of fluorochemicals in the environment” (3M, 1983 [3MA10065465, -471, -476]).
- 3M had the capabilities to analyze groundwater sampled for PFCs in the late 1970s and early 1980s, yet they failed to analyze samples suspected of containing PFCs at

any of their disposal sites during this period (3M, 1979 [3MA00639014]; 3M, 1980 [3MA01406743, -744]).

- Further testing in 1978 on mammals such as monkeys and rats confirmed the toxicity of PFOS and PFOA (3M, 1978 [3M_MN02343995]; 3M, 1992 [3M_MN02252650]; 3M, 1978 [3M_MN02343997]).

Despite this and other evidence concerning the fate of PFCs in the environment and the risks that they posed, I have seen no evidence that 3M took any meaningful steps to reduce the risk posed by releases of PFCs from its landfilled wastes into the groundwater before the 2000s.

In my opinion, 3M's inaction, while PFCs it had landfilled continued to contaminate the environment, was not an adequate response to the known risks to human health and the environment. By allowing leachate to continue to contaminate groundwater, 3M failed to exercise reasonable care.

Incomplete and Misleading Disclosures to Regulators. On many occasions, 3M scientists and other employees provided misleading or incomplete information to regulators and independent researchers. By failing to provide information about PFCs or disposal practices, 3M frustrated outsiders' ability to determine the nature of the harms resulting from PFCs and address their causes. For example:

- 3M made a number of incomplete disclosures to the Minnesota Pollution Control Agency (MPCA) regarding its disposal practices at the Oakdale site. 3M disposed of its wastes at Oakdale from 1956 to 1960. State regulators learned about 3M's disposal of wastes there from area residents—not from 3M—some 18 years later, in 1978 (3M, 1980 [3M_MN00001391]; 3M, 1984 [3MA00296731, -732]). The MPCA requested additional information from 3M, but was told only that “the history of the site is vague” and that 3M believed that “the materials disposed of at this site were discarded product, such as rolls of tape, ‘Scotchbrite’, and some waste materials such as hardened resins and miscellaneous scrap” (3M, 1979 [3MA00284889]). A follow-up letter sent by the agency requested a response “more specific than the letter [previously] sent to the Agency” (3M, 1980 [3M_MN00000351]). Ultimately, the MPCA's investigation determined—with little help from 3M—that a number of 55-gallon drums with chemical waste were buried on site and that there were not just one, but two, disposal sites at the Oakdale site (3M, 1980 [3M_MN00001391, -393-94]). This delay in providing relevant information to the MPCA impaired regulators' ability to assess and respond to potential environmental harm resulting from 3M's waste disposal practices.
- 3M likewise failed to adequately disclose the nature and extent of its waste disposal activities at the Cottage Grove site. In 1981, the MPCA requested information about 3M's hazardous waste disposal practices at the Cottage Grove site with respect to a variety of materials, including “fluorocarbons” (3M, 1981 [3M_MN00000218]). 3M's response provided information about other wastes but omitted any information about fluorocarbons (3M, 1981 [3M_MN00000143]). Similarly, the remedial investigation reports submitted by 3M's contractor did not adequately disclose the

nature of the wastes landfilled at Cottage Grove. The 1986 final report provided a list of twenty chemicals “historically used at the Chemolite Plant” and noted that “[i]t could be expected . . . that wastes disposed of at the Chemolite Center are either combinations of these chemicals or the products of reacting two or more of these chemicals.” But none of those chemicals were PFCs or even contained fluorine (3M, 1986 [3MA00364082, -101-02]).

- Throughout this period, 3M failed to adequately disclose the results of its internal research on PFCs to federal regulators, contrary to section 8(e) of the Toxic Substances Control Act (TSCA) and other provisions of federal law. Enacted in 1976, TSCA required manufacturers to provide all information that “reasonably supports the conclusion” that a chemical “presents a substantial risk of injury to health or the environment.” In many important respects, however, 3M failed to meet this obligation. In April 1978, for example, 3M conducted tests on monkeys and rats lasting up to 90 days to determine the effects of exposure to FC-95, FC-143, FM-3422 (PFOS, PFOA, and N-EtFOSE, which metabolizes to PFOS, respectively). In light of the studies’ “indisputable” findings of “liver toxicity in the rat” and “GI toxicity in the monkey,” 3M researchers concluded that “[t]hese compounds are by no means biologically inert.” (3M, 1979 [3MA00967577]). Despite these findings, 3M decided in May 1978 not to immediately report these results to the EPA under TSCA section 8(e) (3M, 1978 [3MA10066961]).
- Indeed, in an August 21, 2000 letter from 3M’s *Katherine Reed* to Jesse Baskerville of USEPA, Dr. *Reed* disclosed that 3M had identified approximately 30 studies or pieces of information as a supplement to the TSCA section 8(e) dockets for PFOS and related fluorochemicals (3M, 2000 [3MA00847625, -626]; Reed, 2017 (pp. 88-109)). 3M ultimately paid a fine of over \$1.5 million to resolve USEPA’s allegations that 3M failed to notify USEPA of new chemicals it was manufacturing, failed to timely report substantial risk information, and other reporting violations. The USEPA noted that “several of the violations concerned reporting on perfluorinated compounds,” and that the previously unreported information was “valuable” and would “help the scientific community to better understand the presence of toxic substances in the environment” (USEPA, 2006).

Incomplete and Misleading Disclosures to Other Stakeholders. In addition, 3M failed to adequately disclose important information about its PFCs to other stakeholders such as outside researchers, 3M workers, and customers.

- In 1975, 3M employee *G. H. Crawford* reported that he had received a second telephone call from Dr. William Guy with the College of Medicine at the University of Florida concerning his findings of fluorocarbon carboxylic acids (that is, PFOA) in human blood samples. Dr. Guy was trying to understand how PFCs appeared in human blood and wanted to know whether “3M’s fluorocarbon carboxylic acids . . . were present in ‘Scotchgard’ or other items in general use by the public.” Despite 3M’s broad use of PFOA and related chemistries, *Crawford* said “we plead ignorance but advised him that ‘Scotchgard’ was a polymeric material not a FC acid” (3M, 1975 [3MA10034962, -962-63]). Therefore, *Crawford* misled the researcher to prevent the

discovery that 3M's fluorochemicals could be a source of PFCs in human blood. 3M's failure to disclose to researchers that fluorocarbon acids manufactured by 3M were indeed in wide use prevented researchers from developing an understanding of the presence of those compounds in blood samples.

- 3M demonstrated a lack of candor to its own employees as well. As a result of others finding PFCs in human blood, 3M developed an accurate analytical method to determine the concentration of organic fluorine in blood samples in early 1976 and began testing of blood samples for employees at the Chemolite plant shortly thereafter. In the annual report to the Corporate Responsibility Committee in November 1976, 3M's Central Research Analytical Department reported the concentrations of organic fluorine compounds in Cottage Grove personnel at up to 1,000 times the concentrations found in the general population (3M, 1977 [3M_MN00000479]). Yet in the minutes from a 1978 3M Fluorochemicals Technical Review Committee meeting, the committee recommended that chemical workers should not be informed until after other pertinent information including "a detailed plan for all other work related to trace fluorochemicals in blood" is completed (3M, 1978 [3MA10067042]). It was not until May 1980, however, that 3M finalized plans for informing employees, customers, regulatory bodies and other appropriate entities, were approved and set in action (3M, 1980 [3M_MN00000756]). For those who had to wait years to learn the outcome of the blood testing, 3M's actions demonstrated a careless attitude about the health and well-being of its employees as well as other stakeholders.
- Finally, 3M made a number of false representations regarding the properties of its PFC-containing products to 3M customers. For example, 3M falsely represented for years that the fluorochemical surfactants in 3M's Aqueous Film Forming Foam were biodegradable. In a 1989 Technical Information bulletin for FC-783, a variety of AFFF, 3M described the substance as biodegradable and low in toxicity. The bulletin further stated that the 3M AFFF could be treated in a biological treatment system and encouraged environmentally-conscious customers to disperse this material into the environment (3M, 1989 [3M_MN02369894, -895]). In June 1988, 3M was confronted on this issue by Boots & Coots Protective Equipment, a frustrated purchaser from California (3M, 1988 [3M_MN01315290]). Boots & Coots noted its "surprise and total shock" upon learning that the Aqueous Film Forming Foam it had purchased from 3M was not, in fact, biodegradable, causing it "embarrassment and credibility loss." Even after 3M scientist *Eric Reiner* challenged his colleagues to stop "perpetuating the myth" that fluorochemical surfactants are biodegradable later in 1988, 3M continued to advertise Aqueous Film Forming Foam as biodegradable in its 1989 Technical Information Sheet (3M, 1988 [3MA10035965]; 3M, 1989 [3M_MN02369894]). Even as late as 1994, 3M continued encouraging its customers to use AFFF while privately acknowledging that it was not biodegradable. In a 1994 trip report from a meeting with representatives at the Texas A&M Fire Training school, the fire training school representatives expressed concerns over wastewater treatment and discharge of the training wastes. The representatives also expressed concerns about persistent foam that formed in the aeration pond, which 3M attributed

in an internal memorandum to “the non-degradable or slowly degradable surfactants in AFFFs” (3M, 1994 [3M_MN02470154, -155]).

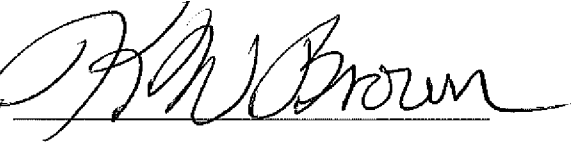
Each of these examples illustrates a way in which 3M withheld relevant information from interested third parties. Due to the nature of the industry, producers of industrial products and waste like 3M often possess information that is not generally available, such as information about the producer’s manufacturing process and waste streams, the properties of its products and wastes, and its waste disposal practices. 3M’s non-disclosure of that information to outside researchers or regulators prevented them from discovering or assessing risks to the environment and human health and thus fell short of the standard of reasonable care.

Violations of Environmental Permits. Even after 3M relocated many of its waste disposal activities away from the four Minnesota sites, it violated permits related to the handling of hazardous wastes.

For example, in 1978, after the Pine Bend landfill refused to accept wastewater treatment plant sludge and incinerator ash from the Cottage Grove plant, 3M began disposing of the sludge and ash on the Cottage Grove site without MPCA approval. Wastewater treatment plant sludge was disposed of at Cottage Grove until at least 1979 and incinerator ash until at least 1980. 3M was eventually fined in 1984, following repeated warnings, for “constructing and improperly operating a hazardous waste storage pile without a state and federal permit” (3M, 1984 [3MA00282920]; Santoro, 2017 (pp. 87-90)).

In sum, 3M failed to exercise reasonable care by dumping harmful PFC-containing wastes in a manner that would allow them to contaminate the groundwater and the Mississippi River. 3M’s violations of permit limitations, lack of candor with regulators and outside researchers, and failure to adequately divulge the characteristics of these wastes were further violations of the standard of care. Finally, as evidence of the dangers of PFCs mounted, 3M declined to take any meaningful steps to prevent continued releases from its landfilled wastes into the environment. Its refusal to adequately respond to a known risk of harm is another, independent failure to act reasonably.

Signed on this 22 day of September, 2017 in COLLEGE STATION, TX

By 

Kirk W. Brown, Ph.D.

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ATTACHMENT 1

Materials Considered

Document Name/Description	Bates Number	Date of Document
Academic Article		
Overview of analytical methods for fluorine in air, water, soil, vegetation, body fluids and tissues	3MA10017409	May-82
Pyrolyses of the Salts of the Perfluoro Carboxylic Acids by J.D. LaZerte, L.J. Hals, T S. Reid and G.H. Smith	3M_MN03412159	1/14/1953
"Fluorocarbons" by J.H. Simons		1949
"Fluorocarbons - Their Properties and Wartime Development" by T.J. Brice		1950
"Industrial and Utilitarian Aspects of Fluorine Chemistry" by H.G. Bryce		1964
"Fluorocarbons and Their Production" by J.H. Simons		1950
"Properties of Fluorocarbons" by A.V. Grosse and G.H. Cady		Mar-47
"The Electrochemical Process for the Production of Fluorocarbons" by J.H. Simons and Coworkers		Feb-49
"Fluorocarbon Chemistry" by J.H. Simons and T J. Brice		1954
"Protein-Fluoroacid Interaction Bovine Serum Albuminperfluoro-Octanoic Acid" by H.B. Klevens and E. Ellenbogen		8/2/1954
"Formation of Complexes of Fluorocarbons and Fluorocarbon Derivatives with Polar Hydrocarbons, Polar Polymers, Proteins and Polypeptides" by H.B. Klevens		11/5/1955
"Perfluorooctanoic Acid Interactions with Human Serum Albumin" by G.L. Nordby and J.M. Luck		1956
Croonian Lecutre - "Lethal synthesis" by R.A. Peters		1951
"The Physiological Action of Organic Compounds Contianing Fluorine" by B.C. Saunders		1961
"Biological Effects of Organic Fluorides" by H.C. Hodge		1963
"Structural Aspects of Monofluorosteroids" by N.F. Taylor and P.W. Kent		1965
"Public Health Engineering: The Travel of Pollution Underground" by A.F. Dappert		1932
Peters, 1951 (Croonian Lecture - Lethal synthesis)		2/28/1952
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Memo from W. McCormick to F. Ubel re Fluorochemical Testing 1980-1981	3M_MN02345153	6/25/1980
Memo from S. Sorenson to File re Meeting with Don Hagen, Central Research	3M_MN02743375	2/22/1982
Letter from L. Magill to Document Control Officer	3M_MN02327291	11/19/1980
Memo from A. Norberg to L. Krogh re FC Consultant Marshall Johnson Briefing on Teratology Studies	3M_MN02350899	11/3/1982
Memo from W. McCormick to D. Ricker re Final Report on R-3116 (Crude C.F. Cof, T-2540CoC) and FM-3452 (POSF C8F17SO@F, T-2541CoC) In Vitro	3M_MN02534652	8/20/1979
Letter from W. Weppner to K. Krause	3M_MN01251204	10/8/1999
Letter from P. Willard to E. Machuga re Food Additive Petition No. OB4197	3MA00257245	
3M Interoffice Memo from H. Bryce to R. Adams re Ecological Aspects of Fluorocarbons - your memo 7/14/71	3MA02496587	9/13/1971
3M Interoffice Correspondence from J. Todd to R. Prokop re Photolysis Studies of FC-95, FC-143 and FM-3422	3MA01409604	1/22/1979
3M Internal Correspondence from A. Welter to D. Ricker re Product Environmental Assessment	3MA00176780	6/22/1979
Email from G. Garner to V. Batroot Re: Fw: Cottage Grove drinking water - need history	3M_MN00906201	2/13/2008
Email from D. Graham to T. Baltutis re F-6002 waste water	3M_MN02465688	5/26/1999
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Memo from G. Hohenstein to Chemolite Center Plant Managers re pH control in the Phase I (inorganic) WWT System	3MA00067419	11/2/1984
Memo from HJVN to meeting attendees re Incinerator Ash and Wastewater Treatment Sludge Disposal	3MA00282200	3/22/1978
Letter from M. Ayers to R. Susag	3MA00284881	6/5/1980
Letter from D. Schnobrich to J. Braun re Oakdale Disposal Sites Remedial Action Plan: Contaminated Soils Treatment Submittal	3MA00285022	3/30/1984

Letter from D. Schnobrich to J. Braun re Oakdale Disposal Sites Remedial Action Plan: February, 1984, Work Summary	3MA00285042	3/15/1984
Letter from R. Susag to M. Ayers	3MA00325986	7/11/1980
Memo from J. McComas to EPCRA Coordinators & Environmental Operations Contacts	3MA00328955	3/26/2001
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Letter from R. Susag to L. Breimhurst	3MA00456743	5/29/1981
Memo from G. Hohenstein to M. Hill re Chemolite Phase III Sludge Disposal	3MA00456787	4/21/1982
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Email from D. Schnobrich to S. Ethier re Results of APE Testing	3MA00471586	1/31/2002
Memo from J. Allison to Multiple Recipients re URGENT NOTICE - James E. St. John, Jr. vs. 3M Company, Morgan County, Alabama Circuit Court Civil Action No. CV-02-408-SWB	3MA00479320	10/9/2002
Memo from P. Book to T. Fasking re Barrel Reconditioning Cottage Grove	3MA00606880	5/24/2004
Letter from D. Schnobrich to J. Braun re Oakdale Disposal Sites Remedial Action Plan: March, 1984, Work Summary	3MA00611644	4/10/1984
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Email from D. Schnobrich to T. Ashenmacher re C4 Manufacturing Plan	3MA00827155	10/16/2001
Email from D. Schnobrich to S. Ethier re Effectiveness of Activated Carbon at Cottage Grove	3MA00827375	3/20/2002
Email from D. Schnobrich to T. Galloway Re: CG NPDES question	3MA00827778	11/20/2002
Email from T. Galloway to D. Schnobrich re FC Screen Preliminary Results	3MA00827783	12/26/2002
Email from T. Baltutis to D. Schnobrich re CG NPDES FC - April Report	3MA00827891	5/7/2003
Email from M. Gaetz to R. Paschke RE: cg fc rpt revisions	3MA00845425	7/22/2003
Email from W. Nelson to B. Bachmeier re 3M Waste Timeline - Approximate	3MA00846332	1/26/2005
Email from F. Luden to K. Reed re Fw: Cottage Grove	3MA00847418	8/29/2005
Email from W. Neumann to G. Hohenstein Re: CG Bldg. 75 GAC System	3MA00864929	4/4/2005
Email from G. Hohenstein to T. Galloway Re: CG Station 4 FC Summary	3MA00864994	4/6/2005
Email from G. Hohenstein to G. Garner Re: Fw: website	3MA00864995	4/6/2005
Email from D. Krueger to G. Hohenstein Re: FC's at 3M Cottage Grove	3MA00866425	7/18/2005
Email from M. Gaetz to G. Hohenstein & R. Paschke re Cottage Grove Sludge	3MA00866656	8/4/2005
Email from G. Garner to F. Luden re Fluorinated Wastes	3MA00886769	1/14/2005
Email from D. Schnobrich to E. Reiner Re: Incineration of Perfluorochemicals	3MA00915146	4/25/2001
Email from D. Schnobrich to S. Ethier Re: Waste Treatment FC Analysis	3MA00915884	8/28/2001
Email from D. Schnobrich to S. Ethier re FC-95 Process Definition	3MA00915944	9/20/2001
Email from D. Schnobrich to T. Galloway Re: next cg fc question	3MA00917579	11/21/2002
Email from D. Schnobrich to D. Krueger Re: mid-year CG FC review	3MA00919094	7/9/2003
Email from T. Brooks to T. Ashemacher Re: Activated Carbon Disposal	3MA00921154	9/27/2004
Email from T. Flicker to G. Hohenstein Re: CF Bldg. 75 GAC system	3MA00923323	4/5/2005
Memo from D. Comeau & P. Book to T. Fasking re Cottage Grove Catio nion Analyses Summary	3MA00948041	3/21/2006
Letter from D. Anderson to D. Comeau re Lab Project Number: 1077316	3MA00948045	9/10/2003
Email from S. Ethier to R. Paschke, G. Hohenstein, & K. Reed re Fw: MPR Comment from Website	3MA01242570	2/23/2005
Memo from G. Hohenstein to B. Bracht & G. Weum re Incineration of Chlorinated, Fluorinated, and Corrosive Materials at the Chemolite Incinerator	3MA01542140	7/16/1984
Memo from R. Susag to R. Svanda re 3M Chmolite Plant NPDES Permit	3MA01934191	11/16/1976
Letter from B. Brott to J.M.Osborne re Interim Storage of 3M Chemolite Waste	3MA01934299	5/2/1978
Letter from T. Nunno to J. M. Osborne re Request for Additional Information on 3M Process Operations	3MA01936472	10/12/1983
Letter from R. Susag to L. Breimhurst	3M-BARR00017068	5/21/1982
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Memo from J. Gagnon to D. Schnobrich re Oakdale Incinerator Ash Oil & Grease Extracts	3MA00300324	6/27/1984
Memo re FC Investigation	3MA00057517	12/15/1981
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Letter from Dohrmann Division (Xertex) to Wade Scheil	3MA01409737	6/29/1982
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3M Internal Correspondence re Fate of fluorochemicals project	3M_MN01429711	3/8/1991
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Memo from M. Elnabarawy re Chemolite Center Environmental Monitoring Study (EMS)	3MA00281846	2/26/1992
Memo from C. Olson re Meeting Notice	3MA00751848	6/1/1992
Memo from R. Howell to C. Burton re Environmental Concerns with Fluorochemicals	3MA00323897	9/15/1992
Memo from J. Mandel to C. Burton re Medical Department projects for assessing human health effects (DRAFT)	3MA00323895	
Letter from P. McKee Pesik to A. Costello	3MA10064529	11/9/1992
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Memo from C. Burton re Fluorochemical Technical Advisory Committee Meeting - 11/12/92	3M_MN00047274	12/1/1992

Memo from J. Marhevka to Attached List re FTAC-What Needs to be Done	3MA00638311	12/15/1992
Letter from G. Adams to Document Processing Center re TSCA 8(E) Substantial Risk Notice on: Lithium Perfluorooctane Sulfonate CAS #29457-72-5 Supplement	3MA10061964	12/29/1992
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Memo from C. Burton re Fluorochemical Technical Advisory Committee Meeting - 2/16/93	3MA00244742	2/17/1993
Memo from S. Gordon to C. Burton re FC-10 Health Hazard Summary	3MA00621678	7/13/1993
Memo from S. Gordon to C. Burton re Revised FX-12 Health Hazard Summary	3MA10016783	8/6/1993
Memo from C. Burton re Meeting Minutes - Fluorochemical Technical Advisory Committee - 9/9/93	3MA10016191	9/20/1993
Memo from C. Burton re Meeting Minutes - Fluorochemical Technical Advisory Committee - 2/22/94	3MA01329221	3/12/1994
Memo from C. Burton re Meeting Minutes - Fluorochemical Technical Advisory Committee - 4/18/94	3MA00323864	4/19/1994
Memo from S. Gordont o C. Burton re Health Hazard Summary of FC-810, FX-845 and Related Materials	3MA10036988	5/26/1994
Memo from S. Gordon to C. Burton re Health Hazard Summary of FC-120	3MA10065317	6/7/1994
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Memo from J. Jensen to Recipients of the 1990 Guide of Records Retention re Guide to Records Retention	3MA00474147	Jan-90
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Email from D. Schnobrich to L. Zabel re Cordova FC Waste Management Review	3MA00000982	11/9/2001
Exhibit 186 - Email from M. Gravadahl to D. Schnobrich Re: PFOA Production	3MA00044477	5/7/2003
Exhibit 189 - Memo from T. Shannon to D. Dworak re Chemolite HF Tar Disposal -- Final Report	3MA01201767	11/18/1976
Exhibit 193 - Memo from W. Myers to G. Hohenstein re Building 15 Acid Drops to Sewer 8/27/1984 - 9/6/1984	3MA00067163	9/11/1984
Exhibit 195 Memo from J. Eberlin to J. Krall re Recovery of Perfluorooctanoic Acid (FC-26) Bottoms (FZ-155)	3MA00082742	9/4/1981
Exhibit 196 - Memo re Meeting Minutes re Processing of Fluorochemical Salts	3MA00967725	7/12/1978
Exhibit 197 - Memo from J. Krall re Status of FC-26 via POSF/I2	3MA00080881	4/22/1976
Exhibit 200 - Memo from R. Johnson to R. Ahlness & C. Hanson re No Subject	3MA10035104	7/1/1977
Exhibit 201 - 3M Interoffice Correspondence re Meeting Minutes from R. Prokop	3MA00967681	9/22/1977
Exhibit 202 - Email from D. Dworak to L. Zabel Re: C-8 Acid Scotch Guard, etc.	3MA00184620	6/7/2000
Exhibit 203 - Memo from L. Zabel to J. Gregory re: Testing issues Cottage Grove	3MA00241504	1/17/2000
Exhibit 204 - Email from P. Logan to J. Mulhausen, S. Kruse & L. Zabel re Union/Mgmt meeting concerning Bldg 15 (C8 acid)	3MA00198032	6/19/2000
Memo re Meeting Minutes June 1976	3M_MN00055527	6/22/1976
Memo re Meeting Minutes - Fluorochemicals Technical Review Committee	3M_MN00055530	4/12/1978
Memo from L. Krogh re No Subject	3M_MN00055534	10/19/1977
Memo from R. Bohon to J. Lazerte re Fate of Fluorochemicals Phase II	3M_MN00055558	5/25/1983
Memo from R. Howell to C. Olson re Fluorochemicals in the Environment	3M_MN00055574	2/5/1992
Email from R. Renner to J. Mandel re Cottage Grove Water Visuals	3M_MN00055780	3/19/2002
Email from M. Santoro to K. Reed re Meeting with MPCA Commissioner	3M_MN00055813	3/3/2004
Memo from S. Corrigan re Notes from the April 17 Meeting on Land Use Planning for the Former Woodbury Landfill Site	3M_MN00055814	4/21/1997
Email from G. Olsen to J. Mandel re Re: Discussion	3M_MN00055852	1/10/2000
Email from M. Santoro	3M_MN00055853	11/23/2005
Memo from T. Baltutis to J. Webster re Surfactants in Wastewater	3M_MN00055857	6/3/1996
Written letter to Bill	3M_MN00055858	
Email from D. Sanders re Meeting Minutes - FC Initiative Core Team - March 1, 2002	3M_MN00055859	3/13/2002
Letter from R. Bilot to M. Santoro & L. Zobel	3M_MN00055869	9/7/2001
Memo from R. Alsup to R. Anderson re Disposal of Solid "Teflon" Wastes Containing C-8 APFC	AR226-1444	8/31/1966
Memo from J. Higginbotham to B. Herbert & More re "Teflon" Scrap	AR226-1445	10/28/1966
Memo from A. Playtis to C. Alt and more re C8 at Dry Run	AR226-1475	4/12/1990
Email from B. Reilly re May	AR226-1477	5/7/2001
Memo from J. Brown to H. Wessel re Proposed Dump Site	3MA00335961	7/13/1960
3M Internal Memo from D. Siddoway, R. Rosen & B. Fong re attached report summary	3MA01201774	7/8/1974
Letter from 3M to EPA re Section 8(e) Toxic Substances Control Act (TSCA) Perfluoralkane Carboxylic Acids and Corresponding Ammonium Carboxylates	3MA01934985	3/20/1981

3M Internal Memo from R. Howell to C. Olson re Fluorochemicals in the Environment	3MA10065446	2/5/1992
Letter from 3M to EPA re Section 8 (e) Toxic Substances Control Act Potassium Salt of Perfluoroalkyl Sulfonates	3M_MN01254205	11/19/1980
Letter from J. Osborne (3M) to J. Hansmeyer (MPCA) re requested data for the boiler ash iron oxide sludge at Chemolite	3MA00276835	4/27/1978
Letter from H. Noordwyk (3M) to C. Perket re Incinerator Ash and Waste Water Treatment Sludge Analyses	3MA00296672	8/19/1977
Request for Information Pursuant to Section 104(e) of CERCLA for the 3M Company in Cottage Grove, Minnesota	3MA00277303	3/15/1993
Letter to Michael Ayers, MPCA, re: Disposal of 3M Waste Materials at Oakdale, Minnesota	3MA00284486	7/11/1980
Letter to Russell Susag, 3M, re: Request for 3M Participation in Hydrogeologic Study at Oakdale, Minnesota	3MA00284871	11/14/1980
Proposed Outline for Hydrogeologic Study at Oakdale, Minnesota	3MA00284872	11/10/1980
Letter to Michael Ayers, MPCA, re: Oakdale discussion on 11/05/80	3MA00284875	11/6/1980
Letter sent to Russell Susag, 3M, re: Land Owner Request for Surface and Ground Water Monitoring Program	3MA00284876	9/26/1980
Letter to Ruth Mancos, USPCA, re: Correspondence on Accidental Release at Cottage Grove 10/25/91	3MA00294048	4/16/1993
Letter to 3M re: Request for Information Concerning Release to Environment 12/10/92	3MA00294059	3/1/1993
Letter to Michael Ayers, MPCA, from Oakdale Active Citizens Group re: Public Meeting	3MA00610626	11/20/1980
Letter to Russell Susag, 3M, re: Complaint Concerning the Chemolite Dump Site	3MA01094939	5/12/1981
Letter to Shawn Ruotsinoja, MPCA, re: Comments to Washington County Landfill - MPCA Proposed Remedy	3MA02655957	3/14/2008
E-mail of notice for Fluorochemical Steering Committee meeting 12/15/97 and agenda	3MA00001846	12/8/1997
Minutes of Fluorochemical Steering Committee Meeting of December 15, 1997	3MA02607004	1/9/1998
Memo to DL Bacon, 3M re: Approach to Development of Documents on Fluorochemical Findings	3MA01452321	6/15/1998
Internal Correspondence re: December 10th Federal Government Affairs Planning Session with attachment	3MA02512422	12/4/1998
Email Correspondence re: Environmental Testing For PBSF (C4F9S02F) and Derivatives - Redacted	3MA01212211	5/5/1999
Email to Bill Weppner, 3M, re: Phaseout of PFOS	3MA00660232	5/16/2000
Email to Bill Weppner, 3M, re: Phaseout of PFOS	3MA00748534	5/16/2000
Email Correspondence re: EPA says it pushed 3M over Scotchgard risk	3MA01623168	5/23/2000
Email to Maruoka Kuniaki, 3M, re: Guidance for your meeting with MHW and MITI Thursday	3MA00231908	5/24/2000
Email Correspondence to 3M Specialty Materials Group re: Businessweek Article	3MA01166197	5/26/2000
Internal Correspondence re: Question & Answers from 5/16 & 5/18 Plant Meetings	3MA01623195	6/20/2000
Email Correspondence to Shawn Kruse and Tim Johnson re: PFOA Management Options	3MA00198086	6/28/2000
Email Correspondence re: PreNotice Meeting C4 Surfactants	3MA00728130	6/28/2000
Announcement – Phase out of 3M products – Decatur Plant	3MA01629628	7/5/2000
Letter to Charles Auer, EPA, re: Phase-out Plan for POSF-Based Products	3M_MN01101973	7/7/2000
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Internal Correspondence re: Meeting Minutes - FC Initiative Core Team Meeting - June 26, 2000	3MA01405013	7/19/2000
Internal Correspondence re: SMMD Bi-Weekly Manager's Meeting Minutes for August 4, 2000	3MA01146584	8/4/2000
Letter to Jesse Baskerville, EPA, re: 3M Company TSCA Section 8(e) Compliance Audit - (04/11/00)	3MA00847675	8/21/2000
Memo to Karen Lannon, EPA re: Domestic Manufacturers or Importers of PFOS Chemicals Other than 3M	3MA00847666	8/31/2000
Internal Correspondence re: Meeting Minutes - FC Initiative Core Team Meeting – 08/31/00	3MA00470649	9/13/2000
Email Correspondence to Teresa Borczik, 3M, re: PPE for new C-4 NSF intermediates/products	3MA00730723	12/14/2000
Email Correspondence to Charles Auer, EPA, re: Production of PFOS Derivatives	3M_MN01022848	3/2/2001
Email Correspondence re: Scotchgard Update - STP Pioneer Press	3MA01196565	5/28/2003
Email Correspondence to Jeffrey Rageth, 3M, re: 3M Story	3MA00496145	11/1/2004
Email Correspondence to Patrick Thornton, 3M, re: FC Phase-Out	3MA01152146	12/14/2004
Email Correspondence to Bill Nelson, 3M, re: FC Phase-Out	3MA01152147	12/14/2004
Email Correspondence to Tracy Baysinger, 3M, re: FC Phase-Out	3MA01152149	12/14/2004
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Email Correspondence to Bill Nelson, 3M, re: Lake Elmo Well Results Comments	3MA02608880	3/29/2005
Memo to Douglas Day, MPCA, re: Revised Selection of Remedy for Upgrade of the Ground Water Treatment System at the Washington County Landfill	STATE_02832319	12/13/2005
Email Correspondence to Kurt Werner, 3M, re: USEPA PFOA Stewardship Initiative	3MA00872619	2/1/2006
Email Correspondence to Howard Bergman et. al., 3M, re 3M Cottage Grove Fish Data - News	3MA01250192	3/13/2006
Email Correspondence re: Question following presentation on 3M PFC facts	3M_MN00567710	1/9/2008
Letter to Minnesota Department of Health re: ATSDR Public Health Assessment - Lake Elmo and Oakdale, Washington County. MN	3M_MN00049463	5/21/2008
Letter to Gary Hohenstein, 3M, re: 3M Grant to MPCA for Implementing Remedial Actions at the Washington County Landfill Related to Perfluorochemicals, Settlement Agreement and Consent Order Dated May 22, 2007	3MA02647222	6/25/2008
Letter to Kirk Mills, 3M, re: MPCA Comments to Review of Groundwater Quality Data, 3M Chemolite Plant, Cottage Grove, MN	3M_MN00000797	5/30/1995
Letter to Russell Susag, 3M, re: Request for Information on 3M Waste Disposal Practices at Chemolite Site	3M_MN00048827	5/4/1981
Letter to Louis Breimhurst, MPCA, re: Information on Alleged Disposal of Industrial Wastes at the 3M Chemolite Plant in Cottage Grove, MN	3M_MN00048829	5/29/1981

Letter to Jack Braun, EPA, re: Amendment to Oakdale Remedial Action Plan Submittal	3M_MN00049037	1/30/1984
Internal Correspondence re: Fluorochemical Steering Cmte Mtg Minutes 11/08/93	3M_MN00055864	11/17/1993
Email Correspondence to Vickie Batroot, 3M re: Analytical Results of Disposal Areas and Cove	3M_MN00996241	12/3/2008
Letter to Randy Minobe, 3M, re: Pollution Liability Insurance Coverage for Oakdale Site	3M_MN01313140	3/15/2006
Letter to Mary Fortado, AIG, re: Insurance Coverage for Claims Related to Oakdale Site - Redacted	3M_MN01313152	5/8/2007
Letter to Scott Stevenson, 3M, re: Insurance Coverage Related to Oakdale Site - Redacted	3M_MN01313348	6/5/2007
Email Correspondence to Dana Schnobrich et. al., 3M, re: FC Waste Initiative	3MA00000974	10/11/2001
Email Correspondence to Lynn Runnings, 3M, re: FC Waste Profile Review Meeting Minutes	3MA00000978	10/20/2001
Email Correspondence to Brad Fong, et al., re: Drying Team Meeting Minutes	3MA00056860	8/16/1999
Internal Correspondence to Bob Paschke, 3M, re: Woodbury Site Update	3MA00264370	12/16/1992
Internal Correspondence to D.W. Johnson, 3M, re: Landfill Dry Scrap Project	3MA00276827	4/24/1974
Letter to David Champion, Wash. Cnty. Admin., re: Routine Investigation of Washington County Landfill	3MA00276884	3/20/1974
Office Memo: 3M Chemolite File re: Review of Remedial Investigation to Evaluate individual Waste Disposal Sites	3MA00279473	3/13/1995
Interoffice Correspondence to R.O. Laine, 3M, re: Permit to Landfill Chemolite Sludge	3MA00280233	9/27/1974
Internal Correspondence, 3M, re: Meeting with MPCA And Phoenix, Inc. Relative To Disposal of Chemolite Sludge at the Pine Bend Landfill	3MA00280406	10/24/1979
Letter to James Hansmeyer, MPCA, re: Disposal of Wastewater Sludge and Incinerator Ash on the Chemolite Plant Site	3MA00280988	9/14/1978
Letter to Russell Susag, 3M, re: Request for Information on 3M Waste Disposal Practices at Chemolite Site	3MA00282605	5/4/1981
Letter to Jack Braun, EPA, re: Oakdale Disposal Sites Remedial Action Plan: June, 1984, Work Summary	3MA00284932	7/26/1984
Letter to Jarle Leirfallom, Commissioner of Conservation, re: Application for Permit to Appropriate Water from 3M Property in Woodbury Village, Minnesota	3MA00286355	6/26/1967
Letter to Jack Braun, EPA, re: Oakdale Disposal Sites Remedial Action Plan: August, 1984, Work Summary	3MA00611787	9/26/1984
Interoffice Correspondence to J.A. Brown, 3M, re: Methods of Improving Waste Disposal Operations at the Woodbury Township Dump Site	3MA00335827	7/30/1963
Interoffice Correspondence to J.A. Brown, 3M, re: Inspection Report of Woodbury Township Dump Site	3MA00335828	7/26/1963
Interoffice Correspondence to J.A. Brown, 3M, re: Crop Effects Due to Acid Waste Fumes at Woodbury Township Dump Site	3MA00335831	7/10/1963
Interoffice Correspondence to J.A. Brown, 3M, re: 07/09/63 Inspection of Woodbury Township Dump Site	3MA00335832	7/10/1963
Interoffice Correspondence to Geology Dept., 3M, re: Pond Sealant Study	3MA00335853	5/15/1962
Interoffice Correspondence to D.H. Cochran re: Waste Disposal Problem at Woodbury Dump Site	3MA00335855	5/14/1962
Correspondence to Hans Wessel, 3M, re: Results of Dump Site Test Borings and Recommendations	3MA00335938	7/26/1960
Memo to R.C. Johnson, 3M, re: Daily Discharge to Chemical Sewer	3MA00456289	9/13/1960
Interoffice Memo to C.W. Bentz, 3M, re: Input to Chemical Sewer Internal Chemical Operations	3MA00456322	9/26/1960
Interoffice Correspondence to H. Parkinson, 3M, re: Disposal of Sludge from Existing Waste Pond – Phase 1 Chemolite Waste Disposal Program	3MA00456347	8/17/1962
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Interoffice Correspondence to D.R. Guthrie, 3M, re: Proceed to Construct Phase II – Waste Water Treatment Facilities at Chemolite	3MA00456431	8/16/1966
Interoffice Correspondence to D.E. Peterson, 3M, re: Pond Sludge Cleaning Chemolite	3MA00456546	5/25/1973
Interoffice Correspondence to Chemolite Sludge File re: Chemolite Landfill Meeting Minutes and Status Report	3MA00456626	5/8/1978
Letter to Paul Brandt, Wash. Cnty, re: Chemolite Sludge Disposal	3MA00456710	2/19/1980
Letter to Paul Smith, Metropolitan Council, re: Chemolite Sludge Disposal	3MA00456730	7/28/1980
Letter to Michael Ayers, MPCA, re: Response to Information Request on Past 3M Chemolite Disposal Sites	3MA00456747	7/28/1981
Letter to Fred Robinette, 3M, re: NOV at the Chemolite Boiler Ash Disposal Area	3MA00456827	3/15/1983
Internal Correspondence to L.H. Hoffmeier, 3M, re: Chemolite Boiler Ash Landfill	3MA00456910	7/17/1984
Email Correspondence to Fred Palensky, 3M, re: Lake Elmo Backgrounder	3MA00550094	8/10/2005
Letter to Aaron Moran, EPA, re: Oakdale Disposal Sites Remedial Action Plan: November-December, 1984, Work Summary	3MA00611843	1/25/1985
Email Correspondence to Jerry Walker, 3M, re: Cottage Grove FC Wastes	3MA00616209	10/5/2001
Internal Correspondence to D.E. Pederson, 3M, re: Chemolite Wastewater Sludge	3MA00722190	5/22/1979
Letter to Robert Lockyear, Wash. Cnty., re: Amendment of Waste Disposed	3MA00722959	9/2/1983
Letter to Louis Breimhurst, MPCA, re: Status Report on 3M Program to Develop a Long-Range Plan for Chemolite Waste Disposal	3MA00722981	2/7/1979
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Interoffice Correspondence to H.G. Bryce, 3M, re: Comments on “The Ecological Aspects of Fluorocarbons”	3MA02496585	8/31/1971

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Interoffice Correspondence to J. A. Brown, re: Possible Improvements to Woodbury Township Site	3M_MN00000142	7/30/1963
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Letter to Robert LaBrosse, Cottage Grove Township, re: Notification of Intent to Install and Operate a Waste Disposal Facility at Chemolite Plant	3M_MN00001428	11/26/1963
Interoffice Correspondence to J.A. Brown, 3M, re: Request for Temporary Approval of Wet Scrap Dumping Permit at Woodbury Dump Site	3M_MN00001429	12/5/1963
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Letter to Harold Jones, Woodbury, re: Temporary Use of Woodbury Site	3M_MN00001431	1/7/1964
Letter to John Pilney, 3M, re: Response Actions at the Chemolite Site	3M_MN00000277	2/6/1964
Interoffice Correspondence to All 3M Lab Personnel, re: Disposal of Waste Solvents Down the Sinks	3M_MN00001432	3/2/1964
Letter to Lyle Smith, MDOH, re: Disposal of Liquid Wastes	3M_MN00001433	3/30/1964
Interoffice Correspondence to H.S. Parkinson, 3M, re: Well water Pollution-Woodbury Township Dump Site Area	3M_MN00000164	5/5/1966
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Letter to O.M. Bielenberg, Chairman, Woodbury Township Board, re: Testing of Water Samples and Cessation of Dumping	3M_MN00001438	7/22/1966
Interoffice Correspondence re: Meeting with State Health Dept. Officials on Woodbury Well Water Problem	3M_MN00001439	8/11/1966
Interoffice Correspondence re: Woodbury Township Meeting to Discuss Well Water Problem	3M_MN00001441	8/23/1966
Interoffice Correspondence to D.R. Guthrie, 3M, re: Residence Well Water Sampling in Woodbury Township and Cottage Grove Village	3M_MN00000728	10/18/1966
Letter to O.M. Bielenberg, Chairman Woodbury Township, re: Well Water Problem in Woodbury Township	3M_MN00001445	12/20/1966
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Letter to J.T. Ling, 3M, re: Approval to Discharge Water to Mississippi River with Attached Permit	3M_MN00001455	4/17/1967
Interoffice Correspondence re: Meeting Minutes Open Field Burning for Wet Scrap Accumulation at Woodbury	3M_MN00000731	11/30/1967
Interoffice Correspondence re: Open Cell Burning at 3M Disposal Site in Woodbury Village	3M_MN00001460	1/9/1968
Memorandum to C.E. Kiester, 3M, re: Woodbury Questions with attached List of Possible Questions	3M_MN00000469	1/11/1968
Letter to Harold Kernkamp, Mayor, Village of Cottage Grove re: Request for Approval, Open Cell Burning at 3M Disposal Site in Woodbury Village	3M_MN00001461	1/11/1968
Letter to Orville Bielenberg, Mayor, Village of Woodbury re: Request for Approval, Open Cell Burning at 3M Disposal Site in Woodbury Village	3M_MN00001464	1/11/1968
Letter to C.E. Kiester, 3M, re: Pumping Test on Woodbury Well No. 1 and Conclusions	3M_MN00001467	1/25/1968
Letter to John Badalich, MPCA, re: Open Cell Burning at 3M Disposal Site in Woodbury Village	3M_MN00001475	1/31/1968
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Interoffice Correspondence to D.R. Guthrie, 3M, re: Progress Report on Groundwater Problem at Woodbury Site	3M_MN00001484	5/2/1969
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Letter to R.D. Miller, MPCA re: Effluent Quality from 3M Chemolite Treatment Plant	3M_MN00001501	8/12/1970
Interoffice Correspondence to H.G. Bryce, 3M, re: Comments on "The Ecological Aspects of Fluorocarbons"	3M_MN00000145	8/31/1971
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Letter to C.E. Kiester, 3M, re: Sludge from the 3M Incinerator Plant Residue	3M_MN00001520	10/1/1971
Interoffice Correspondence to D.E. Pederson, 3M, re: Disposal of Dewatered Sludge, 3M Chemolite	3M_MN00001521	10/5/1971
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Interoffice Correspondence re: Report to Corporate Responsibility Committee on Progress - Fluorochemicals in Blood	3M_MN00000744	10/18/1977
Internal Correspondence to F.A. Ubel, 3M, re: Serum Sample Results - Trace Fluorochemicals	3M_MN00000296	11/21/1977
Interoffice Correspondence re: Chemolite Landfill Meeting Minutes and Status Report	3M_MN00000354	5/8/1978
Interoffice Correspondence, Memo to File, re: Visit to duPont Haskell Laboratories and Present 3M's Findings with Respect to Levels of Fluorochemicals in the Blood of Personnel	3M_MN00000477	6/1/1978
Letter to Jeff Harthum, MPCA, re: Response to Request for Information related to Disposal of Wastes in Oakdale, Minn.	3M_MN00000353	6/25/1979
Internal Correspondence, 3M, re: Meeting Minutes from 07/20/79 meeting with DuPont in Chicago on Fluorochemical Exposure on Employees	3M_MN00000290	8/28/1979
Letter to Arthur Potthoff, OCAW Union, re: 3M Medical Department Programs for Production and Maintenance Workers	3M_MN00001525	12/28/1979
MPCA Office Memorandum re: Meeting with 3M Representatives Concerning the Oakdale Dump	3M_MN00000348	11/10/1980
Interoffice Correspondence to F.A. Udel, 3M, re: OSHA Inspection of Chemolite 03/20/80	3M_MN00001526	3/24/1980
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Memorandum to Steve Mackay, OSHA Investigation of Chemolite Plant	3M_MN00001530	5/15/1980
Internal Correspondence to R. L. Ahlness, 3M, re: OSHA Closing Conference 05/16/80	3M_MN00001531	5/19/1980
Letter to Russell Susag, 3M, re: Request for Disposal Information from 3M at Oakdale Site	3M_MN00000351	6/5/1980
Internal Correspondence to John Verstraete, 3M, re: Disposal Information by 3M at Oakdale Site	3M_MN00000474	6/27/1980
Letter to Russell Susag, 3M re: Transmittal of Draft Report for 3M Woodbury Disposal Pits	3M_MN00000758	8/11/1980
Phone Conversation notes with Paul Hoff, MPCA, re: Release of Information to News Media	3M_MN00000333	10/10/1980
Letter to EPA re: Section 8(e) Toxic Substances Control Act - Potassium Salt of Perfluoroalkyl Sulfonates	3M_MN00001533	11/19/1980
Letter to Terry Hoffman, MPCA, re: Selection of Barr Engineering for Geohydrological Study at Oakdale Site	3M_MN00001536	12/12/1980
Letter to Russell Susag, 3M, re: Confirmation of Barr Engineering for the Geohydrological Study at Oakdale Site	3M_MN00001538	12/22/1980
Internal Correspondence to R.A. Paschke, 3M, re: Release of Barr Engineering Draft Work Plan to Newspapers and Oakdale Active Citizens Organization	3M_MN00000782	1/15/1981
Letter to T. Sherkenbach re: Notice of Future Report on 3M Composition of Wastes Disposed at the Oakdale Site.	3M_MN00000350	1/27/1980
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Single Page - Letter to EPA re: Section 8(e) Toxic Control Substances Act - Perfluoroalkane Carboxylic Acids and Corresponding Ammonium Carboxylates	3M_MN00000783	3/20/1981
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Internal Correspondence to J.J. Verstraete, 3M, re: Meeting on 10/01/81 concerning 3M Future Policy on Oakdale Disposal Site Problem	3M_MN00000343	9/21/1981
Internal Correspondence, 3M, re: Oakdale Newspaper Clippings/Sound Clips	3M_MN00000376	10/21/1981
Letter to Michael Ayers, MPCA, re: Work Plan - Hydrogeological Investigation of Disposal Areas at the 3M Chemolite Plant	3M_MN00001563	11/17/1981
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Letter to R. Rakshpal, EPA, re: Rat Fetus Eye Lens Change Not Due to Fluorochemicals	3M_MN00001570	2/12/1982
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Letter to Louis Breimhurst, MPCA, re: 3M Agreement to Fund Additional Study	3M_MN00001613	5/21/1982
Letter to Russell Susag, 3M, re: MPCA Confirmation of Additional Study with Addendum at Oakdale Disposal Sites	3M_MN00001616	6/8/1982
Letter to Gary Paulson, resident Lake Elmo, re: Analytical Testing of Water Samples	3M_MN00001618	6/25/1982
Letter to Franklin Griffith, 3M, re: Review of Developmental Toxicology Safety Evaluation Studies of FC143 in Rats	3M_MN00001622	11/10/1982
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Letter to Russell Susag, 3M, re: Draft Consent Order and Stipulation Agreement for Oakdale Disposal Sites	3M_MN00001624	4/20/1983
Letter to Gary Paulson, resident Lake Elmo, re: Proposed Market Value Reduction for Homes in Landfill Area	3M_MN00000508	6/20/1983
Letter to Michael Ayers, MPCA, re: 3M Chemolite Hydrogeological Investigation	3M_MN00001631	7/13/1983
Letter to Robert Lockyear, Washington Cnty Planning Dept., re: Disposal of Dry Scrap from 3M Facilities	3M_MN00000329	9/2/1983
Letter to J. Michael Osborne, 3M, re: Request for Additional Information on 3M Process Operations	3M_MN00001657	10/12/1983
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Internal Correspondence to R.H. Susag and M.C. Goldsmith, 3M, re: Response to MPCA Request for Historical Information for Woodbury	3MA00285582	10/13/1992
Email Correspondence to B.E. Hartz et al., 3M, re: Response to Pioneer Press Article and Water Treatment System Carbon Changeout	3MA01956169	9/17/2006
Email Correspondence to John Pilney et al., 3M, re: Notes from Meeting to Discuss the Issue of Managing Fluorochemicals at the Corporate Incinerator	3MA00994711	8/11/1999
Email Correspondence to D.M. Schnobrich et al., 3M, re: FC Waste Initiative	3MA01196704	10/11/2001
Email Correspondence to L.M. Zabel and A.E. Short, 3M, re: Disposal of Fluorochemicals at Rosemount Landfill	3MA01166950	5/1/2001
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Email Correspondence to Larry Zobel, 3M, re: Establishment of a Trace Fluorine Analytical Laboratory at 3M	3MA00032535	11/16/2000
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Email Correspondence to Laura Solem and Summer Streets, MPCA, re: FW PFC Information	STATE_1167661	5/20/2010
Email Correspondence to Todd re: Soil Stockpile Info	3M_MN00714454	11/8/2001
Memorandum to Mark Gaetz, 3M, re: 3M Water Supply Evaluation	3MA00048481	8/20/2001
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Memorandum to Mark Gaetz and Todd Fasking, 3M, re: Data Quality Objectives (DQO)-Cottage Grove FC Disposal Area	3MA00275887	7/9/2002
Email Correspondence to Todd Fasking and Tina Galloway, 3M, re: Cottage Grove Sludge Sample Results	3MA01326865	8/2/2005
FC Team Meeting Notes from 04/28/09	3M_MN00996381	4/29/2009
Email Correspondence String to Nathan Briffett, 3M, re: Use of Carbon Treatment for PFOS at 3M Gorseinon	3MA01835241	3/15/2007
Email Correspondence to Todd Fasking, 3M re: CG Carbon	3MA00948245	1/26/2004
Email Correspondence to B.A. Gibson and H.H. Harapan, 3M, re: Building 15 Roof Removal	3M_MN00705018	9/11/2008
Email Response to Tina Berg, 3M, re: Draft SD003 PFOS Limit	3M_MN00703594	9/29/2010
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Interoffice Correspondence to H.G. Bryce, 3M, re: Comments on "The Ecological Aspects of Fluorochemicals"	3M_MN00047231	8/31/1971
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Internal Correspondence to Craig Burton, 3M, re: Environmental Concern with Fluorochemicals	3M_MN00047239	9/15/1992
Internal Correspondence to S.M. Leahy, 3M, re: Fluorochemical Steering Committee Meeting Concerning Technical Sub-Committee	3M_MN00047270	7/22/1992
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Internal Correspondence to C. Bros et al., 3M, re: Transmittal of Materials Distributed at the 10/7/92 Fluorochemical Technical Advisory Committee Meeting	3M_MN00047369	3/18/1993
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Email Correspondence to Jess Eldridge, 3M, re: Well Sampling At Woodbury	3M_MN00047472	4/12/1994
Internal Correspondence to C. Bros et al., 3M, re: Review of Draft Health Hazard Summary for FC-143	3M_MN00047474	4/14/1994
Email Correspondence to S. Beach, 3M, re: TSCA 8(e) on FC-143	3M_MN00047478	7/19/1995
Memorandum to D.L. Bacon, 3M, re: Performance Evaluation of Robert Howell	3M_MN00047520	2/28/1996
Email Correspondence to Lael Pickett, 3M, re: J.F. Colbert File Notes from DuPont/3M Teleconference 1/31/97	3M_MN00047598	2/13/1997
Email Correspondence to Al Zeitz and Marylee Maendler, 3M, re: Preparation for DuPont Tox/Env'tl Meeting	3M_MN00047601	2/14/1997
Email Correspondence to William Weppner, 3M, re: Tox/Env'tl Issues – DuPont Risk Assessment	3M_MN00047604	2/27/1997
Letter to Roger Zipfel, DuPont, re: Confirmation of Term and Conditions for Analytical Testing Services by 3M to DuPont	3M_MN00047612	4/17/1997
Email Correspondence to Jean Sweeney, 3M, re: Recommendation for Appointment of James Kotsmith to Manager Health Safety and Environmental (Level 14)	3M_MN00375304	10/19/2009
Email Correspondence to Robert Paschke, 3M, re: Brief Timeline Concerning Waste Disposal	3MA01249333	1/26/2005
Email Correspondence to Robert Junnier, Weston Solutions, re: Oakdale RD/RA – Disposal Locations	3MA02662302	1/19/2009
Memorandum to Robert Criswell, MPCA, re: Response to Comments on SW-383 Permit Reissuance Application and Addendum for the 3M Waste Containment Vault	3M_MN00568252	6/20/2008
Email Correspondence to Cliff Jacoby et al, 3M, re: Oakdale Combined Discharge Sampling for June 09	3M_MN00575950	5/22/2009
Email Correspondence to Gary Hohnstein, 3M, re: Ozone Treatment of Wastewater	3M_MN00506797	12/23/2008
Email Correspondence to Nate Arthur, Wash Cnty, re: Conference Call Information Concerning 3M PFC Wastes	3M_MN00582326	11/3/2008
Email Correspondence to R. Paschke, 3M, re: CEP Priorities	3M_MN00696812	2/11/2011
Email Correspondence to D. Stang et al., 3M, re: Agenda for the Consent Order Management Team Meeting 06/17/08	3MA02631291	6/16/2008
Letter to K. Haberman re: Investigation Report 3M Company Woodbury Minnesota 02/1994	3M_MN00001678	2/25/1994
Email Correspondence to Tom Ashenmacher, 3M, re: Landfill Question related to Woodbury FC Soils	3M_MN00583859	8/18/2009
Email Correspondence to K.M. Winogrodzki re: 3M Disposal at Woodbury	3M_MN00585503	7/10/2003
Email Correspondence to Gary Hohenstein, 3M, re: Request by MPCA to Add FC to Annual Sampling at Woodbury	3MA01544777	3/6/2006
Email Correspondence to Robert Paschke, 3M, re: Historical Woodbury Residential Well Sampling	3MA00555642	4/13/2005
Email Correspondence to James Kotsmith, 3M, re: Woodbury Update	3M_MN00568709	6/30/2008
Email Correspondence to Justin Pettinelli, 3M, re: EPM – Task Addition	3M_MN00896478	12/21/2010
3M Internal Correspondence to Paul Ackerman, et al., 3M, re: Fluorochemical Steering Committee Meeting Minutes	3MA00323846	11/17/1993
Email Correspondence to Robert Paschke, 3M, re: Brief Timeline for 3M Waste Disposal	3M_MN00002947	1/26/2005
Defendant 3M Company's Corrected Non-confidential Memorandum in Support of its Motion for Summary Judgement on Plaintiffs' Negligence, Nuisance, Trespass and Punitive Damages Claims	3M_MN00020069	12/10/2008
Letter from S.Kalkstein to The editor of the Fire journal of the NFPA	3M_MN02267863	6/15/1970
Letter from H. Bryce & J. Long to C. Babcock	3M_MN02267865	ND
Memo from F. Junghans to L. Nelson	3MA00077798	9/14/1964
Letter from R. Wands	3MA00214098	11/24/1961
Memo re Teratogenicity of Two Fluorochemical Compounds in Rats (Study Numbers 980TR0008 and 680TR0010	3M_MN02327312	11/12/1980
Letter from M. Osborne to J. Hansmeyer re requested leachate and composition date for the boiler ash and iron oxide sludge	3M_MN00000166	4/27/1978
Memo from R. Susag re Meeting Notice for 9:30 AM Wednesday, April 5	3MA00281185	3/28/1978
Memo re Minutes of the Chemolite Waste Diposal and Water Conservation Committee Meeting	3MA00456259	6/9/1959
Memo from JMO to MJB re Encapsulation of Hazardous Material	3MA00280412	6/27/1979
Letter from J. Menter to R. Susag re 3/7/1979 discussions	3MA00280898	3/9/1979
Meeting Memorandum - Wednesday, December 19, 1973, 8:15 AM, 42-5W (Meeting Minutes Chemolite Sludge Thickening Project)	3MA00456549	12/20/1973
Memo from M. Goldsmith & K. Knoblock to J. Brown re Woodbury Township Dump Site	3M_MN00048254	7/10/1963
Memo from K. Knoblock to J. Brown re Woodbury Township Dump Site	3M_MN00048258	7/26/1963
Memo from C. Kiester to J. Ling re Woodbury Disposal Site	3MA00336067	4/26/1973
Letter from M. Santoro to M. Ayers re 3M Chemolite Hydrogeologic Investigation	3MA00067546	11/17/1981
Internal Correspondence from G. Hohenstein to L. Hoffmeier re Chemolite Phase I Sludge	3MA00854462	5/26/1982
Memo from C. Kiester re Investigation of Woodbury Dump Site	3M_MN00000140	12/5/1963
Letter re Response to the July 12, 2007 MPCA Request for Information on Historical Operations at the 3M Cottage Grove Facility	3M_MN01392934	11/30/2007
Letter to Document Processing Center of Office of Pollution Prevention and Toxics at EPA from W. Weppner re Information on Perfluorooctane Sulfonates and Related Compounds	3M_MN00439748	12/22/2000

Letter to R. Taber from H. Birnbaum	3M_MN01314624	6/7/1966
Letter to H. Hays (National Research Council) from R. Wands	3M_MN01314847	12/19/1963
PFOA M/S & E - 9b: Blood Levels of RF/F In Selected Employees	3M_MN01692291	6/20/1978
Internal Correspondence to L. Krogh from L. Ludford	3MA00065421	9/8/1981
Email to J. Butenhoff et al from R. Purdy re Risk to the environment due to the presnce of PFOS	3MA00242692	12/4/1998
Interoffice Correspondence from J. Belisle re Fluorochemicals in Blood	3MA00967424	11/3/1977
Memo of Meeting - July 12, 1978 re Fluorochemicals in Blood	3MA10034915	7/14/1978
Interoffice correspondence re Meeting re Results of Animal Studies at I.R.D.C.	3MA10066961	5/10/1978
Interoffice correspondence re Meeting Mintes re Fluorochemicals Technical Review Committee	3MA10066974	5/12/1978
Interoffice Correspondence from J. Belisle re Fluorochemicals in Blood	3MA10067224	7/29/1977
Letter from A. Boyden (Minnesota Mining and Manufacturing Company)	3M_MN01002429	5/11/1962
Letter from L. E. Rinehart (3M) re Ignition of Woodbury Liquid Trenches	3MA00337738	11/30/1964
Letter from F.A. Ubel regarding Fluorocarbons with article attachments	3M_MN00057505	8/25/1997
Letter from R.H. Susag to Louis Breimhurst	3MA00364080	5/21/1982
Letter to Metropolitan Waste Management Advisory Committee re Application for Reissuance of Permit SW-224 and Landfill Expansion: 3M Chemolite Intert Landfill	3MA00294816	11/3/1986
Interoffice correspondence re Meeting Minutes regarding Incinerator Ash and Wastewater Treatment Sludge Disposal	3M_MN00052172	3/22/1978
Interoffice Correspondence from H.A. Birnbum to R.R. Burford (Chemical Division)	3MA01789592	10/7/1966
Attachment to Letter of December 22, 2000 Supplemental Submission - Toxicology and Medical Surveillance	3MB00023926	12/22/2000
 Memo from J A. Brown to H. Wessel re Proposed Dump Site	3M_MN00000135	7/13/1960
Field Letter of R. C. Collins et al. re: Meeting to Discuss Merits of Woodbury Dump Site	3M_MN00000231	7/28/1960
Field Letter of R. C. Collins et al. re Woodbury Land Fill Dump and Pollution Prevention	3M_MN00000138	4/20/1961
Field Letter of Allan E. Miller and R.C. Collins	3MA00335929	8/9/1960
Memo from C. Houdek re Rebuilding and Relocation of Sewage Pond - Chemolite Plant	3MA00456329	12/1/1961
Interoffice Correspondence to D. H. Cochran, 3M, re: Waste Disposal Woodburv Dump Site	3M_MN00000220	5/14/1962
Interoffice Correspondence to J.A. Brown, 3M re: Bentonite Lined Trench at Woodbury Township Dump Site	3M_MN00000379	7/26/1963
 Memo to J.A. Brown, 3M, re: Acid Disposal Pit at Woodbury Township Dump Site	3M_MN00000717	7/10/1963
Interoffice Correspondence re: Meeting with State Health Officials relating to Woodbury Dump Site	3M_MN00001425	11/8/1963
 Letter from R. Bohon (3M) to C. Alig (Naval Ship R&D) re FC-206	3M_MN01316603	6/25/1976
Handwritten Letter regarding "ongoing situation at Cottage Grove"	3MA00243643	5/30/1990
Internal Correspondence from T. Baltutis re Surfactants in Wastewater	3M_MN00040517	11/29/1994
Memo from T. Baltutis to J. Webster re Surfactants in wastewater	3MA00457772	6/3/1996
Letter from H. Rogere (Dept of Health) to F.B. Richerson (Minnesota Mining & Manufacturing)	3MA00456232	7/15/1958
Memo re Meeting with State Health Officials Woodbury Dump Site	3MA00336224	11/8/1963
Interoffice Correspondence re Investigation of Woodbury Dump Site	3MA00335790	12/5/1963
Letter from John Jenson (Crookston Clinic) to Minnesota Mining & Manufacturing	3M_MN01314620	11/10/1967
Letter to J. Jensen (Crookston Clinic) from H. Birnbaum	3M_MN01314619	11/27/1967
Letter from J. West (Veterans Administration) to 3M General Offices	3M_MN01314623	6/12/1967
Letter from H. Birnbaum to J. West (Veterans Administration)	3M_MN01314622	6/21/1967
Letter to H. Birnbaum from L. Johns (Veterans Administration Hospital)	3M_MN01314621	8/14/1967
Handwritten Letter to 3M Chemical Division	3M_MN01235364	2/22/1969
Letter to J. Harthum re: Response to Request for Information Pertaining to Disposal of Materials at Oakdale, Minnesota	3MA00284889	6/25/1979
Letter to R. Susag re: 3M Disposal at Oakdale Site	3M_MN00000351	6/5/1980
Letter to R. Susag re: Information Request Concerning Alleged Disposal Site at Chemolite Plant Along the Mississippi River	3M_MN00000218	5/4/1981
Letter to L. Breimhurst, MPCA, re: Response to Request for Information on Waste Disposal at Chemolite Plant from 1950 to 1955	3M_MN00000143	5/29/1981
Letter to J. Baskerville re: 3M Company TSCA Section 8(e) Compliance Audit - (04/11/00)	3MA00847625	8/21/2000
Interoffice Correspondence from G.H. Crawford re Fluorocarbons in Human Blood Plasma	3MA10034962	8/20/1975
Interoffice Correspondence to J.D. La Zerte, 3M, re: Presentation to Corporate Responsibility Committee on Progress – Fluorochemicals in Blood	3M_MN00000479	10/19/1977
Memo from R. Prokop to those present re Meeting Minutes - Fluorochemicals Technical Review Committee	3MA10067042	4/12/1978
 Internal Correspondence, 3M, re: Meeting to Finalize Plans for Informing Individual and Parties of Fluorochemicals in Blood Situation	3M_MN00000756	6/3/1980
Email from D. Kriens to D. Douglas and M. Rys re 3M-PFOS and related compounds in discharge	3M_MN00043945	6/28/2005
MPCA letter from L. Christensen to J. Ling re Notice of Violation, U.S. Environmental Protection Agency and Minnesota Pollution Control Agency Hazardous Waste Violations	3MA00282920	1/11/1984
Notice of Violation from R. Massey (MPCA) to J. Ling (3M)	3MA00611640	4/3/1984
Letter from T. Dellenbach (Washington County Department of Public Health) to G. Hohenstein (3M)	3MA00296018	8/14/1987
Letter G. Wegwart (MPCA) to J. M. Osborne (3M)	3MA00296010	8/21/1987
Letter from B. Thompson (MPCA) to G. Hohenstein (3M)	3MA00278295	7/1/1988
Letter from T. Kelley (MPCA) to R. Bringer (3M)	3MA00370602	9/19/1988
Letter from Eric Reiner to Wakui Katsuhiro, re: Hydrogen Fluoride Toxicity for Plants	3M_MN04747296	6/6/1996
Bacon, Exhibit 03 - Meeting Minutes re: International Surfactant Regulations	3M_MN03423961	1/21/1976
Bacon, Exhibit 04 - FC-129 Biodegradability	3MA10035965	12/30/1988

Bacon, Exhibit 06 - Meeting Minutes	3MA10066616	6/9/1976
Bacon, Exhibit 07 - Brand Transmittal Memo from Dale Bacon to John Butenhoff	3M_MN03108995	12/30/1992
Bacon, Exhibit 10 - Memo from Robert Howell re: Trip Report - Texas A&M Fire Training School	3M_MN02470154	5/5/1994
Bacon, Exhibit 12 - Letter from C. Reich re TSCA Section 8e Decision	3MA10064459	3/20/1998
Bacon, Exhibit 13 - Memo from Donald Theissen re: Fluorochemical Steering Committee Meeting Minutes	3MA00323646	11/17/1993
Bacon, Exhibit 15 - Email from Donna Mandel re: Scientific Publication Strategy	3MA00467427	11/23/1999
Bacon, Exhibit 17 - Email from David Sanders re Manuscript	3MA00198538	9/9/2000
Bacon, Exhibit 18 - Email from Dale Bacon re: Comments on Canadian Document	3MA001095838	2/7/2003
Bacon, Exhibit 19 - Email from Dale Bacon re: Comments on Canadian Document	3MA01095856	2/10/2003
Bacon, Exhibit 21 - Email from Eric Reiner re Articles Added to Fluorochemical Bibliography	3M_MN03426043	8/1/2005
Bacon, Exhibit 22 - Email from Dale Bacon re Planning Document	3MA00546050	1/23/2006
Bacon, Exhibit 23 - Email from Dale Bacon re Stuff (attachment: the Discovery of a new class of POP)	3MA00186126	12/26/2000
Bacon, Exhibit 24 - Email from J. Giesy re Avian Toxicity Reference Values	3M_MN03014876	3/13/2007
Bacon, Exhibit 25 - Email from J. Giesy to D. Bacon re Chironomid Study	3MA01320495	2/21/2006
Bacon, Exhibit 27 - Memo from John Giesy to Dale Bacon re Follow up to February 2, 2006 meeting (revised memo)	3MA01320414	2/17/2006
Bacon, Exhibit 28 - Email from J. Giesy to D. Bacon re ES&T paper	3MA01320043	2/12/2006
Bacon, Exhibit 29 - Email from J. Giesy re paper on human blood	3MA00194174	4/7/2003
Bacon, Exhibit 30 - Email from William Nelson to Dale Bacon re PFOS in fish blood	3MA01320249	2/14/2006
Bacon, Exhibit 31 - Email from J. Giesy to D. Bacon re PFOS in the Environment	3M_MN01093981	7/25/2003
Bacon, Exhibit 32 - Email from Susan Beach to J. Giesy re Review on Report on PFCs in Minnesota	3MA01420224	6/27/2006
Bacon, Exhibit 33 - Email from J. Giesy re Looking for a post-doc candidate	3M_MN03016361	4/3/2007
Bacon, Exhibit 34 - Email from Joe Otterstetter to Rosalie Joyce re Testing	3MA00472514	3/11/2002
Bacon, Exhibit 35 - Email from Dale Bacon to Kathy Reed re Request for analysis of human blood samples of PFOS	3MA00186222	3/11/2002
Falco, Exhibit 02 - Email from Frances Shipman re 3M Phasing Out Some of Its Specialty Materials	3MA01630642	5/16/2000
Falco, Exhibit 04 - Letter from Larry Wendling re Environmental, Health And Safety Measures Relating To Perfluorooctanoic Acid And Its Salts (PFOA)	3M_MN02377792	3/13/2003
Falco, Exhibit 06 - Email from Michael Falco to Michael Nash re Assessment of Long Chain Fluorochemical Use	3M_MN04836974	1/3/2013
Falco, Exhibit 07 - Email from Gary Hohenstein to Falco re SOT Poster - Red Cross Blood Survey	3M_MN04834654	3/9/2011
Falco, Exhibit 11 - Memo re FC Customer Letter	3M_MN04738077	2/11/1999
Falco, Exhibit 12 - FC Customer Letter 1	3M_MN04738078	
Falco, Exhibit 13 - Email from Peter Koelsch re Customer Letter on PFOS and PFOA	3M_MN04777459	9/26/2007
Falco, Exhibit 16 - Email from Linda Zabel to M. Falco re Minutes from conference with Cottage Grove and Cordova	3MA00956222	5/11/2005
Falco, Exhibit 18 - Email from M. Falco to Paul Johnson re Chemical Action Plan for long-chain PFCs leads to regulatory review of TSCA regulatory options, including Section 6 rulemaking	3M_MN00848407	4/21/2010
Falco, Exhibit 19 - Memo from D. Roach to P. Riehle re Organic Fluorine Levels	3M_MN03269963	8/31/1984
Falco, Exhibit 20 - - Email from M. Falco re AFFF test results-query	3M_MN02369801	11/18/2009
Falco, Exhibit 23 - Email from Chetan Jariwala to Dan Hakes re Report on POPS	3M_MN03005883	6/18/2013
Falco, Exhibit 24 - Email from Mark Morken re SCA 8(e) final report transmittal - 05-200, MTDID 6285, PFBF	3M_MN00848670	3/10/2008
Reiner, Exhibit 02 - Letter from H. Butcher re Predisposal Treatment Requirements for Deluge Fluids	3M_MN01235852	4/25/1985
Reiner, Exhibit 03 - Letter from Jim Deyonshire re Foam Systems Testing, Beale A.F.B. California	3M_MN01315290	6/3/1988
Reiner, Exhibit 09 - Email from Eric Reiner to Dale Bacon re HFE-7100 Hydrolysis Study	3M_MN01432228	9/12/1996
Reiner, Exhibit 10 - Memo from Eric Reiner to Chou Chow re Disposal of Scrap FC Electrolyte	3MA01400474	12/30/1988
Reiner, Exhibit 11 - Email from Eric Reiner to V. Pothapragada re Questions of Fluorochemicals	3MA00967645	8/6/1980
Reiner, Exhibit 13 - ACT 603 Activated Sludge Calculators	3M_MN01433334	3/17/1997
Reiner, Exhibit 17 - Memo from R. Bohon to J. Lazerte re Fate of Fluorochemicals Phase II	3MA10065463	5/25/1983
Reiner, Exhibit 18 - Email from Eric Reiner to Misao Shiba re RCRA	3M_MN04741336	9/17/1996
Reiner, Exhibit 20 - Email from Richard Purdy re Rich Purdy's resignation	3M_MN01427584	3/28/1999
Letter to DCO re EPA Docket ID Number OPPT-2004-0001 - Laboratory-Scale Incineration Testing of Fluorotelomer-Based Polymers	3M_MN03192380	12/22/2008

Court Filings

3M's Amended Answers Attachment 1	
Defendant Responses to Plaintiff First Request for Production of Documents	5/17/2011
3M's Answers to First Set of Interrogatories	5/24/2011
3M-Responses to First Set of Requests for Admissions	12/5/2011
3M's Responses to State's Second Set of RFAs	1/9/2012
3M's Responses to 2d RFs	3/9/2012
3M's Responses to State's Third Set of RFAs	3/28/2012
3M's Responses to Fourth Set of Requests for Admission	6/6/2012
3M's Responses to State's Third Set of Interrogatories and Fourth Set of Requests for Production of Documents	10/2/2012

3Ms Responses to Second Set of Interrogatories and Third Set of Requests for Production of Documents		10/3/2012
3M's Answers to the State's 4th ROGS and 5th RFPs-c		10/10/2016
Plaintiff State of Minnesota's Sixth Set of Requests for Production of Documents		10/11/2016
3M's Responses to the State's Fifth Set of ROGs and Seventh Set of RFPs		12/20/2016
Defendant 3M Company's Objections and Responses to Plaintiff State of Minnesota's Third Set of Requests for Admission		3/28/2012
Opening Statements – Paulson et al., v. 3M Company		5/11/2009
Closing Statements – Paulson et al., v. 3M Company		6/16/2009
Defendant 3M Company's Answer to Plaintiffs' First Set of Interrogatories and Response to Plaintiffs' Third Set of Requests for Production of Documents	3M_MN00029316	9/2/2005
Defendant 3M Company's Second Amended Answers to Plaintiffs' Third Set of Interrogatories	3M_MN00031192	10/10/2006
Defendant 3M Company's Sixth Supplemental Answers to Plaintiffs' First Set of Interrogatories	3M-MN00031772	9/21/2007
Trial Testimony of Gary Hohenstein		ND
Trial Testimony of Charles Kiester, Parts I & II		ND
Trial Testimony of Katherine Reed, Parts I & II		ND
Trial Testimony of Michael Santoro Part I		ND
Trial Testimony of Michael Santoro Part II		ND
Deposition		
Deposition of Dean Dworak		2/24/2012
Vol. 1 Michael A. Santoro Deposition Transcript	3M_MN00055483	9/19/2006
Vol. 2 Michael A. Santoro Deposition Transcript	3M_MN00055743	9/22/2006
Deposition of Thomas Ashenmacher		3/7/2012
Deposition of Thomas Ashenmacher, Vol I in Maslowski et al. v 3M Company	3M_MN00039333	12/7/2012
Deposition of Thomas Ashenmacher, Vol II in Maslowski et al. v 3M Company	3M_MN00039629	12/8/2012
Deposition of Venkateswarlu Pothapragada		4/17/2012
Deposition of Mark Gaetz		4/6/2012
Deposition of Robert Howell	3M_MN00047014	11/15/2007
Deposition of James Kotsmith		2/9/2012
Deposition of Katie Winogradzki		2/22/2012
Paulson Deposition of Donny Kriens	3M_MN00048652	11/14/2006
Transcript of Dale Bacon Deposition		8/3/2017
Transcript of Eric Reiner Deposition		8/1/2017
Transcript of Michael Falco Deposition		8/23/2017
Transcript of Gordan Weum Deposition		8/28/2017
Transcript of Linda Zabel Deposition		8/15/2017
Transcript of Larry Zobel Deposition		8/22/2017
Transcript of Deanna Luebker Deposition		8/29/2017
Transcript of Kathy Reed Deposition		8/31/2017
Transcript of Charles Reich Deposition		8/30/2017
Transcript of John Butenhoff Deposition		9/8/2017
Transcript of Susan Beach Deposition		9/15/2017
Transcript of Charles Kiester Deposition		9/14/2017
Transcript of Geary Olsen Deposition		9/8/2017
Transcript of Michael Santoro Deposition		9/15/2017
Transcript of David Richfield Deposition		8/14/2012
Transcript of William Reagen Deposition		9/18/2017
Rough Transcript of Richard Purdy Deposition		9/21/2017
Dissertation		
Harvard Ellenbogen dissertation		May-49
Presentation		
Perfluooctane Sulfonate (PFOS) in the Environment	3M_MN02252789	ND
Manufacturing Drying Team Review	3M_MN02851125	11/19/1999
Basic 3M Presentation to the Cottage Grove Planning and Zoning Commission	3MA00281029	7/24/1978
Cottage Grove Wastewater Carbon Study	3MA00617241	8/13/2004
Cottage Grove FC Initiative	3MA00904546	8/4/2000
Presentation to Minnesota Pollution Control Agency	3M_MN00055818	10/15/2004
Meeting Presentation on PFOS	3MA10070188	ND
Preliminary Draft Rough Outline for Presentation to EPA	3MA10054319	4/15/1998
Presentation - #1 Operational Priority - Redacted	3M_MN00055734	ND
Board of Directors Presentations November 9, 1991 FC Issues	3M_MN00041056	11/9/1998
3M or 3M-Sponsored Peer-Reviewed Scientific Publications/Presentations Prior to the Phase-Out Announcement (1978-2000):	3MA00401223	ND
Presentation to Plant Employees - Redacted	3MA01620983	ND
3M TSCA Section (e) Compliance Audit – Meeting with EPA Toxics and Pesticides Enforcement Division	3MA00229897	9/11/2000

Calendar Entry Appointment - Presentation by Mike Santoro (Director EHS & Regulatory Affairs) focused on the Fluorochemical Initiative	3M_MN00063561	3/11/2004
FC Communications Update Meeting, Conference Call & Net Meeting, U S. and Europe	3MA01071082	10/26/2004
PFC Exposure Reduction Activities at 3M and Dyneon LLC	3M_MN00413227	ND
Fluorochemicals of Interest	3M_MN00565758	ND
Presentation "Trace Fluorine Analysis"	3M_MN00000444	ND
Presentation – Informational Meeting Cottage Grove Site Remedial Investigation (RI) & Feasibility Study	3M_MN01126135	1/31/2008
Presentation entitled "Fluorine Health/Environmental Concerns"	3M_MN00047260	ND
Presentation entitled "Environmental Fate and Effects of Fluorochemicals"	3M_MN00047522	ND
Presentation entitled "Biotransformation of Perfluorooctanoate"	3M_MN00047555	11/11/1996
Working Draft – Oakdale RI/FS Presentation	3M_MN00569903	5/12/2008
Presentation titled "Fluorochemical Decomposition Processes - Quantification and Assessment"	3M_MN04734885	4/27/2000
Bacon, Exhibit 16 - FC Environmental Strategy	3MA00554962	10/11/2004
Falco, Exhibit 03 - PPT: A 3M Core Technology	3M_MN00838987	
Falco, Exhibit 08 - Presentation to EHS Minichapter	3M_MN02373078	3/11/2004
Falco, Exhibit 09 - FC Management Update Corporate EHS Committee	3M_MN02375543	8/2/2010
Falco, Exhibit 10 - Fluorochemical EHS Background	3M_MN03639885	Aug-16
Falco, Exhibit 17 - 2012-2016 FC Reduction Targets	3M_MN04834485	
Falco, Exhibit 21 - Dyneon APFO Replacement Program	3M_MN02372412	Sep-07
Falco, Exhibit 25 - Environmental Health and Safety profile of new Perfluorinate building block versus phased out chemistry	3MA01870640	
Reiner, Exhibit 15 - Environmental Assessment Team	3MA01405333	
Public Materials		
Article in St. Paul Sunday Pioneer Press "3M waste burning test fails" by Allen Short	3MA00382051	3/11/1984
EPA Headquarters Press Release	3M_MN01095149	5/16/2000
3M and the Withdrawal of PFOS: TSCA, Product Liability, and the Precautionary Principle. 33 ELR 10062	3MA00255530	Jan-03
The Path to a Painful Choice. June 5, 2000	3MA01169364	5/26/2000
Article Entitled "Fine against 3M eyed for dumping coal ash"	3MA00281006	8/22/1978
Article titled 'Woodbury Grants Permit for Dump'	3M_MN00001424	8/10/1960
Newspaper Article – "3M Transfers Technician to Avoid Fluorochemicals"	3M_MN00001541	5/22/1981
Article "Dumpsite Excavation Poses No Danger to Residents, 3M Says"	3M_MN00000378	2/8/1984
Article "Nearby Dumpsite Chills Sales of Oakdale Homes, Owners Say"	3M_MN00000346	2/15/1984
Article "Oakdale Cleanup Is Two Years Ahead of Schedule"	3M_MN00000784	7/18/1984
2006-04-25 Consent Agreement		3/9/2006
2006-04-25 Press Release		4/25/2006
2006-04-25 TSCA Audit		6/7/1999
"'Potential exposure' forces 3M transfer" St. Paul Dispatch	3MA10035803	5/22/1981
Weekly Compilation of Presidential Documents		4/13/1970
EPA News Release: EPA Settles Case Involving 3M Voluntary Disclosures of Toxic Substances Violations		4/25/2006
Brice and Trott (U.S. Patent Office: Fluorocarbon Sulfonic Acids and Derivatives)		1/24/1956
Scholberg, et al. (U.S. Patent Office: Electrochemical Production of Fluorocarbon Acid Fluoride Derivatives)		9/13/1955
Clark et al., 1973 (PFCs Having a Short Dwell Time in the Liver)		1973
Dappert, 1932 (Public Health Engineering - The Travel of Pollution Underground)		1932
Grosse & Cady, 1947 (Properties of Fluorocarbons)		1947
Guenthner & Vietor, 1962 (Surface Active Materials from Perfluorocarboxylic & Acids)		1962
Klevens & Ellenbogen, 1954 (Protein Fluoroacid Interaction - Bovin Fluoroacid Interaction)		1954
Klevens, 1955 (Formation of Complexes of Fluorocarbons)		1955
Lewis et. al., 1976 (Incineration of Industrial Wastes at a Large Multi-Product Manufacturing Plant)		1976
Minneapolis Star, 1948		1948
Nordby & Luck, 1956 (Perfluorooctanoic Acid Interactions With Human Serum Albumin)		8/1/1955
Schmidt, 1956 (Soil Nitrification & Nitrates in Water)		1956
Simons, 1948 (US Patent 2447717)		8/24/1948
Simons, 1949 (Fluorocarbons)		1949
Simons, 1950b (US Patent 2519983)		8/22/1950
Van Noordwyk & Santoro, 1978 (Minnesota Mining and Manufacturing Company's Hazardous Waste Program)		1978
Woodward et al, 1961 (Experiences with Ground Water Contamination in Unsewered Areas in Minnesota)		1961
Spreadsheets		
AOI Info Compilation	3MA00046813	ND
Volume treated Phase 1/2	3MA00865752	ND
September-October Data	3MA00917580	ND
Spreadsheet	3MA02497423	ND
N-EtFOSE Alcohol Bibliography	3MA00491366	ND

3M Phase Out Product and Division Table	3M_MN00845627	ND
3M Phase Out Product and Division Table	3MA01620760	ND
Table containing Years 2001-2002 Production Totals for Proposed Extended Phase-Out Applications	3M_MN01101911	7/8/2000
Table containing Proposed Extended Phase-Out Use Distribution and Obligation Analysis	3M_MN01101917	7/8/2000
Table containing Year 2000 Production Base-Line for Phase-Out	3M_MN01101919	7/8/2000
Table containing Year 2000 Production Base-Line for Phase-Out	3MA00723879	7/11/2000
Current CG FC Waste Status	3MA00043765	8/21/2000
Draft – Off-Site Waste Disposal Locations – 3M Cottage Grove, Minnesota	3MA00344394	ND
Off-Site Waste Disposal Locations – 3M Cottage Grove, Minnesota	3MA00401867	ND
Chemolite Waste Survey Operation Data for Building 15	3MA00456294	12/4/1960
Chemolite Waste Survey Operation Data for Building 15	3MA00456295	1/12/1961
3M Cottage Grove FC Analysis from SD 001	3MA00918294	ND
Off-Site Waste Disposal Locations – 3M Cottage Grove, Minnesota	3MA01243198	ND
Test Data for Samples Taken from Plaintiffs' Properties	3M_MN00000712	ND
Chemolite Phase III Sludge – Composition: Analytical Data 1979 - 1982	3M_MN00000439	ND
Chart	3M_MN00067393	ND
Bacon, Exhibit 22A - Lead the Science: 2006 Project Plan	3MA00546051	2006
Falco, Exhibit 15 - Manufacturing Site C8 Emission/Exposure	3MA00955859	ND

Report

Todd Tech Report - FC 95 Photolysis Study Using Simulated Sunlight 01-09-1979	3M_MN00063785	1/9/1979
Elnabarawy Tech Report Bioconcentration of FM 3422 in Bluegill 5-17-1977	3M_MN00429098	
Mendal A. Technical Report - Analytical Methodology and Support 1-17-1979	3M_MN01645178	1/17/1979
Mendal A. Technical Report - Analytical Method FM 3422 11-15-1977	3M_MN01666463	5/18/2000
Welsh Tech Report Adsorption of FC 95 and FC 143 02-27-1978	3MA10036129	2/27/1978
Welter Tech Report - Bioconcentration 8-16-1978	3MA10078436	8/16/1978
Environmental Engineering Laboratory Aquatic Toxicity Data Sheet	3M_MN02255659	12/2/1978
Protocol for Oral Teratology Study of ... In Rats	3M_MN02327303	7/25/1980
Central Analytical Laboratory re Characterization of Decatur RF Values	3M_MN02327314	10/4/1979
Report by C. Hutt & S. Nash	3M_MN02327394	12/18/1981
Technical Report Summary re Trace Fluorochemicals in the Environment	3M_MN02343992	8/4/1978
Extent and Route of Excretion and Tissue Distribution of Total Carbon-14 in Rats after a single Intravenous Dose of FC-95-14C	3M_MN02345360	12/28/1979
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Exhibit 199 - Attachment 2 Typical Flowsheet for PFOS	3M_MN00473622	
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Waste Disposal Timeline Approximate -Dates not Verified w/ Legal - East Metro Landfill Timeline.doc	3M_MN00049958	ND
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Waste Disposal Interview Responses of Frank O'Neill, 3M retired	3MA02512657	11/3/1980
Waste Disposal Interview Responses of A.E. (Tim) Raymond, 3M retired	3MA02512663	10/30/1980
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Attachment 3 - Typical PFOA Flowsheet	3M_MN00115548	ND
Attachment 4 - Typical PFBA Flowsheet	3M_MN00115550	ND
Attachment 5 - Cottage Grove PFC Manufacturing Facility Summary of Cell Output (1976-1998)	3M_MN00115552	ND
Attachment 6 - Summary of Cottage Grove PFC Production Records	3M_MN00115554	ND
Attachment 8 - 3M Cottage Grove PFC Air Permitting History	3M_MN00473762	ND
Attachment 9 - Bibliography of Articles within 3M's Possession Related to Fluorochemical Atmospheric Fate & Transport	3M_MN00473770	11/13/2007
Attachment 10 - Cottage Grove PFC Manufacturing Plant Industrial Hygiene Sampling	3M_MN00473994	ND
Attachment 11 - Summary of Off-Site Waste Disposal Locations CG Site	3MA02525222	ND
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Technical Report Summary Final Comprehensive Report on FC 95	3MA10066577	3/15/1979
Technical Report Summary Analysis for Fluorochemicals in Blugill Fish	3M_MN01639704	5/1/1979
Incident Report Chemolite enter Foaming From Chemolite Wastewater Effluent	3MA00293930	9/10/1984
Report re Discussion of Chemolite Wastes with Mr. Johannes of the State Water Pollution Control Board	3MA00456233	8/26/1958
Status of Investigative Study Relating to an Industrial Waste Dump in Oakdale Minn.	3M_MN00001391	10/28/1980
Remedial Actions to Alleviate Groundwater Pollution from a Former Industrial Waste Disposal Site	3MA00296731	9/30/1984
Authorization to Discharge and the Construct Wastewater Treatment Facilities Under the National Pollutant Discharge Elimination System and State Disposal System Permit Program	3MA00277403	9/27/1985
Authorization to Discharge and the Construct Wastewater Treatment Facilities Under the National Pollutant Discharge Elimination System and State Disposal System Permit Program	MN.103.0969 000096	6/6/1977
US EPA Application for Permit to Discharge Wastewater	3MA00110772	2/5/2002
Hazardous Waste Generator Inspection Report	3MA00296025	6/24/1987
State Enforcement sheet	3MA00370749	5/30/1989
Laboratory-Scale Thermal Degradation of Perfluoro-octanyl Sulfonate and Related Substances	3M_MN04748576	7/3/2003
Incineration of Fluorochemicals with Perfluorooctanesulfonyl Moities	3M_MN04748860	
Central Analytical Laboratory Report No. 7230	3MA00639014	10/4/1979
Products of incomplete combustion of POSF Based Fluorochemicals	3M_MN04735973	9/30/1999
Bacon, Exhibit 01 - Interim Technical Report on Environmental Product Assessment of "Light Water" Agent	3M_MN01235783	1/30/1973
Bacon, Exhibit 02 - Technical Report Summary re Fate of Fluorochemicals in the Environment	3M_MN03424083	1/9/1978
Bacon, Exhibit 08 - Technical Report Summary re Decatur, Alabama - Tennessee River Fish	3MA01409559	5/22/1979
Bacon, Exhibit 09 - Technical Report Summary re Fate of Fluorochemicals	3MA01406743	6/23/1980
Bacon, Exhibit 14 - An Introduction to Perfluorooctanesulfonic Acid and Its Salts	3MA00347660	11/18/2003
Bacon, Exhibit 20 - Canadian Environmental Protection Act, 1999 (CEPA 1999):Ecological Screening Assessment Report on Perfluorooctane Sulfonate	3MMN02513116	Jun-16
Bacon, Exhibit 26 - Cost-benefit analysis of repeating the chronic study of the potential effects of PFOS on reproduction in quail	3MA02513752	
Falco, Exhibit 05 - Environmental Matters and Litigation	CHARTIS00021031	
Falco, Exhibit 14 - FC Emission Reduction Management Team	3M_MN02998909	
Falco, Exhibit 22 - Port St. Lucie, Florida Water Resample and Area Investigation for the Empirical Human Exposure Assessment Multi-City Study	3M_MN02375068	1/24/2001
Falco, Exhibit 26 - Acute Toxicity to Fish	3M_MN03641067	
Falco, Exhibit 27 - FC Core Team 2004 - 2005 Project/Process Priorities	3M_MN00838661	
Reiner, Exhibit 05 - Technical Report Summary re Commercial Chemical Division	3MA00467579	9/1/1983
Reiner, Exhibit 06 - Chart	3MA10078794	
Reiner, Exhibit 07 - Products of incomplete combustion of POSF Based Fluorochemicals	3MA01412201	6/2/1999
Reiner, Exhibit 08 - Notes from the Environmental Science Information Meeting 3/8-9/00	3MA02512845	
Reiner, Exhibit 12 - Technical Information AFFF FC-783	3M_MN02369894	
Reiner, Exhibit 14 - Exposure Assessment Team	3MA01405574	
Reiner, Exhibit 16 - FC Exposure Assessment Plan	3M_MN00046323	
Expert Report of Charles Andrews		9/22/2017
Interim Report #2: Determination of Serum Half-Lives of Several Fluorochemicals	AR226-1086	1/11/2002

ATTACHMENT 2

Kirk W. Brown, Ph.D.

Biographical Data

Principal Consultant; KW Brown, Environmental Consultant

Born: July 3, 1940; Bethlehem, PA

Citizenship: U.S.A.

Marital Status: Married

No. of Children: 3

Education

Ph.D., Agronomy, University of Nebraska, 1969

M.S., Agronomy/Plant Physiology, Cornell University, 1964

B.S., Agronomy, Delaware Valley College, 1962

Areas of Expertise

Fate and Movement of Salt, Oil, Metals, Organic Chemicals, Gases, Nutrients, Pesticides and Pathogens in Soil, Air and Groundwater Environments; Remediation of Metal and Organic Chemical Contaminated Soils and Groundwater; Leachability and Translocation of Metals and Organic Chemicals in the Soil Profile; Fixation and Stabilization of Metals in the Environment; Characteristics of Hazardous and Municipal Wastes; Industrial Waste Stream Identification; Classification and Fingerprinting of Waste Materials; Disposal of Municipal, Industrial, and Hazardous Waste by Land Treatment and Landfilling; Land Treatment of Sewage Sludge, Industrial Wastewater and Sludge; Bioremediation of Polluted Soils; Vapor Extraction of Soils; Toxicity and Risk-based Assessment of Soil Contaminants to Plants and Animals; Flux of Volatile Chemicals in Air; Air Dispersion Modeling; Influence of Chemicals on the Permeability of Landfill Liners; Sources and Transport of Methane; Composting of Municipal and Hazardous Waste; Design and Operation of Septic Systems; Nonpoint Source Pollution; Expansive Properties of Clay Soils; Soil Solution Sampling; Fate of Mutagenic Compounds in Soil; Mold and Fungal Growth; Reclamation of Drastically Disturbed Lands; Aerial Photo Interpretation; Soil Use and Suitability Classification; Agricultural Water Use Efficiency; Crop Water Stress; Golf Green and Athletic Field Construction; Use of Windbreaks; Soil Crusting; Gas Movement in Soil.

Academic

Professor Emeritus, Soil and Crop Sciences, Texas A&M University, 2001-Present.

Professor, Soil and Crop Sciences, Texas A&M University, 1981-2001.

Associate Professor, Soil and Crop Sciences, Texas A&M University, 1973-1981.

Assistant Professor, Soil and Crop Sciences, Texas A&M University, 1970-1973.

Visiting Scientist, Center of Plant Physiological Research, Wageningen, Netherlands, August, 1969-July, 1970.

Research Assistant, University of Nebraska, June, 1965-December, 1969.

Teaching Assistant, Cornell University, September, 1964-June, 1965.

COURSES TAUGHT**Soil Physics (Undergraduate Course No. 445) 1970-2001.**

The practical aspects of soil texture, structure, water management, as well as the theoretical aspects of soil water potentials, and the movement of water, ions, gas, and heat in the soil.

Advanced Soil Physics (Graduate Course No. 617) 1970-1988.

An in-depth study of the physical properties of soil including basic principles which regulate the dynamics of soil, water and ion movement, soil aeration, and soil thermal relationships. Equations describing these processes are presented and references to current literature are provided for outside reading.

Kirk W. Brown

Reclamation of Drastically Disturbed Lands (Graduate Course No. 615) 1979-1986.

Concepts influencing the reclamation, revegetation, and establishment of a stable ecological system on lands that have been drastically disturbed by strip mining, severe erosion, or toxic waste contamination.

Land Disposal of Wastes (Graduate Course No. 616) 1987-2001.

The theoretical and practical aspects of the land treatment and landfilling of a wide range of municipal, industrial, and hazardous wastes. Emphasis has been placed on the fate and mobility of various waste constituents in the soil and the influence of soil physical and chemical properties on constituent fate.

Short Courses Taught

Soil Science Institute (One month course) 1984, 1986, 1992, 1993

Land Treatment of Industrial Waste - Chemical Engineering Society, 1982, 1983.

Landfill Liner Design, University of Texas - 1986, 1987.

Society Memberships

American Society of Agronomy, 1970-2001

Soil Science Society of America, 1970-2001

American Chemical Society, 1970-2001

International Society of Soil Science, 1970-2001

Editorial Board

Environmental Engineering Science, formerly Hazardous Waste and Hazardous Materials. 1989-2001.

Reviewed Papers For

Soil Science Society of America Proceeding; Soil Science, Journal of Environmental Quality; Environmental Engineering Science, formerly Hazardous Waste and Hazardous Materials; ATSDR; American Petroleum Institute; Water, Air & Soil Pollution; Waste Management & Research, Water Pollution Control Federation; Water Research; Waste Management; Journal of Hazardous Materials; Archives of Environmental Contamination and Toxicology.

Elected Positions

Chairman, ASA Section A5, 1989-90

General program chairman for ASA meetings, 1973

Chairman, ASA Section A3, 1972

Committee Appointments

National Academy of Sciences, National Research Council Committee on Environmental Technologies Subcommittee on Landfills (1995-1998).

EPA Review for Risk Assessment for Petroleum Industry Hazardous Waste Listing Determination (Sept 1995).

Environmental Geosciences Advisory Committee of the American Geological Institute representing the Soil Science Society of America (1993-2000).

National Academy of Sciences (NRC) Committee on Remedial Action Priorities for Hazardous Waste Sites (1991-1994).

Texas Natural Resource Conservation Commission Committee on rules on Wastewater Treatment Plant Sludge, Water Treatment Plant Sludge and Septic Tank Sludge Disposal (1992-1993).

Texas Water Commission Committee to Develop Regulations on the Land Application of Sewage Sludge (1992-93).

Faculty of Toxicology Executive Committee, Texas A&M University (1990-93).

Texas Governor's Infrastructure Committee on Free Trade (1991).

Oklahoma Corporation Commission on Land Application of Oil Field Drilling Waste (1990-1991).

Texas Department of Health Ad Hoc Committee for Revising the Construction Standards for On-Site Sewage Facilities (1989-90).

EPA Hazardous Waste Center Review Panel (1988).

Kirk W. Brown

National Science Foundation, Environmental Engineering Div., Review Panel (1987-1995).
Texas Dept. of Health Septic Disposal Regulations Revision Panel (1987).
Advisory Panel to Chicot Aquifer Management Project (Louisiana). McNeese State University, LA (1987-1990).
ASA Editorial Committee "Reaction and Movement of Organic Chemicals in Soils" 1987.
Advisory Panel to U.S. Congressional Office of Technology Assessment (OTA) on An Assessment of the Effectiveness of the EPA in Identifying, Prioritizing and Cleaning Up Hazardous Waste Sites (1987-1995).
Organizing Committee for SSSA Workshop on Utilization, Treatment and Disposal of Waste on Land (1985).
Panel to Write Research Needs for Hazardous Wastes Treatment and Disposal for National Science Foundation. Drexel University, PA (1986).
EPA Technical Advisory Panel on the Adequacy of Ground Water Monitoring at Hazardous Waste Landfills (1985).
Panel to Write the Mutagenicity Sample Preparation Protocol for EPA (1984).
EPA Panel to Review the Acceptability of Landfill Disposal of Sewage Sludge (1984).
Office of Water Regulations and Standards Committee on Municipal Sludge Landfilling to Advise EPA on the Pollutants which should be Regulated for Various Disposal Options and the Methods or Procedures to be Used for Regulating such Pollutants (1984).
Advisory Panel to U.S. Congressional Office of Technology Assessment (OTA) to Determine the Effectiveness of Current Programs to Clean Up Uncontrolled Hazardous Waste Sites (1983-84).
EPA Science Review Panel for Environmental Engineering Research Grants (1982-1998).
United States Environmental Protection Agency Land Treatment Task Force (1981-1985).

Significant Reports Resulting from Committee Assignments

National Research Council. 1999. "Groundwater & Soil Cleanup, Improving Management of Persistent Contaminants".
National Research Council. 1994. "Ranking Hazardous Waste Sites".
Office of Technology Assessment, Congress of the United States of America. 1989. "Coming Clean, Superfund Problems Can be Solved".
Office of Technology Assessment, Congress of the United States of America. 1985. "Superfund Strategy".

University Committees

Texas A&M University Environmental Safety and Health Committee (1987-90).
Council of Principal Investigators, Texas A&M University (1986-1990).
Texas Agricultural Experiment Station 5-Year Planning Board.
Texas A&M University Faculty Forum (1979-82).
Texas Agricultural Experiment Station Grant Support Committee (1976-77).

Awards

Texas A&M University College of Agriculture Award for Excellence in Teaching (1995)
Texas A&M University System Award for Excellence in Graduate Teaching (1988)
ASA Environmental Quality Research Award (1988)
Fellow - Soil Science Society of America (1987)
Fellow - American Society of Agronomy (1986)
Distinguished Alumni Award, Delaware Valley College (1986)
Superior Achievement Award for Research, Soil and Crop Sciences Department, Texas A&M University (1986)
Pollution Engineering Magazine Award of Merit for Outstanding Editorial Contribution "The Case for Aboveground Landfills" (1984)

Books Authored

Hazardous Waste Land Treatment. 1983. Butterworth Publishers, 10 Tower Office Park, Woburn, MA 01801.
Reactions and Movement of Organic Chemicals in Soils. 1989. Sawhney, B. L. and K. W. Brown. SSSA/ASA Publishers, SSSA Special Publication No. 22, 494 pgs.

Professional Experience Outside the United States

Visiting Scientist at Center of Plant Physiological Research, Wageningen (1969-70).

Kirk W. Brown

Testimony Before Legislative Bodies

Texas House of Representatives - Environmental Affairs Committee, April 1987. Testified on the need for legislation to set up a waste management plan for the state.

Texas Governor's Taskforce on Oil Spills, February 1985. Testified on the fate of oil spill debris and disposal technology options.

Texas Governor's Taskforce on Hazardous Waste, November 1984. Testified on the effectiveness of landfills for disposal technology.

Texas Governor's Taskforce on Hazardous Waste, June 1984. Testified on the impact of organic chemicals on the permeability of soils.

U.S. House of Representatives - Science and Technology Committee, November 1982. Testified on the adequacy of EPA's liquid management system to protect groundwater at hazardous waste landfills.

Texas House of Representatives - Environmental Affairs Committee, April, 1982. Testified on the impact of organic chemicals on the permeability of clay liners.

Consulting

Founder and President of K. W. Brown and Assoc., Inc., (1980- 1991). Chief technical consultant to K. W. Brown Environmental Services (1991-1999), SI Group, LP (2000-2009), TTI Environmental Consultants (2009–2011), and as an independent consultant (2011-Present). Past consulting activities have included assignments with Dupont, Alcoa, General Motors Corporation, Minnesota Mining & Manufacturing, WR Grace, Owens Corning, Union Pacific Railroad, Chevron, Shell, Exxon, Texaco, Arco, Sunoco, El Paso Products, New York Attorney General's Office, Illinois Attorney General's Office, Minnesota Attorney General's Office, Minnesota Pollution Control Administration, U.S. EPA, U.S. Army Corps of Engineers, and U.S. Dept. of Justice.

Consulting activities have included consultations on the cleanup and disposal of wastes, the impacts of hazardous waste on the environment, assessment and remediation of exploration and production releases, the design of hazardous waste landfills and solid waste management units, and the fate and mobility of chemicals in the soil, groundwater, and air, as well as, providing expert testimony at permit hearings, mediation hearings, civil suits, and before legislative bodies on these topics. My expertise has been utilized for site assessments, data review and interpretation, the study of fate and transport of contaminants in the environment, waste management activities, historical oilfield and landfill operations, and other related environmental matters. I have reviewed and interpreted a large quantity of analytical data for air, soils and groundwater, as well as boring logs, field logs, technical reports, and other information related to the environmental conditions of a site. I have prepared and reviewed remedial action plans for hundreds of sites including sites contaminated with metals, organic chemicals, pesticides, biological pathogens and petroleum production wastes. I have designed and implemented remedial actions at numerous hazardous waste sites under the auspices of both state and federal regulatory authorities.

As a consultant, I have evaluated or analyzed hazardous substances in industrial waste streams from numerous industries including the lumber and paper industries, the printing industry, chemical manufacturing industry, petroleum exploration, production, processing and refining industries, plastics and rubber products industry, leather tanning and finishing, metal smelting and finishing, electric utilities, and the electronic components manufacturing industry, among others. I have conducted extensive research on the hazardous substances contained in municipal and household waste with a special emphasis on the fate and mobility of these constituents in the environment after disposal in municipal solid waste landfills. I have provided evaluations and assessments for numerous waste disposal and landfill sites including the following: Love Canal Landfill, Lowrey Landfill, Helen Kramer Landfill, Junker Landfill, Lemberger Landfill, Laurel Park Landfill, Beacon Heights Landfill, RCA-Buzby Landfill, Valleycrest Landfill, Boarhead Farms, Pennsauken Landfill, Lone Pine Landfill, Ft. Bend County Landfill, and Sinton Landfill, among others. In addition, I have also provided expert testimony for civil actions involving the following Superfund sites: Hardage Criner, Montana Pole, National Gypsum, Brio/Dixie Oil Processors, Sikes' Pits, Turtle Bayou, Metal Bank of America, Tar Creek, and the West Dallas Lead Site.

Guest Lectures

Dewatering of confined dredge spoil areas. In: *Second International Symposium on Dredging Technology*. BHRA Fluid Engineering, Cranfield, Bedford, England. Paper G1:1-24. (1977).

Kirk W. Brown

Revegetation of drastically disturbed lands. Texas A&M Lignite Symposium. April 17-18. (1980).

Impact of surface mining on water quality. Texas A&M Lignite Symposium, April 17-18, 1980.

Factors influencing the biodegradation of API separator sludges applied to soils. Presented at the Seventh Annual Research Symposium at Philadelphia, PA. March 16-18, 1981.

Land treatment of industrial hazardous wastes. Presented at a Symposium and Workshop on Hazardous Waste Management. Louisiana State University, November 16-20, 1981.

Effect of organic chemicals on clay liner permeability. A review of the literature. Presented at the Sixth Annual Research Symposium at Philadelphia, PA. 1981.

Land disposal of oily wastes. Brest, France. August, 1982.

Influence of organic liquids on the permeability of clay soils. Harwell, Great Britain. July, 1982.

Use of sewage effluent for irrigation. Adelaide, Australia. June, 1982.

Influence of organic liquids on the integrity of liners to pits, ponds, lagoons and landfills. Waste Water Analysts Assoc., Houston, TX. November, 1982

Reclamation of strip mined lands. Sierra Club, Austin, TX. November, 1982.

Waste disposal on range land. Range Science Department, Texas A&M University. College Station, TX. November, 1982.

The politics of hazardous waste disposal. Political Science Department, Texas A&M University. College Station, TX. October, 1982.

The treatment and disposal of hazardous, industrial and toxic waste. American Society of Civil Engineers, Austin, TX. September, 1982.

Effect of organic fluids on the permeability of clay soil liners. Presented at the Eighth Annual Research Symposium at Ft. Mitchell, Ky. March 8-10, 1982.

The fate of mutagenic compounds when hazardous wastes are land treated. Presented at the Eighth Annual Research Symposium at Ft. Mitchell, Ky. March 8-10, 1982.

The influence of chemicals on the permeability of clay liners. Presented at Hazardous Waste Conference, Chicago, Ill. June 28-29, 1983.

Cleanup of chemicals spilled on soils. Presented at the Texas Agricultural Extension Service Conference, Houston, Texas. June 23, 1983.

The reclamation of strip mined land. Presented at Texas Environmental Coalition in Austin, Texas Jan. 22, 1983.

The influence of selected organic liquids on the permeability of clay liners. In: D. W. Shultz (ed). Land Disposal, Incineration, and Treatment of Hazardous Waste. Proceedings of the 9th Annual Research Symposium at Ft. Mitchell, Ky. May 2-4, 1983.

Panel on land treatment of sewage sludge. EPA Workshop on Sewage Disposal, Denver, CO. March 1983.

Land disposal of hazardous liquids. Waste Management Conference, Houston, TX. February 1983.

Alternatives to land disposal of waste. Dept. of Agriculture Seminar, University of Houston. Sept. 10, 1984.

How to write a successful research proposal. Soil Science Graduate Seminar, Soil & Crop Sciences Dept, Texas A&M University, Sept. 19, 1984.

The advantages of above ground disposal. Waste Tech Conference, Houston, October 30, 1984.

Potential groundwater implications of surface storage of toxic substances. Groundwater Symposium, Gunter Hotel, San Antonio, Texas. October 30, 1984.

Clean up of spills; Alternative disposal methods. Geotechnical Engineering for Waste Disposal Symposium, University of Texas, Austin. November 2, 1984.

The properties of soils and containment of waste. Environmental Engineering Seminar, Civil Engineering Dept., Texas A&M University, College Station, 1984.

Carbon dioxide flux at the earth's surface. Texas A&M University, College Station, February 1984.

Above ground landfills in hazardous waste management schemes. National Conference and Exhibition on Hazardous Waste and Environmental Emergencies. Houston, Texas, March 1984.

Fate of mutagens applied to soil. Environmental Toxicology and Pharmacology Seminar. Texas A&M University, College Station, March, 1984.

Permeability of compacted soils to solvents mixtures and petroleum products. Presented at the Tenth Annual Research Symposium at Cincinnati, Ohio, April 1984.

Simulation of Potential Rainfall Conservation from Two Cross-Diked Furrow Bed Designs. Texas A&M University, College Station. February 1984.

Kirk W. Brown

The soil scientist as a consultant. Soil Science Graduate Seminar, Panel Discussion. Soil & Crop Sciences Dept, Texas A&M University, Sept. 12, 1984.

Land disposal of hazardous waste. Agricultural Engineering Dept. Graduate Seminar, Agricultural Engineering Dept., Texas A&M University. Sept. 13, 1984.

Geotechnical engineering for waste disposal projects. University of Austin, Texas, October 1985.

Monitoring the unsaturated zone. Presented at the National Specialty Conference. Land Treatment: A Hazardous Waste Management Alternative, April 16-18, 1985, Austin, Texas.

Ability of sorbents to retain liquids in landfills, 10th Annual American Organization of Analytical Chemists' Spring Workshop, Dallas, Texas April, 9-11, 1985.

Geotechnical engineering for waste disposal projects. University of Austin, Texas, October 1986.

Potential health effects of hazardous waste contaminants in groundwater. Public Health Grand Rounds, University of Pittsburgh Graduate School of Public Health. January 23, 1986.

Geotechnical engineering for waste disposal projects. University of Texas, Austin, October 1986.

Influence of organic liquids on the hydraulic conductivity of soils. University of Cambridge, United Kingdom. September 9-11, 1987.

Design and construction of the growth media in golf greens, Montreal, Canada, 1987.

Groundwater pollution problems associated with fertilizers, pesticides, and leaking storage tanks. Pro Show, Dallas, November 1987.

Mutagenic testing of hazardous waste sites. Southwest Environmental Mutagenic Society, Houston, November 1987.

The use of lime for waste disposal and treatment of hazardous waste contaminated sites. National Lime Association, Phoenix, AZ, April 1987.

A soil scientist as an expert witness - Presented to the Soil Survey and Land Resource Workshop. February 19, 1988.

Guest lecture to Rio Brazos Audubon Society - May 2, 1988.

Presentation to the Texas Association of Milk, Food and Environmental Sanitarians, June, 1988.

Guest lecture to Range Science Ecology and Land Use class. Dept. of Range Science, Texas A&M University, Nov. 18, 1988.

Hazardous Waste: A general overview. Agricultural Engineering, Environmental and Water Resources Engineering and Texas Water Resources Institute Seminar, Texas A&M University, College Station, TX. January 1989.

The need for community recycling. Environmental Organization, Civil Engineering Dept., Texas A&M University, College Station, TX. February 1989.

Superfund sites: The problems and the solutions. Industrial Hygiene Seminar, Texas A&M University, College Station, TX. February 1989.

Hazardous waste disposal on the Gulf Coast Texas. Texas ASA Annual Meeting. Galveston, Galveston County, Texas, February 1989.

New technologies for liners - Presented at the Conference on Prevention and Treatment of Groundwater and Soil Contamination in Petroleum Exploration and Production. Calgary, Alberta, Canada, May 9-12, 1989.

Guest Lecture to Range Science Ecology and Land Use Class: Dept. of Range Science, Texas A&M University, College Station, TX. Oct. 4, 1989.

Ongoing and future research in the geowaste area. Presented to the Geo Waste Group Meeting, Civil Engineering Dept. Texas A&M University, Nov. 1, 1989.

Waste disposal: where do we go from here? Presented to the MSC Great Issues: Environmental Symposia. Texas A&M University, College Station. Nov. 7, 1989.

Innovative technologies from the 1990s in environmental matters. Presentation to South Texas College of Law Environmental Law Symposium, January 17, 1990.

Waste disposal, past, present, and future. Presented at the seminar entitled "Disposing of Hazardous Materials". MSC, Texas A&M University, College Station, TX January 1990.

Panel discussion session at Vertisol Management Workshop: International Collaboration in Research, Training and Extension. Texas A&M University, College Station, June 25-29, 1990.

Municipal waste disposal - where do we go from here. Presentation to Texas Environmental Action Coalition, Texas A&M University, College Station, TX. Sept. 5, 1990.

Presentation to the Texas Section of American Society of Agricultural Engineers, College Station, TX. October 11, 1990.

Kirk W. Brown

Presentation on golf green construction at Canadian Golf Superintendents Association Conference, Montreal, Canada. Dec. 11, 1990.

Environmental Soil Science and Technology. Presentation to the 1991 Texas Agric. Experiment Station Conference - Environmental Soil Science Session, College Station, TX. January 1991.

Movement of pesticides to groundwater. Presentation to the Texas Association of Agricultural Consultants. Austin, Texas, January 21, 1991.

Movement of pesticides to groundwater. Presentation to the Texas Agricultural Extension Service Conference for Producers, Austin, TX, January 25, 1991.

Pesticide rinsate disposal options. Presentation to the Research Center Administrators Society meeting, Dallas, Texas February 3-5, 1991.

Movement of pesticides to groundwater. Presentation to the Texas Agricultural Extension Service Conference for Grounds Keepers. Round Rock, Texas, February 21, 1991.

Liners for Hazardous Waste Sites. Presented at the Hazardous Waste Management Division's Lecture Series. U.S. Environmental Protection Agency, Region 6, 1445 Ross Ave., Suite 1200, Dallas, TX. 1991.

Decontamination of polluted soils. Presented at the Second International Conference on the Biogeochemistry of Trace Elements, Taipei, Taiwan, Republic of China. Sept. 5-10, 1993.

Using plants to reclaim contaminated sites. Crop Science Seminar. Soil & Crop Sciences Dept., Texas A&M University, College Station, TX, October 24, 1994.

Vadose zone modeling of the fate and movement of volatile contaminants, Geological Society of America, South-central Section Conference, Austin, TX, March 12, 1996.

Banning of liquid wastes from landfills - development of the technical data and the regulations, South Texas Environmental Conference, Corpus Christi, TX, March 29, 1996.

The science behind RCRA/CERCLA enforcement (Part II), Science For Environmental Attorneys, Denver CO, November 6, 1997.

Scientific Publications

1. Allen, L. H. and K. W. Brown. 1965. Shortwave radiation in a corn crop. *Agron. J.* 57:575-580.
2. Brown, K. W. and W. Covey. 1966. The energy budget evaluation of the micrometeorological transfer processes within a corn field. *Agri. Meteorol.* 3:73-96.
3. Brown, K. W. and L. J. Wright. 1967. Comparison of momentum and energy balance method of computing vertical transfer within a crop. *Agron. J.* 59:427-432. C701.
4. Brown, K. W. and N. J. Rosenberg. 1968. Errors in sampling and infrared analysis of CO₂ in air and their influence in determination of net photosynthetic rate. *Agron. J.* 60:309-311.
5. Brown, K. W. 1969. A model of the photosynthesizing leaf. *Phys. Plant* 22:620-637.
6. Brown, K. W. and N. J. Rosenberg. 1969. Computer program for plotting time dependent meteorological data. *Agric. Meteorol.* 6:463-464.
7. Brown, K. W. and N. J. Rosenberg. 1970. Concentration of CO₂ in the air above a sugar beet field. *Mo. Weather Rev.* 98:75- 82.
8. Brown, K. W. and N. J. Rosenberg. 1970. The influence of leaf age, illumination and upper and lower surface differences on stomatal resistance of sugar beet (*Beta vulgaris*) leaves. *Agron. J.* 62:20-24.
9. Brown, K. W. and N. J. Rosenberg. 1970. The effect of windbreaks and soil water potential on stomatal diffusion resistance and photosynthetic rate of sugar beets (*Beta vulgaris*). *Agron. J.* 62: 4-8.
10. Brown, K. W. and N. J. Rosenberg. 1970. Energy and CO₂ balance of an irrigated sugar beet (*Beta vulgaris*) field in the Great Plains. *Agron. J.* 63:207-213.
11. Brown, K. W. and N. J. Rosenberg. 1970. Shading inverted pyranometers and measurements of radiation reflected from an alfalfa crop. *Water Res. Res.* 6:1782-1786.
12. Rosenberg, N. J. and K. W. Brown. 1970. Improvements in the van Bavel-Myer automatic weighing lysimeter. *Water Res. Res.* 6:1227-1229.
13. Briggs, W. W., A. R. Edison, J. D. Eastin, K. W. Brown, J. W. Marengville, and M. D. Clegg. 1971. Photosynthesis light sensor and meter. *Ecology* 52:125-131.
14. Brown, K. W. and N. J. Rosenberg. 1971. Turbulent transport and energy balance as affected by a windbreak in an irrigated sugar beet (*Beta vulgaris*) field. *Agron. J.* 53:351-355.
15. Brown, K. W. and N. J. Rosenberg. 1971-2. Shelter-effects on micro-climate, growth and water use by irrigated sugar beets in the Great Plains. *Agric. Meteorol.* 9:241-263.

Kirk W. Brown

16. Brown, K. W. and N. J. Rosenberg. 1973. A resistance model to predict evapotranspiration and its application to a sugar beet field. *Agron. J.* 65:341-347.
17. Duble, R. L. and K. W. Brown. 1973. Environmental concerns for the golf superintendent. *USGA Green Section Record*. 11:10-13.
18. Brown, K. W. 1974. Calculations of evapotranspiration from crop surface temperature. *Agric. Meteoro.* 14:199-209.
19. Holder, C. B. and K. W. Brown. 1974. Evaluation of simulated seedling emergence through rainfall induced soil crusts. *Soil Sci. Soc. Amer. Proc.* 38:705-710.
20. Brown, K. W., C. J. Gerard, B. W. Hipp and J. T. Ritchie. 1974. A procedure for placing large undisturbed monoliths in lysimeters. *Soil Sci. Soc. Amer. Proc.* 38:981-983.
21. Rosenberg, N.J. and K. W. Brown. 1974. "Self-checking" psychrometer system for gradient and profile determinations near the ground. *Agric. Meteoro.* 13: 215-226.
22. Spotts, J. W. and K. W. Brown. 1975. A technique for installing induction coils in a profile with minimum soil disturbance. *Soil Sci. Soc. Amer. Proc.* 39: 1006-1007.
23. Jordan, W. R., K. W. Brown and J. C. Thomas. 1975. Leaf age as a determinant in stomatal control of water loss from cotton during water stress. *Plant Physiol.* 56:595-599.
24. Brown, K. W. and R. L. Duble. 1975. Physical characteristics of soil mixtures used for golf green construction. *Agron. J.* 67:647-652.
25. Brown, K. W. 1975. A device for isolating soil columns with minimum disturbance. *Soil Sci. Soc. Amer. Proc.* 39:1008-1009.
26. Brown, K. W. and N. J. Rosenberg. 1975. Annual windbreaks boosts yields. *Crop and Soils Magazine*. p. 8-11. Apr-May, 1975.
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- "To investigate the necessity of a sand layer between the top mixture and gravel layer in golf green construction." 1978-1979. Funded by the United States Golf Association, Greens Section for \$3,220. Final Report submitted March, 1980.
- "To develop a plan to minimize the volume of runoff water which must be treated and disposed of and to assess the feasibility of land disposal of the runoff water and sludge." 1979-1980. Funded by Texas Engineering Extension Service for \$11,058.40. Final Report submitted April, 1980.
- "Investigate the concentration of heavy metals and certain other physical and chemical properties - Gibbons Creek Lignite Mine." 1980. Funded by Texas Municipal Power Agency for \$12,500. Final Report submitted April, 1980.
- "Improved water and nutrient management through high-frequency irrigation." 1977-1980. Funded by Texas Water Resources Institute for \$179,435. Work completed June, 1980.
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- "Root distribution of bermudagrass grown on reclaimed lignite spoil." 1980-1981. Funded by the Center for Energy and Mineral Research for \$12,590. Final Report submitted August, 1981.
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- "Investigate the influence of organic matter quality and placement on the establishment of grass and the physical properties of golf green mixes." 1979-1981. Funded by the U. S. Golf Association, Green Section for \$10,177. Final Report submitted February, 1982.
- "Metal uptake by grasses grown on reclaimed lignite spoils." 1979-1980. Funded by the Center for Energy and Mineral Research for \$13,100.
- "Soil disposal of API pit wastes." 1977-1980. Funded by the Environmental Protection Agency for \$184,104. Final report submitted in 1981.
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- "Completion of Field Investigation and an Evaluation of Mechanisms by which Organic Liquids Alter the Permeability of Clay Soils". 1984-1985. Funded by EPA for \$59,000. Final report submitted in 1986.
- "Mobility and Stability of Mutagenic Compounds in Municipal Sewage Sludge Amended Soil." 1984-1986. Funded by Environmental Protection Agency. for \$281,800.
- "Development of a Capillary Wick Unsaturated Zone Pore Water Sampler." 1985-1986. Funded by Environmental Protection Agency for \$236,353.
- "Evaluation of the Thickness of Clay Liners Required to Meet RCRA Requirements". Funded by Environmental Protection Agency. 1987-1989. First year funding \$122,184.
- "Development of a Pesticide Rinse Water Digester". 1986-88. Funded by Texas Water Resource Institute for \$58,000.
- "Determination of the optimum furrow dike size to minimize rainfall runoff". 1985. Funded by Texas Water Resource Institute for \$17,500.
- "In situ vapor extraction of volatile contaminants at Superfund sites" 1987-88. Funded by Texas Water Resource Institute for \$40,000.
- "Development of a comprehensive testing protocol to assess the hazard of an uncontrolled hazardous waste site". 1987-89. Funded by Environmental Protection Agency for \$315,897.
- "Evaluation of the Bacterial Mutagenicity and Chemical Characteristics of Municipal Landfill Leachate". 1988-1990. Sponsored by Texas Water Resource Institute, \$47,500.
- "Bioassay Directed Chemical Characterization of Hazardous Organic Chemicals in Waste Contaminated Environments". Funded by National Institute of Health, 1989-1992, \$422,000.
- "The Use of Short-Term Bioassays to Assess the Human Health Hazard of Uncontrolled Hazardous Waste Sites". Funded by National Institute of Health, 1989-1992, \$607,000.
- "In Situ Bioremediation of Hazardous Substances in the Vadose Zone". Funded by USEPA, 1988-1991, \$341,164.
- "Effectiveness of Multiple Liner Systems for Hazardous Waste Containment Facilities". Funded by USEPA, 1988-1991, \$387,203.
- "The Use of In-Vessel Composting as a Treatment Technology for Hazardous Waste Minimization". Funded by Gulf Coast Hazardous Substance Research Center, June 1, 1991-April 30, 1994, \$107,471.
- "Site Assessment." Funded by NIH for \$334,650 for first 3 years. 1992-1996.
- "Demonstration of the Degradation of Toxic Organics in Composted Municipal Solid Waste." Funded by Texas Water Commission for \$135,000 for two years, 1992-1994.
- "A Preliminary Demonstration of the Use of In-Vessel Composting for Degradation of Waste Propellants." Sponsored by Day & Zimmermann, Inc. 1993. Funds amounted to \$18,138.

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“Water Use Efficiency and Wetting Patterns Associated with Directed Subsurface Irrigation.” Sponsored by Texas-Israel Exchange Program through the Texas Department of agriculture 1995-1996 Funds amount to \$27,770.

ATTACHMENT 3

**Listing of Trial or Deposition Testimony by K. W. Brown
Since January 1, 2013**

Cause No. 22052-10563, consolidated with Cause No. 22052-09367 and Cause No. 22052-09366; <i>Corby Baker, et al., Plaintiffs, v. Fluor Corporation, et al., Defendants</i> in the Missouri Circuit Court, Twenty-Second Judicial Court, State of Missouri. Case involved personal injury claims related to exposure to lead mining wastes. Retained by the Plaintiffs.	4/23/14
Case No. 1:09-CV-0228, DNH-DRH, consolidated with Case No. 1:11-CV-006; <i>Village of Stillwater, et al., Plaintiffs, v. General Electric Co., Defendants</i> in the United States District Court, Northern District of New York. Case involved contamination of the Hudson River with polychlorinated biphenyls. Retained by the Plaintiffs.	4/16/14
Cause No. 052-09605; <i>Charles A. Burnia, et al., Plaintiffs, v. Fluor Corporation, et al., Defendants</i> in the Circuit Court of St. Louis, Twenty-Second Judicial Circuit, State of Missouri. Case involved personal injury claims related to exposure to lead mining wastes. Retained by the Plaintiffs.	8/19/13