AIR MODELING ANALYSIS OF POTENTIAL HISTORICAL RELEASES AT

Solutia, Inc. W.G. Krummrich Plant, Sauget, Illinois

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EXECUTIVE SUMMARY

Under contract to Booz Allen Hamilton, Inc. (Booz Allen), Risk Management & Engineering Ltd. (RME) conducted an air deposition model analysis for the Solutia, Inc. plant (formerly owned and operated by Monsanto) and located in Sauget, Illinois (a/k/a the "William G. Krummrich Facility" or "Facility"). The purpose of this project was to provide information to support the planning of potential soil sampling efforts, which may be performed as part of the U.S. Environmental Protection Agency's (EPA's) ongoing oversight of response activities associated with the Facility.

RME conducted the following tasks to complete the project:

- Task 1 – Characterize Historic Emissions
- Task 2 – Perform Air Deposition Modeling
- Task 3 – Prepare Technical Report.

RME reviewed various facility historical documents and polychlorinated biphenyls (PCBs) manufacturing-related documents to: (1) recreate an historical timeline of Facility operations, (2) develop estimates of PCB emissions to the air over time, and (3) develop a set of source characteristics that describe how PCBs may have been released into the air. For subsequent deposition modeling performed under Task 2, RME defined upper air and surface meteorological data sets and executed the air deposition model (AERMOD) to estimate the deposition flux resulting from the historical emissions. RME then estimated soil concentrations that could have resulted from the deposition flux, and presented this information on a series of figures contained herein. RME also compared the results to existing soil concentration data and performed a detailed sensitivity analysis to assist reviewers of the report understand potential uncertainties due to: (1) gaps in historical data, and (2) necessary assumptions associated with preparing an air deposition model for a site or facility.

The key results of RME's analysis are summarized on Figure 11. The modeled soil concentration isopleths indicate potential impacts to certain off-site residential areas in the range of 265 micrograms per kilogram (µg/kg) to 801 µg/kg of total PCBs in soil. Off-site areas where modeled soil concentrations exceed EPA's conservative total PCBs screening level of 1 milligram per kilogram (mg/kg) are generally limited to non-residential areas immediately surrounding the Facility.

Reviewers should consider that the scope of this analysis did not include evaluation of all potential air emission sources of PCBs in the area or non-air emission sources (such as stormwater runoff). However, the modeled results are generally in agreement with the existing soil sampling data available to RME during this project, with the exception of some outliers (as discussed further in Section 6 of this report). As detailed herein, insufficient information was available to effectively model dispersion and deposition of contaminants other than PCBs that were associated with Facility manufacturing processes (i.e., dioxins and furans).

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1.0 INTRODUCTION

Under contract to Booz Allen Hamilton (Booz Allen), Risk Management & Engineering Ltd. (RME) conducted an air deposition model analysis at the Solutia, Inc. plant (formerly owned and operated by Monsanto) located in Sauget, Illinois (a/k/a the "William G. Krummrich Facility"). Throughout this report, RME refers to the overall plant as the WGK Facility, Krummrich Facility or the Facility. The project objectives were to:

1. Assess the potential historic releases of polychlorinated biphenyls (PCBs) and dioxin/furans to air that may have occurred from historical processes at four former operating areas of concern (AOCs) that include:
    a. Former PCB Manufacturing Plant
    b. Former Waste Incinerator
    c. Former Chlorobenzene Storage Area
    d. Former Chemical Warfare Plant.

2. Evaluate the potential for wind deposition of on-site contaminated soils to neighboring properties, within the locus defined herein.

3. Evaluate airborne releases from other potential source areas determined to have been historically present at the Facility.

To achieve the project objectives, RME conducted the following tasks:

- Task 1 – Characterize Historic Emissions
- Task 2 – Perform Air Deposition Modeling
- Task 3 – Prepare Technical Report

To accomplish Task 1, RME conducted a review of documents, developed an historic emissions timeline, performed quality assurance (QA) checks, and performed a data gap analysis. The documents that RME reviewed to characterize the historical emissions are listed in Section 7. In general, the documents referenced for this project included:

- Site-related environmental reports prepared by both Monsanto (the predecessor to Solutia, Inc. and former operator of the Facility); Solutia, Inc. and its contractors; and contractors for the U.S. Environmental Protection Agency (EPA)

- Historical reports prepared by EPA regarding the manufacturing, use, and disposal of PCBs in the United States

- Historical aerial photographs of the Facility and environs

- Databases describing the typical performance characteristics of hazardous waste incinerators

- A report prepared by the EPA National Enforcement Investigations Center (NEIC) related to litigation at Monsanto's former PCB manufacturing facility in Anniston, Alabama.

From the document review, RME was able to: (1) recreate an historical timeline of operations, (2) develop estimates of PCB emissions to the air over time, and (3) develop a set of source characteristics that describe how PCBs were released into the air for the purpose of the subsequent deposition modeling performed under Task 2.

To accomplish Task 2, RME defined the upper air and surface meteorological data sets, set up and executed the air deposition model (AERMOD), performed required QA checks, and performed a data gap analysis. RME obtained the five-year (1983–1987) upper air meteorological data set from the Salem Leckrone Airport located in Salem, Illinois and obtained the five-year (1983–1987) surface meteorological data set from the St. Louis Lambert Field Airport. The meteorological data were processed via AERMET. To address the albedo, Bowen Ratio, and surface roughness parameters, RME obtained the site surface characteristics described by the U.S. Geological Survey (USGS) in its land use and land cover data and processed this data via AERSURFACE. Terrain elevations were obtained from USGS 7.5 minute Digital Elevation Model (DEM) data and processed via AERMAP. To address the fastest mile wind speed data required for estimating emissions of re-suspended dust (i.e., soil particulates), RME obtained the fastest mile data set (1965–1982) for St. Louis Lambert Field Airport from the National Climatic Data Center (NCDC).

This report (Task 3) details the: (1) historical emissions characterization, (2) air deposition modeling, (3) soil concentration modeling, (4) RME's analysis of the air deposition modeling results, and (5) RME's analysis of the uncertainty related to certain engineering data.

RME was not able to obtain emissions data for dioxins and furans from any of the former operating areas, nor was RME able to identify emission source characteristic information related to the Former Chemical Warfare Plant. Therefore, dioxins and furans were not considered in this study nor were emissions from the former Chemical Warfare Plant.

2.0 HISTORICAL EMISSIONS CHARACTERIZATION

RME reviewed various documents and historical aerial photographs obtained from Booz Allen, regulatory guidance documents, and documents and historical aerial photographs obtained through Internet research in order to: (1) characterize the historical emissions of PCBs to the air from the Former PCB Manufacturing Plant, Waste Incinerator, and Former Chlorobenzene Storage Area operating AOCs; (2) evaluate the potential for wind deposition of on-site contaminated soils; and (3) evaluate the potential air releases from other potential source areas determined to have been historically present at the Facility. The following provides an overall summary of the historical chemical manufacturing and waste management operations, and historic emissions timeline specific to each former operating area and other potential source areas (a detailed timeline is provided in Tables 1 and 2).

2.1 Historical Summary of Chemical Manufacturing

Chemical manufacturing at the Facility began in approximately 1907. The original owner and operator of the Facility was Commercial Acids Company (CAC), which manufactured sulfuric, muriatic (hydrochloric), and nitric acids. CAC expanded operations in 1914 when it purchased the neighboring Sandoval Zinc Company that manufactured zinc chloride. It expanded again in 1916, when it began manufacturing phenol by sulfonation[1] (Solutia 2000). In November 1917, Monsanto purchased the Facility from CAC.

From 1917 to 1926, Monsanto continued to expand operations to include the manufacturing of heavy acids, zinc chloride, phenol, salt cake and nitric cake, chlorine, caustic soda (soda ash), chlorobenzenes, para-nitroaniline, catalysts for contact, and sulfuric acid (Solutia 2000). Throughout the 1930s, Monsanto continued expansion of the Facility to include production of nitrated organic chemicals, chlorophenols, benzyl chloride, hydrogenated products, phosphorus halides, phosphoric acid, and Aroclors™ (PCBs).

After World War II, Monsanto sold 15 acres to the U.S. Government for construction of the Chemical Warfare Plant. Monsanto leased the Chemical Warfare Plant from the U.S. Government in 1947 and began manufacturing 2,4-D and 2,4,5-T herbicides. Monsanto also produced Santomerse (sodium dodecylbenzenesulfonate) and alkylbenzene in the late 1940s (Solutia 2000). Monsanto continued to expand the product line at the WGK Facility throughout the 1950s to include potassium phenyl acetate, monocloroacetic acid, tricresyl phosphate, adipic acid, phosphorus pentasulfide, and fatty acid chloride (Solutia 2000).

In 1960, Monsanto purchased the Chemical Warfare Plant from the U.S. Government and expanded it to accommodate a nitration facility, a phenol production unit, and production of a germicide and oil additives. Monsanto continued to expand through the 1960s to produce chlorinated cyanuric acid, chlorine, caustic soda, potash, ortho-dichlorobenzene, sulfuric acid and calcium benzene sulfonate, and expanded its para-nitrochlorobenzene, nitrochlorobenzene, ortho-nitrophenol and PCBs production units.

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[1] Reaction of sulfur trioxide or other “sulfonating agent” with various hydrocarbons to create sulfonic acids.

In the 1970s, Monsanto shut down the Phenol Department, updated the Santosite facilities, and started the production of orthonitrophenol and benzyl chloride. Monsanto sold a section of the WGK Facility to a subsidiary of Ethyl Corporation in 1971 and dismantled the Santosite Department in 1979 (Solutia 2000). RME estimates that the Facility ceased Aroclor™ production sometime in 1976 or 1977. This estimate is based on statements in the following references: (1) EPA 2005 (a/k/a the "Beihoffer Report") that the Facility ceased Aroclor™ production in 1977, (2) statements in Solutia 2000 (a/k/a the "Current Conditions Report") that Aroclor™ production facilities were dismantled in 1977, and (3) statements in EPA 1976 (a/k/a, the "PCBs in the U.S. Report") that production was ongoing at the time that report was issued.

In the 1980s, Monsanto ceased butyl benzyl chloride production and dismantled the plant in 1986, and ceased manufacturing chlorine and dismantled the chlor-alkali facilities in the mid-1980s (Solutia 2000). Monsanto continued to scale down operations in the 1990s, beginning with the discontinuation and dismantling of the ortho-Nitrophenol and Phosphorus Trichloride Departments. Two business units that operated at the Facility also changed ownership in the early 1990s. In 1997, Monsanto reorganized by forming Solutia, Inc. (Solutia) to handle its primary chemicals manufacturing business. The Facility was absorbed into the Solutia organization.

In 1999, Flexsys discontinued production of 4-nitrodiphenylamine, and the Power House at the Facility was dismantled. In 2000, Solutia reorganized to form a joint venture with FMC and Astaris, which combined the phosphorus manufacturing units of the companies. At the time the Current Conditions Report was prepared, Astaris owned the phosphorus pentasulfide production unit, which was operated by Solutia (Solutia 2000). Current site operations were characterized by EPA Region 5 as being minimal.

2.2 Historical Summary of Waste Management

From 1917 to the 1950s, process wastes from the Facility were disposed both on and off site (Solutia 2000). In 1932, the Village of Monsanto, Illinois (now Sauget) installed sewer lines into which the Facility connected and discharged wastewater (Solutia 2000). In 1952, the renamed Village of Sauget began operating a wastewater treatment plant at the Cahokia Chute west of the Facility, to which the Facility and other industrial facilities discharged wastewater. EPA stated in the 1976 "PCBs in the U.S. Report" that the Facility discharged 2.70 lbs/day of various PCBs to the Village of Sauget wastewater treatment system (EPA 1976).

From 1957 to 1977, Monsanto disposed of wastes in the 36-acre River's Edge Landfill located at Sauget Area 2, Site R, adjacent to the Mississippi River. The types of waste disposed in the River's Edge Landfill included organics, inorganics, solvents, pesticides, heavy metals and drums (Solutia 2000). Site R is now one of the principal areas of contamination that comprise the Sauget Area 2 National Priority List (NPL) Site, and remedial actions have included installation/operation of a final cover system and a slurry wall groundwater containment system between the former waste disposal area and the east bank of the River.

Between 1971 and 1977, PCB wastes were stored in the PCB Warehouse and then incinerated in the Waste Incinerator. Monsanto reported that a total of 151,000 tons of organic waste was incinerated during the operation of the Waste Incinerator (Solutia 2000). However, other documents show that the design capacity of the incinerator was approximately 1,142 pounds per hour (lb/hr). Over a seven-year period this design capacity equates to a total quantity incinerated of 35,000 tons. Thus, the 151,000 tons of incinerated material could be a significant overestimation of actual waste combusted, unless: (1) the documents describing the incinerator design capacity is incorrect; or (2) the Current Conditions Report is inaccurate and/or includes waste that was incinerated off site in the total. Incineration of PCB waste on site ceased in 1977, but additional PCB wastes were stored in drums at the PCB Warehouse until 1981 (Solutia 2000).

From 1966 to 1973, Monsanto also disposed of wastes from the Facility in a 90-acre landfill located south of the River Terminal at Sauget Area 1 (Site Q). Site Q is also part of the Sauget Area 2 NPL Site. Disposed wastes included municipal solid wastes, liquid chemical wastes, septic tank wastes, drums, organics, inorganics, pesticides, and paint sludges (Solutia 2000). From 1973 to 1980, wastes from the Facility were disposed at an Illinois Environmental Protection Agency (IEPA)-permitted landfill located north of Monsanto Avenue and west of Route 3 at Sauget Area 2 (Site P). Disposed wastes included non-chemical wastes from Monsanto, as well as general waste and diatomaceous earth filter cake from Ethyl Corporation (Solutia 2000).

2.3 Former PCB Manufacturing Plant

Through its review of documents and aerial photographs, RME determined the Former PCB Manufacturing Plant to be located on the east side of the Facility (refer to Figures 1, 2, and 3). In its analysis of the documentation, RME determined that the Former PCB Manufacturing Plant remained in approximately the same location; however, physical changes at this operation occurred over time. RME attributes the physical changes of this operation as likely to be related to the historical expansion and contraction of the PCB Manufacturing Plant in response to demand (Figures 1–3).

EPA estimated that Monsanto manufactured 99.8 percent of all commercial PCB formulations/mixtures of PCB homologs (trade named Aroclors™ by Monsanto) used in the United States from 1930 to 1975, with manufacturing beginning on or about 1929 (EPA 1976). Monsanto manufactured PCBs at two plants: the Krummrich Facility and a second facility located in Anniston, Alabama. However, available documents do not clearly indicate when manufacturing of PCBs actually began at the Krummrich Facility. EPA stated in the "PCBs in the U.S. Report" that Monsanto as a company began domestic production of PCBs in 1929, without identifying whether such production was conducted at the Anniston, Alabama facility or at the Krummrich Facility (EPA 1976). An unreferenced statement in an EPA NEIC report prepared by Mr. Jon Beihoffer ("Beihoffer Report") identifies PCBs production beginning at the Facility on or about 1936, with production at the Anniston, Alabama plant beginning in 1929. According to the Beihoffer Report, the two plants had similar design capacities and generally similar production rates throughout their operational lives (EPA 2005). In absence of any other data, RME used 1929 as the start date of PCBs manufacturing for the purpose of estimating average emissions, and 1936 as the start of PCBs manufacturing operations for the purpose of computing concentrations of PCBs in soil resulting from airborne transport and deposition.

The manufacturing of PCBs was accomplished by chlorinating biphenyl with anhydrous chloride in the presence of ferric chloride to produce crude Aroclors™, and then distilling the crude Aroclors™ to obtain the finished products (refer to Diagram 1 below). The PCBs manufacturing process involved the release of PCBs into the ambient air. As shown on Diagram 1, releases to the air occurred from the blower tank during crude Aroclor™ manufacturing and from distillation process via the Chlorination Section and the Condenser. In addition, EPA review of internal Monsanto documents described manufacturing-related air emissions occurring from tank vents, hydrochloric acid scrubbers, blow tank jets, vacuum jets, drumming operations, charging the still, filtration, earth treatment, tank car and tank truck loading, surface area evaporation, and leaks and spills. EPA quoted one internal Monsanto document which stated that:

> *"The most severe Aroclor™ concentrations were encountered during charging the still, filtration, earth treatment, and drawing out the hot Aroclor™ into the drums."* (EPA 2005)

FIGURE 2.1-1A. PREPARATION OF CRUDE CHLORINATED BIPHENYLS-MONSANTO KRUMMRICH PLANT

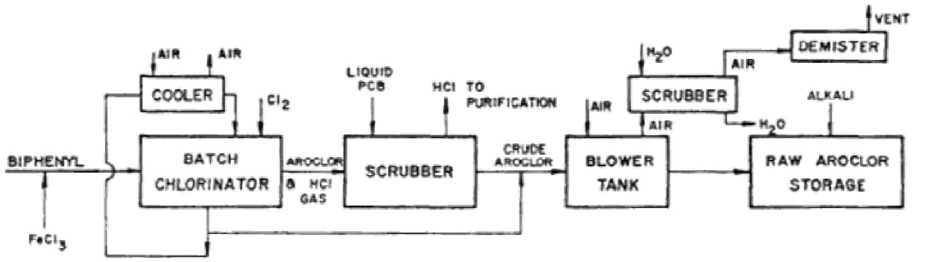

FIGURE 2.1-1B. DISTILLATION OF CRUDE PRODUCTS-MONSANTO KRUMMRICH PLANT

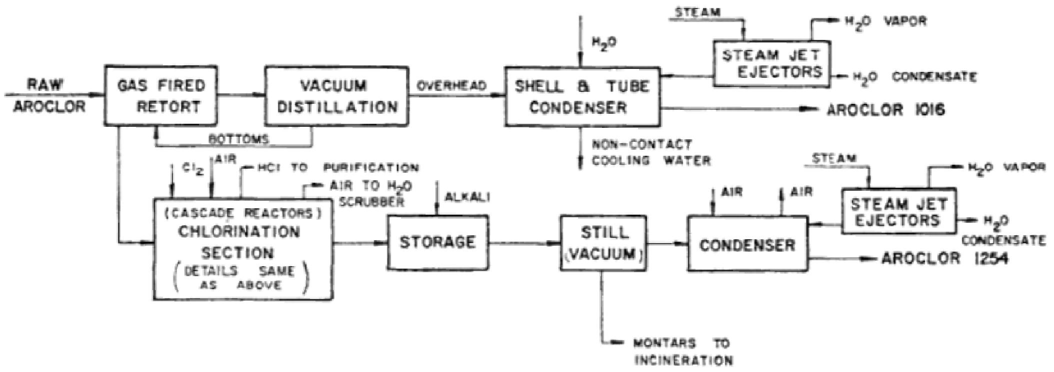

Diagram 1 – PCB Manufacturing Process Flow Diagram (Source: EPA 1976)

EPA also cited an internal Monsanto emission estimate for PCB air releases at the Anniston Plant from Aroclor™ drumming, tank car loading, Montar drumming, and the hydrochloric acid (HCl) scrubbers at 12.76 pounds per day (lbs/day), at a production capacity of 53 million pounds per year (lbs/yr) (EPA 2005). (Montars are derived from the still bottoms of the distillation process.) Thus, the 12.76 lbs/day estimate does not represent the entirety of PCB air releases from the manufacturing process, because it does not include emissions from some of the operations with the highest PCB air release concentrations as noted above (e.g. charging the still, filtration, and earth treatment).

Beihoffer prepared a production-related PCB emissions factor for the Anniston Plant of 87.9 lbs of PCB air emissions per million pounds of PCBs produced (8.79 x 10^{-5} lbs PCBs released to the air per lb of Aroclor™ produced), by multiplying the Monsanto emissions estimate by 365 days per year and dividing the resultant by the stated Aroclor™ production capacity of 53 million lbs/yr (EPA 2005). RME used this identical emissions factor for the purpose of estimating Aroclor™ emissions from manufacturing at the Facility, because the Anniston Plant and Krummrich Facility were described in the documentation as having the same design and production capacities.

RME then determined the annual PCBs production rate at the Facility and applied the above emission factor to estimate total PCB emissions from Aroclors™ manufacturing. Annual Krummrich Facility production rates were determined by subtracting the production at the Anniston Plant (based on Beihoffer's review of internal Monsanto documents) from the total annual Aroclor™ production reported by EPA in its 1976 "PCBs in the U.S. Report". The 1976 report provided detailed annual production figures for the years 1960 through 1974, but only estimates for years prior to 1960. RME then inspected this data to identify natural breaks in production rates over time. The PCB emissions were averaged for each time period, and this average emission rate was then modeled. A total of three time periods were modeled for PCB emissions from the Facility:

- 1936–1959
- 1960–1970
- 1971–1976

Even though total PCB production more than quadrupled between 1960 and 1970, the above breakpoints were chosen because: (1) all data prior to 1960 were estimates, (2) production declined significantly in the period 1970–71, and (3) higher production levels resumed from 1972 through 1976. In RME's opinion, the growth in production over the 1960-1970 timeframe and the averages of production over this period do not significantly affect the results of the air deposition modeling (i.e., additional granularity of emissions data over this time period is not required).

A summary of the estimated emission rates for the Former PCB Manufacturing Plant is provided in Table 3.

2.4 Former Waste Incinerator

Through its review of documents and aerial photographs, RME determined the Former Waste Incinerator to be located near the center of the Facility (Figures 1–3). In its analysis of the available documentation, RME determined that the Former Waste Incinerator did not move its location. (In the 1970s, Monsanto submitted an air permit application to the IEPA to construct and operate a waste incinerator at another location at the Facility. However, according to the available records, the new waste incinerator was never permitted or built.) By reviewing aerial photographs, RME was also able to observe that there were many physical changes that occurred at and adjacent to this area of operation over time. RME attributes the physical changes of this area of operation to modifications of adjacent operations and not to be associated with the incinerator itself.

Monsanto operated the Former Waste Incinerator at the Facility from 1970/71 to 1977 for the incineration of liquid waste from PCB manufacturing, including Montars (still bottoms from the distillation process), bottoms from the separator sumps, and waste liquids collected in drip pans (EPA 1976). EPA describes the Former Waste Incinerator as a John Zink unit consisting of a combustion chamber, quench pot, high energy venturi scrubber, packed tower scrubber, and demister (refer to Diagram 2 below). The combustion chamber was reportedly operated at 2,200 degree Fahrenheit (°F) at five percent excess oxygen, with a waste retention time inside the combustion chamber of between two and three seconds (EPA 1976). The unit had a design capacity of 10 million lbs/yr (which equates to 1,142 lbs/hr at 8,760 hours of operation) and operated at a service factor of 0.60, which equates to a six million lbs/yr actual capacity (EPA 1976).

To develop an emission rate for the Former Waste Incinerator, RME was required to estimate the destruction efficiency. To estimate the destruction efficiency of the Former Waste Incinerator, RME identified three incinerators of a similar design that are operated by Eastman Kodak, General Electric (GE), and Texas Eastman from the Maximum Achievable Control Technology (MACT) database for hazardous waste incinerators (EPA 2010b). Of these three incinerators, RME selected the GE incinerator as the unit most similar to the Former Waste Incinerator, based on its air pollution control system, tested thermal firing rate, and tested PCB waste feed rate. The GE unit demonstrated a destruction efficiency of 99.9999 percent for PCB wastes that were trial-burned at average temperatures of 1,692°F.

FIGURE 2.4-1. PROCESS FLOW DIAGRAM OF THE JOHN ZINK INCINERATOR AT MONSANTO'S KRUMMRICH PLANT

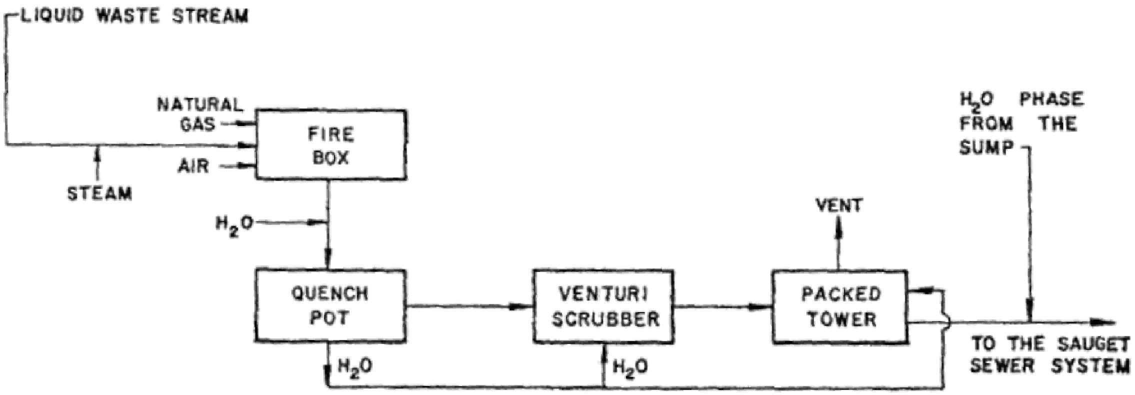

Diagram 2 – Waste Incinerator Process Flow Diagram (Source: EPA 1976)

The total PCBs emission rate for the Former Waste Incinerator at the Facility was estimated at 0.0001 percent of the design capacity waste feed rate. The maximum design feed rate, rather than the reported actual capacity feed rate, was used to estimate emissions because of the uncertainty associated with destruction efficiency. In RME's opinion, the destruction efficiency used in this analysis is uncertain, because the Former Waste Incinerator was operated in the early 1970s before current Resource Conservation and Recovery Act (RCRA), Toxic Substances Control Act (TSCA), and Clean Air Act (CAA) regulations were promulgated and significant regulatory oversight of incinerators by EPA or state environmental agencies was conducted. In contrast, the destruction efficiency reported for the GE incinerator occurred during a tightly controlled test of a unit that should be well-maintained. Thus, it is possible that the Former Waste Incinerator did not operate at 99.9999 percent destruction efficiency during its period of operation. The intent of using the maximum design capacity feed rate (which would overestimate emissions) was to offset the uncertainty of assuming a destruction efficiency that is better than was actually delivered by the incinerator.

A summary of the estimated emission rates for the Former Waste Incinerator is provided in Table 3. A total of two time periods were modeled for the incinerator. One time period (1971–1976) was modeled in conjunction with PCB manufacturing emissions, because emissions from both sources occurred concurrently. A second time period (1977) was modeled to reflect incinerator emissions, only because PCBs manufacturing and that related component of emissions ceased before the 1976 to 1977 time frame.

2.5 Former Chlorobenzene Storage Area

Through its review of documents and aerial photographs, RME determined the Former Chlorobenzene Storage Area to be located near the southwest corner of the Facility (Figures 1–3). In its analysis of the available documentation, RME determined that the Former Chlorobenzene Storage Area remained in approximately the same location, and that there were many physical changes that occurred at (and adjacent to) this operation over time. RME attributes the physical changes of this operation to be related to expansion and contraction of adjacent operations (refer to Figures 1 – 3). Current Chlorobenzene Storage Area site operations are characterized by EPA Region 5 as being minimal. Further, correspondence and statements by EPA Region 5 indicate that the PCB-contaminated soils in the Former Chlorobenzene Storage Area were covered with gravel in 2004, with the most contaminated portions paved in 2009.

Based on the historical information that RME was able to obtain, this area appears to have been used as a staging area for materials storage and shipping. RME has assumed that some of the materials stored and shipped from this area were PCBs and that some of this material was spilled onto the soil at various times over the years, based on soil sampling data that confirms PCB contamination of the soil. There are no records that indicate the volume of PCB-type materials that may have been stored in this area, nor any records that documented the amount of PCB wastes possibly spilled. However, based on a review of the historical soil investigations in this area, the concentrations of PCBs in the soil appear to be related to localized spillage of PCB-laden materials.

The PCB emissions from the Former Chlorobenzene Storage Area were assumed to take the form of soil and dust particles that were re-suspended by wind erosion and mechanical agitation, and then blown onto the surrounding areas. The dust re-suspension emissions from the Former Chlorobenzene Storage Area were developed based on EPA Office of Air and Radiation (OAR) Publication AP-42, Section 13.2.5 (EPA 2010c). The procedure described by this EPA guidance recommends using fastest mile wind speed (FMWS) and the threshold friction velocity (TFV) values consistent with the size of soil particles that are being eroded.

RME obtained and analyzed soil particle data from a soil map developed by the U.S. Department of Agriculture (USDA), National Resources Conservation Service (NRCS) for the study area, as well as data described in the Soil Survey of St. Clair County prepared by the predecessor agency (Soil Conservation Service) to the NRCS (NRCS 2010; NRCS 1978, Table 12). RME also consulted with EPA Region 5 personnel knowledgeable about the Facility regarding the soil type at the site. RME determined from this data that the dominate soil type in the area of the Facility is silty clay with 90 to 100 percent passing a No. 200 Sieve. The opening diameter of a No. 200 Sieve is 0.075 millimeters (mm), which RME used as the size of soil particle subject to wind erosion at the site. From Table 13.2.5-1 of AP-42, a TFV of 43 centimeter per second (cm/sec) was selected as being most representative of the particle size in the study area. RME also obtained and analyzed FMWS data from the National Climatic Data Center for the St. Louis Lambert Field Airport for the time period of 1965 to 1981, the entire time period for which data was available.

RME used the procedures recommended in EPA Publication AP-42 to estimate soil wind erosion emissions. The concentration of PCBs in the soil was developed by averaging all the soil sample results reported for the Former Chlorobenzene Storage Area obtained from Volume II of the Solutia RCRA Corrective Measures Study (Solutia 2004). The average soil concentration was estimated at 2,823 mg/kg. Appendix A summarizes the emissions estimating procedure used for the Former Chlorobenzene Storage Area.

2.6 Former Chemical Warfare Plant

Through its review of available documents and aerial photographs, RME determined the Former Chemical Warfare Plant to be located north of the main Facility (Figures 1–3). In its analysis of the documentation, RME determined that the Former Chemical Warfare Plant remained in approximately the same location. From review of available aerial photographs, RME was also able to observe that there were many physical changes that occurred at and adjacent to this area operation over time. RME attributed the physical changes of this area of operation to be expansion and contraction of the Former Chemical Warfare Plant (refer to Figures 1–3).

RME was not able to locate a process flow diagram, source characteristics data, or emissions data for the Former Chemical Warfare Plant. Therefore, PCB emissions from the Former Chemical Warfare Plant could not be modeled.

2.7 Other Possible Sources

In its review of the available documents, RME investigated other potential PCB-emitting source areas determined to have been historically present at the Facility and/or at neighboring sites or facilities. Other potential sources identified by RME included the following:

- *Waste Pit associated with the Former Incinerator Area*. As part of the Former Incinerator process, PCB liquid wastes were dumped from containers into a waste pit at the incinerator. Fugitive vapor emissions from this pit could have been released to the air.

- *Village of Sauget Waste Water Treatment Plant (WWTP).* The Krummrich Facility discharged its wastewater to the Village of Sauget WWTP beginning in 1932. EPA stated in the 1976 "PCBs in the U.S. Report" that the Facility discharged 2.70 lbs/day of PCBs to the Village of Sauget WWTP (EPA 1976). Vapor emissions from the wastewater treatment lagoons at the WWTP could have been released to the air.
- *Miscellaneous Off-site Sources from Neighboring Facilities.* RME's scope did not include the identification of possible off-site sources. However, it is possible that neighboring facilities either used PCB materials in their manufacturing processes and/or generated PCB emissions.

The above-listed sources were not included in the air deposition modeling, because RME was not able to obtain the operation-specific data required for air deposition modeling. Further, it is RME's opinion that if other off-site sources included re-suspension of dust, these sources would contribute inconsequentially to PCB deposition at areas that are not close to the source of the emissions. RME has based this observation on its analysis of the air deposition modeling performed for the Former Chlorobenzene Storage Area (refer to Section 5.0).

3.0 AIR DEPOSITION MODELING

The following provides a discussion of the meteorological, terrain, source parameter, and deposition parameter data that were used in the air deposition modeling. All of the meteorological data used in the analysis are provided in Appendix B.

3.1 Meteorological Data

RME obtained five years of surface meteorological data from the St. Louis Lambert Field Airport (Station ID No. 13994) and five years of upper atmosphere data from the Salem, Illinois Airport (Station ID No. 3879) to support the air deposition modeling. The Lambert Field weather station is located approximately 15 miles northwest of the Facility, and the Salem Airport weather station is located approximately 65 miles east of the Facility. The data were obtained from www.webmet.com, which is a data source site supported by Lakes Environmental, in Solar and Meteorological Surface Observation Network (SAMSON) format. RME selected the years 1983–1987 for use in the analysis, because complete data sets of both surface and upper air data (including precipitation) were available for these years of data. Alternative sources of more local model-ready meteorological data were sought but the more local sources either did not have complete data sets or did not have a five year data set, or both.

The data were processed using Lakes Environmental's American Meteorological Society (AMS) EPA Regulatory Model (AERMOD) Meteorological Preprocessor (AERMET) View, Version 6.7.1, which utilizes EPA's AERMET meteorological pre-processing program. Annual average albedo, Bowen Ratio, and surface roughness were derived from EPA's AERSURFACE program, which was implemented for 12 directional sectors based on the USGS National Land Cover Data (NLCD) for Missouri. (Missouri data were used because AERMOD requires the land use to be reflective of the data measurement site.) The five years of meteorological data were combined to prepare a single data set for modeling.

The wind rose depicting the five years of surface data is shown on Diagram 3 below. The wind rose indicates that the prevailing winds reaching the Facility and environs originate primarily from the South, Southeast, and West/Northwest, with the highest-speed winds generally coming from the West/Northwest.

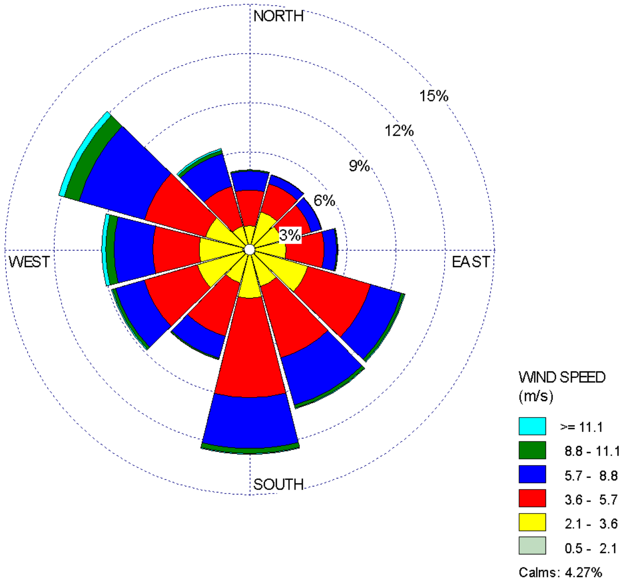

Diagram 3 – Wind Rose Diagram (Blowing From)

3.2 Terrain Data

RME used the AERMOD Terrain Processor (AERMAP) program embedded into Lakes Environmental AERMOD View version 6.7.1. USGS 7.5-minute digital elevation model (DEM) terrain data were downloaded from www.webgis.com and processed via AERMAP. An overview of the terrain surrounding the Krummrich Facility is shown below. As confirmed, the terrain in the close vicinity of the Facility is highly altered and urbanized; the closest areas of terrain resembling natural features are (to the West) St. Louis' Forest Park and (to the East) Fairview Heights, Illinois. The urbanized features extend North and South along the Mississippi River well beyond the study area for this analysis.

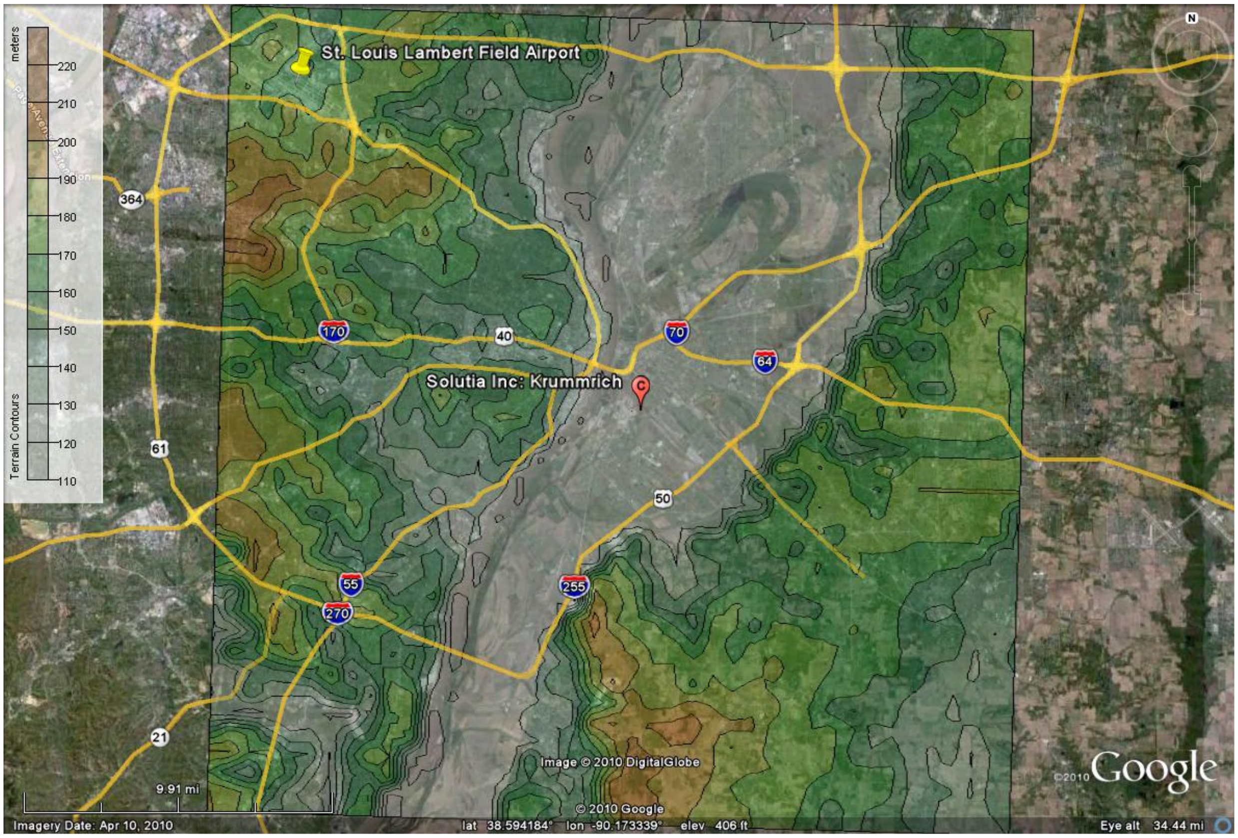

Diagram 4 – Terrain in Vicinity of the Krummrich Facility

3.3 Source Parameters

AERMOD was executed for each time period of emissions using the Lakes Environmental model interface AERMOD View, Version 6.7.1. AERMOD replaced ISCST3 as EPA's model of choice for analyses confined to study areas within 50 kilometers from the source. AERMOD uses Gaussian dispersion in the horizontal and vertical planes for stable conditions, and a non-Gaussian probability density function in the vertical plane for unstable conditions. The model output of interest for this analysis is the annual average total deposition, based on the five years of meteorological data used in the analysis. The Former PCB Manufacturing Plant emissions were modeled as a volume source (i.e., model of multiple point sources), the Former Waste Incinerator emissions were modeled as a point source (i.e., a single emission point), and the Former Chlorobenzene Storage Area dust re-suspension emissions were modeled as an area source (i.e., a graphically defined area).

Two sets of source parameters were prepared and modeled for the Former PCB Manufacturing Plant and Former Waste Incinerator sources to evaluate the impact of uncertainty associated with these parameters. The two sets of source parameters were differentiated by using the letters "a" and "b" at the end of model input files. Table 4 summarizes the model input parameters for the Former PCB Manufacturing Plant and Former Waste Incinerator sources, and the model input parameters for the Former Chlorobenzene Storage Area is discussed in Section 3.3.3. All of the deposition modeling input and output files are provided in Appendix C. Downwash was not considered in the analysis, because RME could not obtain detailed data on building heights.

3.3.1 Former PCB Manufacturing Plant Source Parameters

PCB manufacturing emissions were modeled as a volume source because RME assumed that all the emissions occurred inside the manufacturing building and were released to the air through roof vents and other openings in the building. It is clear from the record that not all the manufacturing emissions were released in this manner. For example, the emissions from the hydrochloric acid scrubbers were most likely released from stacks. However, no data were available to describe these point source manufacturing emissions and, according to the Beihoffer Report, Monsanto had opined in internal company documents that the most significant emissions occurred from charging the still, filtration, earth treatment, and transferring hot Aroclor™ into drums; emissions that most likely would have occurred as fugitive sources inside the manufacturing building and then subsequently released through roof vents.

The key parameters required for modeling a volume source are: (1) release height, (2) side dimension, (3) initial lateral dimension (Sigma y), and (4) initial vertical dimension (Sigma z). Release height was selected as 100 feet (ft) for the "a" parameters based on inspection of the aerial photographs, and 80 ft for the "b" parameters based on professional judgment and experience. The side dimension of 79 ft was selected based on scaling the longest dimension of the manufacturing building from the aerial photographs. Sigma y and Sigma z parameters were calculated based on EPA guidance (EPA 1992) where:

- Sigma y = Side Length/4.3
- Sigma z = Building Height/2.15

The center of the volume source was placed at the following coordinates (Chart 1):

Chart 1: Coordinates of PCB Manufacturing Volume Source

UTM X	UTM Y
746,775.20	4,275,942.62

UTM – Universal Transverse Mercator

3.3.2 Former Waste Incinerator Source Parameters

The Former Waste Incinerator stack parameters were based on the stack parameters demonstrated by a PCB incinerator operated by GE at its Waterford, New York facility during its PCB trial burn and RME's professional experience with other similar incinerator systems. RME could not locate any data that described the stack gas flow rate, stack temperature, and stack diameter associated with the Former Waste Incinerator.

3.3.2.1 Stack Gas Flow Rate

The GE incinerator demonstrated an average stack gas flow rate of 20,373 dry standard cubic feet per minute (dscfm), at an average thermal firing rate of 28 million British Thermal Units per hour (BTU/hr). The stack gas flow rate of the Former Waste Incinerator was developed by dividing the Monsanto thermal firing rate by the GE thermal firing rate, and then multiplying by the GE stack gas flow rate. The thermal firing rate of the Former Waste Incinerator was estimated based on the design values for a new incinerator that was planned by Monsanto but never constructed. Contract documents provided by EPA Region 5 indicated that the new incinerator was to have a maximum design feed rate of 21.76 million lbs/yr, with a design thermal firing rate of 60 million BTU/hr (Monsanto 1977).

Assuming the heating values and relative quantities of the various wastes to be incinerated by the un-built incinerator were similar to the heating values and relative quantities treated by the Former Waste Incinerator, the resulting ratio results in a thermal firing rate for the Former Waste Incinerator of 27.57 million BTU/hr. Thus, the ratio of the Monsanto incinerator (Former Waste Incinerator) thermal firing rate to the GE firing rate is 0.98 (27.57/28). This ratio was multiplied by the GE stack gas flow rate results in a stack gas flow rate for the Former Waste Incinerator of 20,060 dscfm. The 20,060 dscfm stack gas flow rate was corrected to actual conditions based on stack gas temperature and moisture content derived from RME’s professional experience.

3.3.2.2 Other Stack Gas Parameters

Other stack gas parameters such as moisture content, stack temperature, and stack diameter were based on RME’s experience conducting air deposition modeling for other incinerators with wet air pollution control systems. It has been RME’s experience that the moisture content of stack gases from wet air pollution control systems is generally high relative to other systems, and stack temperatures are generally low relative to other systems. It has also been RME’s experience that stack diameters generally range from three to five feet in diameter, with stack heights generally in the range of 100 ft or less. Stack temperature and moisture content for “a” parameters were set at 125°F and 34 percent, and 75°F and 38 percent moisture for “b” parameters. Stack diameter for “a” and “b” parameters was set at 4 and 5 feet respectively.

The Former Waste Incinerator was placed at the following coordinate:

Chart 2: Coordinates of Incinerator Point Source

UTM X	UTM Y
746,414.07	4,275,771.17

3.3.3 Former Chlorobenzene Storage Area Source Parameters

The Former Chlorobenzene Storage Area was modeled as a polygon area source with an initial vertical dimension equal to zero. The polygon is defined by the coordinates in Chart 3, as follows:

Chart 3: Coordinates of Chlorobenzene Area Source

UTM X	UTM Y
746,076.18	4,275,654.41
746,299.49	4,275,639.01
746,281.01	4,275,538.14
746,002.25	4,275,393.37

3.4 Deposition Parameters

The deposition modeling was conducted for two separate phases: a particle phase and a vapor phase. Both phases of modeling are required because PCBs are typically assumed to be present in both phases when released into the environment. The particulate phase occurs when a portion of the PCBs is condensed onto the surface of particles. The vapor phase is the dominant phase of some PCB releases such as those from combustion stacks. AERMOD requires certain parameters for each phase.

3.4.1 Particulate Phase

AERMOD provides two methods for the specification of particle phase deposition input parameters. Method 1 requires the modeler to specify a particle size distribution. Since no particle size distribution data were available for the Former PCB Manufacturing Plant or Former Waste Incinerator sources, RME chose a second method for specifying particle phase deposition parameters (Method 2). In Method 2, it is assumed that less than 10 percent of the particles have a size greater than or equal to 10 microns (µm) in diameter, with a mean diameter of the distribution equal to 0.63 µm. This selection is reasonable for the manufacturing and incinerator sources, because it is unlikely that particles greater than 10 µm in diameter would travel upwards through the manufacturing building and escape through the roof vents. Furthermore, it is RME's experience that wet air pollution control systems similar to that used by the Former Waste Incinerator often exhibit particle size distributions with 100 percent of the particles being less than 10 µm in diameter.

Method 1 was used for the Former Chlorobenzene Storage Area, because site data supplied by EPA and soil surveys of the area indicated that the dominant surface soil type is silty clay, with 90 to 100 percent of the particles passing a No. 200 sieve (the slot diameter of a No. 200 sieve is 0.075 µm). Thus, for the Former Chlorobenzene Storage Area the particle size distribution was represented by a single particle size with a mean diameter of 0.075 µm and density of one gram per cubic centimeter (g/cm^3).

3.4.2 Vapor Phase

AERMOD requires four chemical specific parameters to implement the vapor phase deposition algorithms including:

- Pollutant diffusivity in air
- Pollutant diffusivity in water
- Cuticular resistance
- Henry's Law Constant

RME selected Aroclor™ 1254 as a surrogate for PCBs for the modeling exercise. Aroclor™ 1254 was selected because it was: (1) manufactured by Monsanto for use in capacitors (Monsanto 1960), which was one of the most common uses of PCBs (EPA 1976); and (2) because it represents one of the more toxic formulations of PCBs commercially produced, as defined by EPA (EPA 2005). Aroclor™ 1242 was also a candidate for selection, because in 1952 it replaced Aroclor™ 1254 as the commercial PCB formulation primarily used in capacitors. Aroclor™ 1242 was ultimately not selected as a surrogate, because its deposition parameters result in deposition fluxes that are not as conservative as Aroclor™ 1254, and further RME understood that the intent of this study was to provide conservative estimates of deposition so that additional off-site soil sampling could be planned. Aroclor™ 1016, one of the less toxic commercial PCB formulations, was not manufactured until 1971 (EPA 1976), and thus was not selected to represent deposition parameters because of the relatively short length of time it was manufactured, compared to the other Aroclors™. Values for the deposition parameters for Aroclor™ 1254 were obtained from a draft report prepared by Argonne National Laboratory (ANL 2002).

Chart 4 lists the parameters that were used for the vapor phase depositing modeling:

Chart 4: Parameters Used in Vapor Phase Deposition Modeling

Parameter	Value	Source
Diffusivity in Air (D_a)	0.0429 cm^2/s	ANL 2002, Table C.3
Diffusivity in Water (D_w)[1]	0.4 cm^2/s	ANL 2002, Table C.3
Cuticular Resistance (rcl)	325 s/cm	ANL 2002, Table D.3, midpoint of range
Henry's Law Constant (H)	24.0 $Pa\text{-}m^3/mol$	ANL 2002, Table D.3, midpoint of range

1. This value is actually 4×10^{-4} cm^2/s. RME evaluated the impact of using 0.4 rather than 4×10^{-4} as part of the uncertainty analysis and found there was no impact to the results.
2. $Pa\text{-}m^3/mol$ – Pascal-cubic meters per mole

3.4.3 Land Use Categories

The deposition algorithms in AERMOD require the user to define land use categories for different compass sectors. The land use categories RME used to support the modeling are defined in Table 5. The model does not allow the user to specify different land use categories for different radii within a specific sector. Therefore, the model assumes the land use category is relevant from the emission source to the limits of the modeling grid. As discussed in Section 6.2.3, even though the area is highly urbanized, the land use was not specified as "Urban" in the model because that would have underestimated deposition impacts.

3.5 Receptor Grid

A multi-tier receptor grid was established for the project. The first grid tier placed receptors on 100 meter (m) centers out to 2,000 m from the grid origin (746,423.00, 4,275,746.00). The second tier established receptors on 500 m centers out to 5,000 m from the grid origin. The third tier established receptors on 1,000 m centers out to 10,000 m from the grid origin.

4.0 SOIL CONCENTRATION MODELING

The EPA task order scope of work notes that one purpose of this study is to provide data and information that can be used to support the planning of additional off-site soil sampling activities, if those activities are determined to be necessary by EPA. RME's proposal stated that it would consider the availability of resources after the deposition modeling effort was completed to derive soil concentrations from the deposition flux results provided by the modeling effort—if RME believed that the deposition flux results alone could not provide sufficient planning information. RME determined after completing the deposition modeling that sufficient resources were available to estimate soil concentrations and that estimated soil concentrations would provide data superior to the deposition flux results alone to support the planning of potential off-site soil sampling activities. Thus, as described in RME's proposal, soil concentrations were estimated from the deposition flux results provided by the deposition modeling.

RME used the algorithms contained in EPA's *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (EPA 2005), Appendix B, Equations B-4-1 through B-4-6, to estimate the soil concentrations resulting from the AERMOD deposition modeling. The soil loss constant was calculated based on the chemical-specific parameters provided in the companion database to the *Protocol* for Aroclor™ 1254. A summary of the soil concentration computations for each grid node is provided in Appendix D.

In additional to chemical-specific data, another critical input to the estimation of soil concentrations is the time period of emissions, because more contaminants accumulate in the soil the longer an emission source operates. The time period of emissions for the Former PCB Manufacturing Plant and Former Waste Incineration was established based on the length of the operation periods, as described in Sections 2.3 and 2.4. For the Former Chlorobenzene Storage Area, the emissions were assumed to have begun in 1954, because the area was not active in the 1940 aerial photo but was in the 1968 aerial photo. The year 1954 was chosen as the mid-point between 1940 and 1968. Dust re-suspension emissions were assumed to end in 2004 when the site was covered with gravel.

5.0 RESULTS

5.1 Description

The soil concentration values were computed for each emission time period and then summed to provide a total soil concentration at each grid node. The total soil concentration at each modeled grid node was imported into ArcMap, Version 9.3.1 for presentation. Additionally, the off-site total PCB soil concentrations provided in EPA Region 5's *Removal Program Site Assessment Report for Sauget/East St. Louis Residential PCB/Dioxin Sampling Site* (EPA 2010a) were also overlain onto the presentation figures for comparison to the modeled soil concentration values. The results of the analysis are shown in Figures 4 through 11. Modeling results were evaluated both with and without the contribution of dust re-suspension emissions from the Former Chlorobenzene Storage Area. This is because the emission estimates and deposition modeling associated with the Former Chlorobenzene Storage Area are much more uncertain than the other sources (the method used to estimate them was also more conservative). The results of the analysis can be described as follows:

- Figures 4 and 5 show the results of the modeling using the emission rates described in Section 2 (not including the Former Chlorobenzene Storage Area emissions) using both model source parameters "a" and "b." The "a" and "b" assumption sets produced very similar predicted dispersion patterns and soil concentrations. The modeled soil concentrations are generally less than the sampled soil concentrations.
- Figures 6 and 7 display the modeling results with the emission rates increased by a factor of 10. In these figures the modeled soil concentrations are generally consistent with the Northern soil sampling results within a factor of two to three, which is consistent with the annual average concentration accuracy demonstrated by AERMOD for simple terrain and complex terrain with no downwash as described in EPA's preamble to 40 CFR 51 (Federal Register 68222, Vol. 70, No. 216, November 9, 2005). The soil sampling results obtained from areas south of the Facility are generally higher than the modeled values. Moreover, the sampling indicated detections of PCBs in soil outside the limit of the plume boundary predicted by the model. The 4,400 µg/kg concentration detected at one location north of the Facility cannot be reconciled with the modeling results, even at 10 times the predicted concentration, although this value may be an outlier. In general, the remaining concentrations north of the Facility were consistent with the 10 times modeling results scenario.
- Figures 8 and 9 show the results of modeling with the emission rates described in Section 2.0 increased by a factor of 100. Under this scenario, the modeled soil concentrations are generally greater than the sampled soil concentrations. Further, the plume boundary expands to incorporate some (but not all) of the locations south of the Facility where PCBs were detected in soil.
- Figure 10 shows the soil concentrations associated with dust re-suspension emissions from the Former Chlorobenzene Storage Area, and Figure 11 shows these concentrations added to the soil concentrations from the other two sources. Figure 10 demonstrates that

dust re-suspension emissions are generally confined to the area where the emissions occur as compared to the other emission sources, from which dispersion appeared to be more widespread. This is generally consistent with releases from stacks and high temperature manufacturing operations, where the height of the release contributes to greater travel distance.

5.2 Correlation with Soil Sampling Data

Review of all the figures show that figures representing deposition modeling with source parameters "a" and emission estimates increased by a factor of 10 best fit the currently available soil sampling data, assuming that the PCB concentrations in the soil are exclusively the result of deposition from Facility emission sources. These figures (Figures 6 and 11) show relatively good agreement with the Northern soil sampling data. However, the Southern soil sampling data are generally higher than the modeled values.

5.2.1 Correlation Issues—Meteorological Data

RME believes that the modeled soil concentrations could be more consistent with the southern soil samples if the methodology used for this analysis allowed for a more accurate consideration of a terrain influenced wind field that is indicative of the Facility. It is likely that the actual meteorology at the Facility has a more significant North-South component than is represented by the St. Louis Lambert Field Airport meteorological data, due to the Facility's location in a river valley that extends in a generally North-South direction. The river valley would tend to channel winds from the Northwest into a more North-to-South direction, with greater deposition occurring south of the site than would be represented by the St. Louis Lambert Field meteorological data. This increase in deposition could be significant given that the second most frequent wind direction in the meteorological dataset is the Northwest direction. (The most frequent direction is South, as indicated on Diagram 3, the Wind Rose.)

The terrain influenced directional wind field could be investigated in more detail by conducting a deposition modeling analysis using the EPA recommended diagnostic three-dimensional meteorological model (CALMET) and an air quality dispersion model (CALPUFF). CALMET would be used to process the meteorological data, and CALPUFF would be used to model the deposition, rather than using AERMET and AERMOD as was used for this study. It should be noted that AERMOD is the regulatory model of choice for studies where the model extent is less than 50 kilometers (km) from the source, although, based on RME's experience, it is reasonable to surmise that CALPUFF could provide representative results for this study area.

5.2.2 Correlation Issues—Emission Estimates

The fact that an increase in the emission estimates by a factor of 10 increases the correlation with the soil sampling data also makes sense, because there is evidence that the emission estimates described in Section 2.0 may be biased low. The emission factor for the Former PCB Manufacturing Plant source is likely biased low, because it does not reflect emissions from charging the distillation still, filtration, and earth treatment, which Monsanto reported as being sources of some of the most severe emissions. Further, as also discussed in Section 2.0, assuming a destruction efficiency of 99.9999 percent may be giving more destruction credit to an incinerator operated in the early 1970s than is reasonable, given the technology in use at that time.

5.3 Most Significant Deposition Source

The analysis shows that PCB soil concentrations from air emissions at the WGK Facility are dominated by the emissions from the Former PCB Manufacturing Plant. This can be shown by examining the deposition fluxes, time periods of deposition, and modeled soil concentrations for two different time periods; with one time period consisting of a period in which manufacturing emissions occurred but the incineration emissions did not, and the other time period representing only operation of the Former Waste Incinerator. The Former Chlorobenzene Storage Area dust re-suspension emissions can also be evaluated in this manner. However, as shown on Figure 10, the aerial extent of emission impacts from dust re-suspension is minor compared to the Former PCB Manufacturing Plant and Former Waste Incineration emissions.

Evaluation of Chart 5 below confirms that PCB manufacturing emissions at the Facility drive the soil concentrations due to deposition. This is attributed to the manufacturing emissions being of greater magnitude than the other sources, occurred over a longer period of time, and also occurred over a large area. Thus, any refinement in the emissions estimates should be focused on the emissions associated with the Former PCB Manufacturing Plant at the Facility.

Chart 5: Comparison of Deposition Flux and Time Period of Emissions between Sources

Emission Source	Time Period of Referenced Flux and Soil Concentrations	Maximum Total Particle Deposition Flux (g/m^2/year)[1]	Maximum Total Vapor Deposition Flux (g/m^2/year)[1]	Maximum Soil Concentration (µg/kg)[2]	Total Time of Emission (yr)
Former PCB Manufacturing Plant	1960 – 1970	0.01756	5.6 x 10^{-4}	2,197	41
Former Waste Incinerator	1977	9.8 x 10^{-4}	1 x 10^{-5}	22	7
Former Chlorobenzene Storage Area (dust re-suspension)	1954 – 2004	6.8 x 10^{-4}	NA	681	50

1. Deposition flux shown is based on source parameters "a."
2. Maximum soil concentration reported is based on the original emissions estimate x 10.

NA = Not Applicable

6.0 UNCERTAINTY ANALYSIS

A modeling analysis of this type is inherently uncertain due to the overall lack of hard data about historical time periods of operation, and the numerous engineering and scientific judgments and calculations that must be made to describe complex physical and chemical processes. Reviewers and decision-makers should be aware of these uncertainties and ensure that the results are not given more or less weight than is appropriate. Chapter 8 of the EPA's *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (EPA 2005) provides an excellent review of the uncertainty associated with projects of this nature. The impact on the results of some of the engineering and scientific judgments made as part of this analysis is provided below.

6.1 Emissions Estimates

The limited soil sampling data suggests that the emission estimates presented in Table 3 of this study are perhaps biased low by a factor of 10 or less. The actual emissions are probably no greater than the estimates multiplied by a factor of 100, based on the correlation with the soil sampling data. Given the lack of available data describing emissions over time, and the long period of time over which emissions occurred, it is RME's opinion that an emission estimate that is perhaps within a factor of 10 of actual emissions represents a reasonable degree of uncertainty for a study of this type.

6.2 Deposition Modeling

The deposition flux modeling results are influenced by a variety of parameters. Some of these parameters have little or no impact on the results while others have significant impacts. RME examined some of the parameters qualitatively, and others were examined quantitatively. The quantitative analysis involved RME conducting multiple model runs using source parameters "a" at two different receptor locations. The receptor locations for which model parameters were varied and results determined are shown on Diagram 5 below. One location was Receptor No. 858 (the Far Receptor) of the complete receptor grid, which is located near the area of EPA soil sampling results (refer to Figures 4 through 11). Another receptor chosen was Receptor No. 970 (the Close Receptor), which is located closer to the source of the emissions.

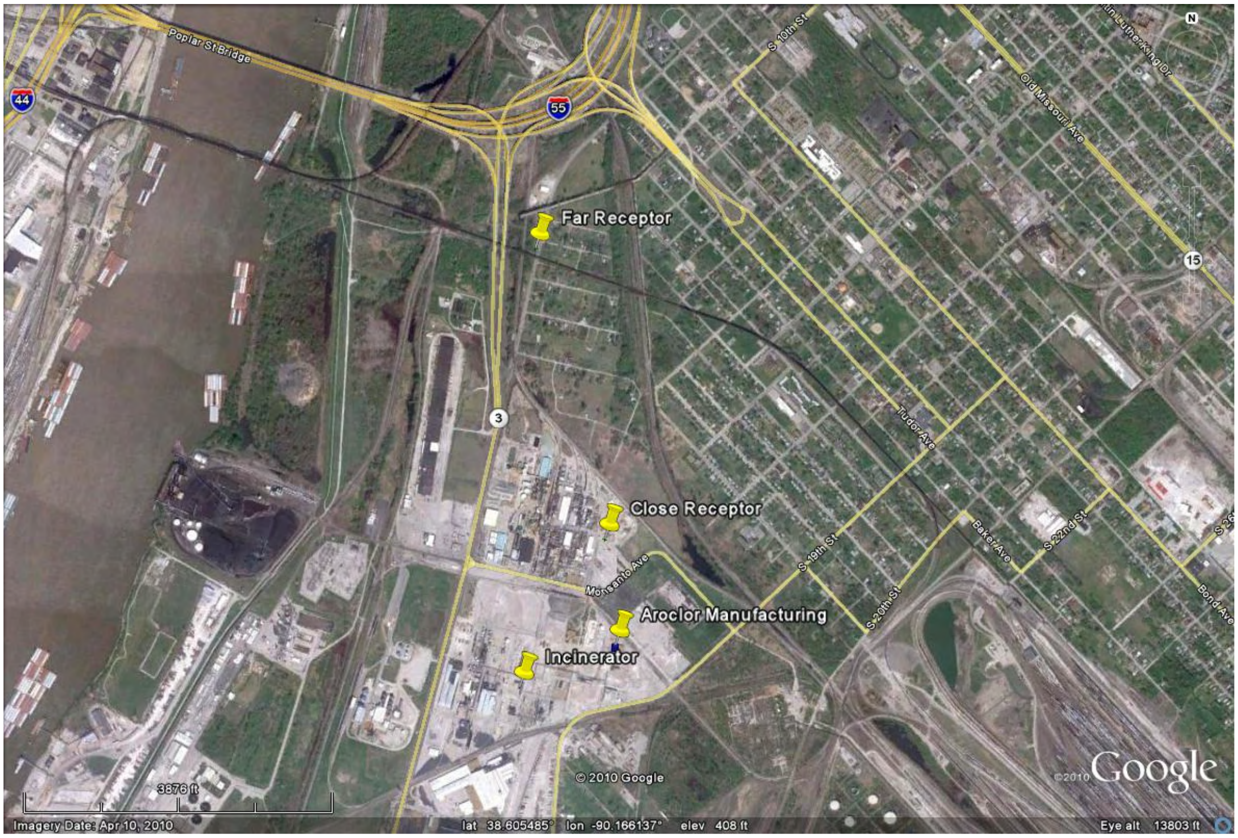

Diagram 5 – Receptor Locations for which Model Parameters were Varied

6.2.1 Meteorological Data

The influence of meteorological data is described in detail in Section 3.0 above. It is expected that refinement of the meteorological data processing to more accurately account for terrain-influenced wind fields (resulting from the location of the Facility in a river valley) would cause the soil concentration isopleths shown on Figures 4 through 11 to expand in a more southern direction (similar to the shape of the projected plume north of the facility). Such an analysis might narrow the gap between the modeled soil concentrations and the soil sampling data.

6.2.2 Lack of Downwash Consideration

The decision to not consider downwash in the modeling effort due to the lack of data could result in modeled deposition fluxes that are close to the sources to be biased low. This is because downwash causes the modeled ambient concentrations to increase close to the source, and the ambient air concentration is a parameter that is used to calculate deposition flux. Such an increase close to the source could be offset by the fact that land use close to the surface is Urban; the following section describes this impact. Modeling results for receptor grid nodes located farther away from modeled sources are not expected to be significantly affected by the decision not to consider downwash in the analysis.

6.2.3 Land Use Categories

The model is sensitive to land use categories. For example, the model will return a deposition flux result of zero if the land use for a sector is specified as “Urban Land Use-No Vegetation.” The land use categories chosen for this modeling effort were based on land uses at a distance from the source in order to evaluate the deposition impacts at areas that are not on plant property. The land uses chosen were either “Rangeland” or “Suburban Area-Grassy.” The model does not allow the user to specify different land uses within the same sector for areas located at differing distances from the source. Therefore, this analysis possibly overestimates the deposition impacts close to the source where the land use is Urban, because the land use for the entire sector is specified as Rangeland or Suburban.

6.2.4 Plume Depletion

RME turned the “Plume Depletion” feature of AERMOD on for purposes of conducting the particle phase deposition modeling, but turned it off for the vapor phase deposition modeling in order to shorten model run times. This decision could have had the result of biasing the deposition flux results high for receptor grid nodes located farther away from the sources, because the purpose of the plume depletion algorithm is to remove contaminant mass from the plume as it is deposited into the environment. However, before making this decision, the model was tested to determine if there was a difference in deposition flux at a distance from the source regardless of whether plume depletion was turned on or off. Chart 6 below demonstrates the relative insensitivity of the model to this parameter:

Chart 6: Comparison of Plume Depletion Feature On versus Plume Depletion Off

AERMOD Result	Description	UTM-X	UTM-Y	Plume Depletion On	Plume Depletion Off
Concentration (µg/m^3)	N-Closer to Sources	746,723.00	4,276,346.00	0.07101	0.07101
	N-@ Area of Soil Sampling	746,423.00	4,277,446.00	0.01427	0.01427
Total Vapor Deposition (g/m^2/yr)	N-Closer to Sources	746,723.00	4,276,346.00	0.00034	0.00034
	N-@ Area of Soil Sampling	746,423.00	4,277,446.00	0.00006[(a)]	0.00006
Dry Vapor Deposition (g/m^2/yr)	N-Closer to Sources	746,723.00	4,276,346.00	0.00034	0.00034
	N-@ Area of Soil Sampling	746,423.00	4,277,446.00	0.00006	0.00006
Wet Vapor Deposition (g/m^2/yr)	N-Closer to Sources	746,723.00	4,276,346.00	0	0
	N-@ Area of Soil Sampling	746,423.00	4,277,446.00	0	0

a. As shown in many of these charts, the air deposition model often outputs results for depositional flux with only one significant digit.

6.2.5 Deposition Parameters

In its *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities*, EPA opines that the deposition flux of PCBs is thought to be almost entirely a function of the vapor phase component of the deposition. The Protocol recommends that the fraction of Aroclor™ 1254 in combustion emissions that are present in the vapor phase be set at 99.2 percent of the total deposition flux. This causes the soil concentration modeling to be particularly sensitive to the modeled total vapor phase deposition flux, since the particulate fraction of the deposition represents only 0.8 percent of the total PCB deposition flux.

However, the vapor phase fraction of some airborne emissions containing PCBs may be much less than 99.2 percent of total PCBs—for example, particulate emissions associated with Aroclor™ earth treatment (e.g., at the Former PCB Manufacturing Plant) or dust re-suspension (e.g., at the Former Chlorobenzene Storage Area). As previously noted, the emissions factor developed by EPA's Beihoffer and used in this analysis does not address the emissions associated with Aroclor™ earth treatment. Further, this analysis did assume that dust re-suspension emissions from the Former Chlorobenzene Storage Area occur entirely in the particulate phase. Thus, where possible and appropriate, the vapor phase fraction was varied from the Protocol's default value of 99.2 percent.

Nevertheless, this analysis is sensitive to vapor phase deposition, because a vapor phase fraction of 99.2 percent was used for the purpose of estimating PCB soil concentrations that are related to the deposition of emissions from PCB Manufacturing and PCB Waste Incineration. An assumed vapor phase fraction of 99.2 percent was selected due to the lack of any other credible information, and because the emissions that are represented by the Beihoffer emissions factor seem to be predominately vapor in nature (e.g., Aroclor™ and Montar drumming, and HCl scrubber releases).

6.2.5.1 Henry's Law Constant

The total vapor phase deposition flux is the sum of the dry vapor deposition flux and the wet vapor deposition flux. It has been RME's experience that the wet vapor deposition flux is often the driver in this equation. However, in this analysis, the wet vapor deposition flux does not contribute to the total vapor deposition. This is because the Henry's Law Constant for Aroclor™ 1254 is too high for the PCBs to become soluble in the precipitation. An example of this is shown in the chart below where all other parameters were held constant and the Henry's Law Constant was varied. The results show that varying the Henry's Law Constant by a factor of 100 results in minimal impacts to the modeled deposition flux, particularly at locations further from the emission source (Chart 7). Thus, wet deposition does not significantly contribute to the deposition of Aroclor™ 1254 vapor in the environment.

Chart 7: Sensitivity of Vapor Deposition to Henry's Law Constant for Aroclor™ 1254

AERMOD Result	Location Description	UTM-X	UTM-Y	H = 24 ($Pa\text{-}m^3/mol$)	H = 0.24 ($Pa\text{-}m^3/mol$)	H = 2,400 ($Pa\text{-}m^3/mol$)
Total Vapor Deposition ($g/m^2/yr$)	N-Closer to Sources	746,723.00	4,276,346.00	0.00034	0.00048	0.00024
	N-@ Area of Soil Sampling	746,423.00	4,277,446.00	0.00006	0.00008	0.00005
Dry Vapor Deposition ($g/m^2/yr$)	N-Closer to Sources	746,723.00	4,276,346.00	0.00034	0.00045	0.00024
	N-@ Area of Soil Sampling	746,423.00	4,277,446.00	0.00006	0.00008	0.00005
Wet Vapor Deposition ($g/m^2/yr$)	N-Closer to Sources	746,723.00	4,276,346.00	0	0.00002	0
	N-@ Area of Soil Sampling	746,423.00	4,277,446.00	0	0.00001	0

$Pa\text{-}m^3/mol$ – Pascal cubic meters per mole

6.2.5.2 Diffusivity in Air

Similar to Henry's Law Constant, the model is relatively insensitive to the diffusivity in air parameter for Aroclor™ 1254, particularly at a distance from the emission source. Chart 8 below shows impacts of varying the diffusivity in air by a factor of 100 while holding all other parameters constant.

Chart 8: Sensitivity of Vapor Deposition to Diffusivity in Air for Aroclor™ 1254

AERMOD Result	Location Description	UTM-X	UTM-Y	$D_a = 4.29 \times 10^{-2}$ cm^2/s	$D_a = 4.29$ cm^2/s	$D_a = 4.29 \times 10^{-4}$ cm^2/s
Total Vapor Deposition ($g/m^2/yr$)	N-Closer to Sources	746,723.00	4,276,346.00	0.00034	0.00032	0.00021
	N-@ Area of Soil Sampling	746,423.00	4,277,446.00	0.00006	0.00006	0.00004
Dry Vapor Deposition ($g/m^2/yr$)	N-Closer to Sources	746,723.00	4,276,346.00	0.00034	0.00032	0.00021
	N-@ Area of Soil Sampling	746,423.00	4,277,446.00	0.00006	0.00006	0.00004
Wet Vapor Deposition ($g/m^2/yr$)	N-Closer to Sources	746,723.00	4,276,346.00	0	0	0
	N-@ Area of Soil Sampling	746,423.00	4,277,446.00	0	0	0

cm^2/s – square centimeters per second

6.2.5.3 Diffusivity in Water

The model results are also insensitive to this parameter for Aroclor™ 1254. Chart 9 below shows impacts of varying the diffusivity in water by a factor of 100,000, while holding all other parameters constant. There are no changes in model results that result from varying this parameter for Aroclor™ 1254.

Chart 9: Sensitivity of Vapor Deposition to Diffusivity in Water for Aroclor™ 1254

AERMOD Result	Location Description	UTM-X	UTM-Y	$D_w = 0.4$ cm^2/s	$D_w = 4 \times 10^4$ cm^2/s	$D_w = 4 \times 10^{-4}$ cm^2/s
Total Vapor Deposition ($g/m^2/yr$)	N-Closer to Sources	746,723.00	4,276,346.00	0.00034	0.00034	0.00034
	N-@ Area of Soil Sampling	746,423.00	4,277,446.00	0.00006	0.00006	0.00006
Dry Vapor Deposition ($g/m^2/yr$)	N-Closer to Sources	746,723.00	4,276,346.00	0.00034	0.00034	0.00034
	N-@ Area of Soil Sampling	746,423.00	4,277,446.00	0.00006	0.00006	0.00006
Wet Vapor Deposition ($g/m^2/yr$)	N-Closer to Sources	746,723.00	4,276,346.00	0	0	0
	N-@ Area of Soil Sampling	746,423.00	4,277,446.00	0	0	0

cm^2/s – square centimeters per second

6.2.5.4 Cuticular Resistance

The model is very sensitive to this parameter as shown in Chart 10 below, even at distances relatively far from the emission source. Varying the cuticular resistance (rcl) by a factor of 10 results in a significant difference in the deposition flux, with smaller values having higher deposition fluxes than larger values. The rcl for Aroclor™ 1254 varies between 160 and 490, according to Table D.3 of the ANL Report (ANL 2002). RME chose 325 to represent the midpoint of this range. The range of rcl values for all the Aroclors™ reported in Table D.3 is 160 to 9,400. Thus, the use of Aroclor™ 1254 to represent all the PCB deposition in the study area is conservative, because Aroclor™ 1254 has lower values of cuticular resistance as compared to other Aroclors™ that were also emitted during the time period over which emissions occurred.

Chart 10: Sensitivity of Vapor Deposition to Cuticular Resistance for Aroclor™ 1254

AERMOD Result	Location Description	UTM-X	UTM-Y	rcl = 325 s/cm	rcl = 3,250 s/cm	rcl = 32.5 s/cm
Total Vapor Deposition (g/m^2/yr)	N-Closer to Sources	746,723.00	4,276,346.00	0.00034	0.00006	0.00209
	N-@ Area of Soil Sampling	746,423.00	4,277,446.00	0.00006	0.00001	0.00040
Dry Vapor Deposition (g/m^2/yr)	N-Closer to Sources	746,723.00	4,276,346.00	0.00034	0.00006	0.00209
	N-@ Area of Soil Sampling	746,423.00	4,277,446.00	0.00006	0.00001	0.00040
Wet Vapor Deposition (g/m^2/yr)	N-Closer to Sources	746,723.00	4,276,346.00	0	0	0
	N-@ Area of Soil Sampling	746,423.00	4,277,446.00	0	0	0

s/cm –seconds per centimeter
Deposition flux results stated exactly as returned by the model.

6.2.5.5 Other PCB Formulation (Aroclor™ 1242)

Finally, for purposes of evaluating the impact of changing multiple parameters at one time, deposition parameters were changed to be consistent with Aroclor™ 1242, another common Aroclor that was manufactured by Monsanto after 1952. As shown in Chart 11 below, the deposition flux is reduced by a factor of six if the parameters for Aroclor™ 1242 are used instead of the parameters for Aroclor™ 1254. RME believes that this reduction in deposition flux is primarily because the cuticular resistance for Aroclor™ 1242 is 3,120 seconds per centimeter (s/cm), compared with 325 s/cm for Arcolor™ 1254. Thus, modeling all of the PCB deposition as if it were Aroclor™ 1254 is conservative.

Chart 11: Comparison of Deposition Flux between Aroclor™ 1254 and Aroclor™ 1242

AERMOD Result	Location Description	UTM-X	UTM-Y	Aroclor™ 1254	Aroclor™ 1242
Total Vapor Deposition (g/m^2/yr)	N-Closer to Sources	746,723.00	4,276,346.00	0.00034	0.00009
	N-@ Area of Soil Sampling	746,423.00	4,277,446.00	0.00006	0.00001
Dry Vapor Deposition (g/m^2/yr)	N-Closer to Sources	746,723.00	4,276,346.00	0.00034	0.00009
	N-@ Area of Soil Sampling	746,423.00	4,277,446.00	0.00006	0.00001
Wet Vapor Deposition (g/m^2/yr)	N-Closer to Sources	746,723.00	4,276,346.00	0	0
	N-@ Area of Soil Sampling	746,423.00	4,277,446.00	0	0

6.3 Use of AERMOD to Model Former Chlorobenzene Storage Area

As described in Section 3.3.3 of this report, dust re-suspension emissions from the Former Chlorobenzene Storage Area were developed based on AP-42, Section 13.2.5. The procedure described by this EPA guidance recommends using the FMWS and the TFV to develop the emissions estimates. Emissions do not occur if the actual FMWS does not exceed the TFV of the contaminated soil over which the wind is blowing. A problem arises when using AERMOD to predict the deposition of dust re-suspension emissions, because the model: (1) does not use the FMWS in its algorithms; and (2) assumes emissions occur at every hour of meteorological data (unless a variable emission file that defines when dust re-suspension emissions occur is provided as an input). The construction of such an input file is not possible, because the FMWS data is not provided for every hour; only the maximum value for a 24-hour period is provided by the archived data sets.

To address this issue, RME used a procedure based on the AP-42 guidance and the typical FMWS and direction recorded at the St. Louis Lambert Field Airport to estimate the annual average dust re-suspension emissions from the Former Chlorobenzene Storage Area. Further, the analysis used by RME assumed that the entire area of the Former Chlorobenzene Storage Area was disturbed between each successive FMWS event, which is conservative but highly unlikely given the overall size of the area.

In summary, the procedure used by RME assumes that:

- The wind direction of the FMWS measurements is not significantly different than the predominate wind directions of the meteorological data set used to support the deposition modeling
- The dust re-suspension emissions occur all the time (even when they should not because the soil has not been disturbed or the FMWS does not exceed the TFV)

- Dust re-suspension emissions are less than actual emissions on some days
- Dust re-suspension emissions are greater than actual emissions on other days.

Thus, of all the results presented in this report, the Former Chlorobenzene Storage Area soil concentrations are the most uncertain and the most conservative.

The wind direction consistency was tested by comparing the direction of the FMWS measurements to the wind rose of the meteorological data used to support the deposition modeling using the same number of wind direction sectors. Chart 12 below shows that the direction of the FMWS data is not significantly different than the meteorological data used to support the deposition modeling.

Chart 12: Comparison of Fastest Mile Wind Speed Directions to AERMOD Met Data Directions

Blowing From Direction (degrees)	FMWS Data Frequency (%)	AERMOD Data Frequency (%)
45 (NE)	7.7	7.2
90 (E)	6.1	8.7
135 (SE)	20.6	15.3
180 (S)	10.4	17.0
225 (SW)	13.6	11.7
270 (W)	14.8	14.6
315 (NW)	18.8	13.9
360 (N)	8	7.5

The impact of assuming that dust re-suspension emissions occur even when the FMWS does not exceed the TFV was evaluated by determining the overall percent of FMWS measurements that exceeded the TFV. A total of 5,326 days of FMWS data were available for evaluation. A summary of the number of days that the TFV was equal to or greater than 17 miles per hour (mph) for this data set is shown in Chart 13 below and equaled 54.1 percent of the measurements. This percentage was extrapolated to 365 days.

Chart 13: Frequency That Fastest Mile Wind Speed Exceeds the Threshold Friction Velocity

Total Days of Data	5,326		
Days ≥ 17 mph	2,879		
Percent of Total ≥ 17 mph	54.1%		
Day Description	**Number of Days**	**Percent of Total Days**	**Number of Days out of 365 days**
Days ≥ 40 mph	30	0.6%	2
Days ≥ 35 mph	73	1.4%	5
Days ≥ 30 mph	232	4.4%	16
Days ≥ 25 mph	542	10.2%	37
Days ≥ 20 mph	894	16.8%	61
Days ≥ 17 mph	1,108	20.8%	76
Total Number of Days FMWS is Exceeded			**197**

Thus, the total number of days that the FMWS likely exceeded the TFV in a given year is 197. It is unknown how many hours within a given day the TFV is exceeded, but since erosion emissions are thought to occur for only a brief period of time before the all of the erodible material is removed until the next soil disturbance, it is likely that for a given square foot of soil, erosion emissions in the Former Chlorobenzene Storage Area would occur at most once or twice a day (except for areas located in well-traveled thoroughfares). Because the emissions are assumed to occur continually over a 10.5 acre (42,744 m^2) area, assuming continual dust re-suspension emissions from the Former Chlorobenzene Storage Area results in soil concentrations that are very conservative.

Finally, because the RME procedure used an annual average emission factor, the overall mass of emissions deposited in the surrounding area is the same as if the magnitude of emissions were varied with respect to erosion events. The impacts of this assumption are considered to be significantly less than the assumption that dust re-suspension emissions occur continually over a 10.5-acre area.

In conclusion, it is RME's opinion that the soil concentrations resulting from dust re-suspension emissions from the Former Chlorobenzene Storage Area are the most uncertain and conservative reported in this study. The impact of dust re-suspension emissions is limited to a relatively small area (refer to Figure 10), even with the conservative assumptions used in this study.

6.4 Soil Concentrations

The uncertainty in the soil concentration calculations is related to the uncertainty in the emissions estimates and air deposition modeling, because both of these factors are important inputs to the soil concentration calculations. Another important factor that affects soil concentration is the time period over which deposition occurs. RME does not believe that the time period over which deposition occurs is a source of significant uncertainty, because the historical record is fairly well defined with regard to when deposition started and when it ended. A final source of uncertainty in the soil concentration calculations is the soil loss constant. RME calculated the soil loss constant based on the equations and chemical-specific parameters described in EPA's *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities.* Those calculations resulted in the following soil loss constants:

Chart 14: Soil Loss Constants for Aroclor™ 1254

Soil Loss Constant	**Value (yr^{-1})**
Volatilization (K_{sv})	2.2×10^{-2}
Leaching (K_{sl})	9.7×10^{-20}
Runoff (K_{sr})	3.5E x 10^{-4}
Total (K_s)	**2.2×10^{-2}**

As shown in Chart 14 above, the volatilization loss constant dominates. As the loss constant increases, the soil concentration at the end of the deposition period decreases. Thus, an actual soil loss constant that is greater than the loss constant used for this analysis would result in lower modeled PCB soil concentrations.

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TABLES

TABLE 1: HISTORICAL SUMMARY OF CHEMICAL MANUFACTURING

YEAR	OWNER	EVENT	MANUFACTURING LINE	YEAR MANUFACTURING ENDED
1907	Commercial Acids Company (CAC)	Began Operations	Sulfuric Acid	
			Muriatic Acid	
			Nitric Acid	
1914	CAC	Purchased neighboring Sandoval Zinc Company	Zinc Chloride	
1916	CAC		Phenol by sulfonation	1970
1917 - 1925	Monsanto	Acquires CAC and names it Plant B	Zinc Chloride, Phenol, Salt Cake and Nitric Cake	
1925	Monsanto		Chlorine	
			Caustic Soda	
1926	Monsanto		Chlorobenzenes	
			para-Nitroaniline	
			Catalysts for contact sulfuric acid plants	
1930's	Monsanto	Rapid Expansion	Nitrated Organic Chemicals	
			Chlorophenols	
			Benzyl Chloride	
			Aroclors (1936 - 1976)	1977 - dismantled
			Hydrogenated products	
			Phosphorous Halides	
			Phosphoric Acid	
1939 - 1945	Monsanto	WWII - Expansion was halted to support war efforts		
~1940	Monsanto	Monsanto sold 15 acres to the U.S. Government for construction of the Chemical Warfare Plant (CWP)		
~1942	Monsanto	Operations Began	CWP	
1947	Monsanto	Monsanto leased the CWP from the U.S. and began manufacturing	2,4 – D Herbicide	
			2,4,5-T Herbicide	

TABLE 1: HISTORICAL SUMMARY OF CHEMICAL MANUFACTURING

YEAR	OWNER	EVENT	MANUFACTURING LINE	YEAR MANUFACTURING ENDED
1948/1949	Monsanto	Began manufacturing detergent ingredients	Santomerse #1	
			Alkylbenzene	
1950	Monsanto		Potassium Phenyl Acetate	
1951	Monsanto		Monochloroacetic Acid	
1951	Monsanto	Plant named William G. Krummrich (WGK) in honor of plant manager		
1954	Monsanto		Tricresyl Phosphate	Early 1990's
			Adipic Acid	
1955	Monsanto		Phosphorous Pentasulfide	
1956	Monsanto		Fatty Acid Chloride	
			Santolube 393	
1960	Monsanto	Monsanto purchased the CWP and continued expansion of operations	Germicide and oil additive	
			Nitration facility	
			Modernized Phenol Production Unit	
		Constructed River Terminal with storage tanks to store Sulfuric Acid, Toluene, Caustic Soda, Monochlorobenzene, and Fuel Oil. These materials were transferred via underground piping to the plant.		1980's - dismantled and piping was drained, flushed and grouted.
1963	Monsanto	Expanded output to 100 tons of Chlorine, 70 tons of Caustic Soda, and 55 tzons of Potash per day	Chlorinated Cyanuric Acid	
			New Chlorine Unit	
1964	Monsanto		ortho-Dichlorobenzene	
			Commercial biodegradable detergent intermediate	
1966	Monsanto	QC and R&D Lab	Laboratory	
1967	Monsanto	Built new sufluric acid unit to replace 2 smaller units and expanded para-Nitrochlorobenzene. Expansion resulted in 50% increase of production.	New Sulfuric Acid unit	
			Expansion of para-Nitrochlorobenzene unit	

TABLE 1: HISTORICAL SUMMARY OF CHEMICAL MANUFACTURING

YEAR	OWNER	EVENT	MANUFACTURING LINE	YEAR MANUFACTURING ENDED
1968	Monsanto	Built new unit and expanded others	Calcium Benzene Sulfonate (Santolube 290)	
			Expansion of Aroclor	
			Expansion of Nitrochlorobenzene	
			Expansion of ortho-Nitrophenol	Early 1990's
1970	Monsanto	Shutdown Phenol Department and updated the Santosite Facilities to increase production		1979 - dismantled Santosite Departments
1971	Monsanto	Sold the North Plant Area (i.e. CWP) to Ethyl Corporation		
1972	Monsanto		Orthonitrophenol Department	
1976	Monsanto	This replaced an older plant	Benzyl Chloride/Santicizer-160 Plant	1981 - decommissioned
1977		Dismantled Aroclor plant		
1979		Dismantled Santosite Department		
1981		Ceased, decontaminated, and decommissioned Benzyl Chloride/Santicizer-160 Plant btu did not dismantle for plans to resume when market improved		
1986		Market did not improve so the Benzyl Chloride/Santicizer-160 Plant were converted	Santoflex (a rubber chemical product)	
1986+		Ceased Chlorine manufacturing and dismantled the Chlor/Alkali facilities.		
Early 1990's		Ceased operations and dismantled the ortho-Nitrophenol and Phosphorous Trichloride Departments		
	Occidental Chemical purchased the ACL			
	Flexys assumed ownership of the 4-Nitrodiphenylamine and Santoflex units			1999
1997	Monsanto spun off its chemical business to form Solutia inc.			
2000	Solutia and FMC formed a JV called Astaris combining both companies Phosphorous units. Astaris owns the Phosphorous Pentasulfide unit and is operated by Solutia.			

TABLE 2: HISTORICAL SUMMARY OF WASTE MANAGEMENT

YEAR	OWNER	EVENT	WASTE MANAGEMENT PRACTICE	UNIT	LOCATION	CLOSURE
1932	Monsanto	The village of Monsanto installed sewer lines	WGK tied into the village system	Sewer System	Plant Wide	
1952		Village of Sauget started operating a WWTP	WGK wastewater effluent sent to WWTP	Sewer System	Cahokia Chute to West of facility	
1965 - 1978		Use of open lagoons	WWTP clarifier sludge disposed in a series of lagoons	lagoons	Sauget Area 2, Site O	Lagoons covered with 2' of clay and vegetated
1957 - 1977		Disposal of wastes in 36-acre landfill	Wastes included organics, inorganics, solvents, pesticides, heavy metals, and drums	Rivers Edge Landfil	Sauget Area 2, Site R - adjacent to Mississippi River	Compacted clay cap
1966 - 1973		Disposal of wastes in 90-acre landfill	Wastes included MSW, liquid chemical wastes, septic tank wastes, drums, organic and inorganic, solvents, pesticides, and paint sludges	Landfill	Sauget Area 1, Site Q - south of River Terminal	
1971 - 1977		Storage and incineration on-site	Wastes were stored in the PCB Warehouse and then incinerated in an on-site unit. A total of 151,000 tons of organic waste was incinerated during its operation.	PCB Warehouse and Incinerator	Near middle of WGK Facility	Incinerator - 1977
1981/1982		Waste continued to be stored in PCB Warehouse	Waste stored for off-site incineration	PCB Warehouse	Northeast area of WGK Facility	1981/1982
1981		Constructed new waste storage unit (Building BBU)		Building BBU		Currently used for <90 storage of HW

TABLE 3: WGK FACILITIES ESTIMATED AROCLOR AIR EMISSIONS 1929 - 1977

	FORMER PCB MANUFACTURING PLANT(1)					FORMER WASTE INCINERATOR(2)			
YEAR	Estimated Annual Aroclor Production		Estimated Annual Aroclor Air Emissions using Biehoffer's AEF emitting 365 days/yr (lbs)		Estimated Annual Aroclor Air Emissions (g/sec)	Feed Rate (lbs/hr) (2)(3)	DRE	Emissions (lb/hr)	Emissions (g/sec)
1929	1,000,000	lbs	88	lbs	1.26E-03	NA	NA	NA	NA
1930	1,000,000	lbs	88	lbs	1.26E-03	NA	NA	NA	NA
1931	1,000,000	lbs	88	lbs	1.26E-03	NA	NA	NA	NA
1932	1,000,000	lbs	88	lbs	1.26E-03	NA	NA	NA	NA
1933	1,000,000	lbs	88	lbs	1.26E-03	NA	NA	NA	NA
1934	1,000,000	lbs	88	lbs	1.26E-03	NA	NA	NA	NA
1935	3,000,000	lbs	264	lbs	3.79E-03	NA	NA	NA	NA
1936	1,569,800	lbs	138	lbs	1.98E-03	NA	NA	NA	NA
1937	2,944,596	lbs	259	lbs	3.72E-03	NA	NA	NA	NA
1938	2,798,628	lbs	246	lbs	3.54E-03	NA	NA	NA	NA
1939	3,999,171	lbs	352	lbs	5.06E-03	NA	NA	NA	NA
1940	6,535,428	lbs	574	lbs	8.26E-03	NA	NA	NA	NA
1941	9,071,685	lbs	797	lbs	1.15E-02	NA	NA	NA	NA
1942	10,457,882	lbs	919	lbs	1.32E-02	NA	NA	NA	NA
1943	10,457,882	lbs	919	lbs	1.32E-02	NA	NA	NA	NA
1944	10,457,882	lbs	919	lbs	1.32E-02	NA	NA	NA	NA
1945	10,457,882	lbs	919	lbs	1.32E-02	NA	NA	NA	NA
1946	10,457,882	lbs	919	lbs	1.32E-02	NA	NA	NA	NA
1947	11,844,079	lbs	1,041	lbs	1.50E-02	NA	NA	NA	NA
1948	12,137,409	lbs	1,067	lbs	1.53E-02	NA	NA	NA	NA
1949	12,272,150	lbs	1,079	lbs	1.55E-02	NA	NA	NA	NA
1950	12,406,891	lbs	1,091	lbs	1.57E-02	NA	NA	NA	NA
1951	16,811,568	lbs	1,478	lbs	2.13E-02	NA	NA	NA	NA
1952	15,258,086	lbs	1,341	lbs	1.93E-02	NA	NA	NA	NA
1953	16,326,000	lbs	1,435	lbs	2.06E-02	NA	NA	NA	NA
1954	13,607,000	lbs	1,196	lbs	1.72E-02	NA	NA	NA	NA
1955	17,106,000	lbs	1,504	lbs	2.16E-02	NA	NA	NA	NA
1956	23,052,000	lbs	2,026	lbs	2.91E-02	NA	NA	NA	NA
1957	24,848,000	lbs	2,184	lbs	3.14E-02	NA	NA	NA	NA
1958	22,309,000	lbs	1,961	lbs	2.82E-02	NA	NA	NA	NA
1959	23,691,000	lbs	2,082	lbs	3.00E-02	NA	NA	NA	NA

	FORMER PCB MANUFACTURING PLANT(1)					FORMER WASTE INCINERATOR(2)			
YEAR	Estimated Annual Aroclor Production		Estimated Annual Aroclor Air Emissions using Biehoffer's AEF emitting 365 days/yr (lbs)		Estimated Annual Aroclor Air Emissions (g/sec)	Feed Rate (lbs/hr) (2)(3)	DRE	Emissions (lb/hr)	Emissions (g/sec)
AVERAGE	**9,996,061**		**879**		**1.26E-02**	NA	NA	NA	NA
						NA	NA	NA	NA
1960	11,609,000	lbs	1,020	lbs	1.47E-02	NA	NA	NA	NA
1961	10,393,000	lbs	914	lbs	1.31E-02	NA	NA	NA	NA
1962	13,955,000	lbs	1,227	lbs	1.76E-02	NA	NA	NA	NA
1963	19,129,000	lbs	1,681	lbs	2.42E-02	NA	NA	NA	NA
1964	23,040,000	lbs	2,025	lbs	2.91E-02	NA	NA	NA	NA
1965	26,496,000	lbs	2,329	lbs	3.35E-02	NA	NA	NA	NA
1966	25,113,000	lbs	2,207	lbs	3.18E-02	NA	NA	NA	NA
1967	29,773,000	lbs	2,617	lbs	3.76E-02	NA	NA	NA	NA
1968	34,171,000	lbs	3,004	lbs	4.32E-02	NA	NA	NA	NA
1969	42,760,000	lbs	3,759	lbs	5.41E-02	NA	NA	NA	NA
1970	49,692,000	lbs	4,368	lbs	6.28E-02	NA	NA	NA	NA
AVERAGE	**26,011,909**		**2,286**		**3.29E-02**	NA	NA	NA	NA
1971	33,032,000	lbs	2,904	lbs	4.18E-02	1142	0.999999	0.001142	1.44E-04
1972	38,600,000	lbs	3,393	lbs	4.88E-02	1142	0.999999	0.001142	1.44E-04
1973	42,178,000	lbs	3,707	lbs	5.33E-02	1142	0.999999	0.001142	1.44E-04
1974	40,466,000	lbs	3,557	lbs	5.12E-02	1142	0.999999	0.001142	1.44E-04
1975[4]	40,466,000	lbs	3,557	lbs	5.12E-02	1142	0.999999	0.001142	1.44E-04
1976[4]	40,466,000	lbs	3,557	lbs	5.12E-02	1142	0.999999	0.001142	1.44E-04
AVERAGE	**39,201,333**		**3,446**		**4.96E-02**	1142	0.999999	0.001142	1.44E-04
1977	NA	NA	NA	NA	NA	1142	0.999999	0.001142	1.44E-04

NOTES:

(1) PCB production data was obtained from the March 2005 technical report titled *Evaluation of Monsanto's Polychlorinated Biphenyl (PCB) Process for PCB Losses at the Anniston Plant* as prepared by Jon L. Beihoffer.

(2) According to a Monsanto letter dated November 26, 1991, Monsanto reported that a total of 151,000 tons of organic waste was incinerated at this unit from 1971 to 1977. At this quantity, this would result in 4,924 lb/hr.

(3) According to the February 26, 1976 Final Report titled *PCBs in the United States Industrial Use and Environmental Distribution* document, it is reported that the incinerator at the Monsanto Plant has a rated design capacity of 10 million lb/yr and that since the start of its operation this unit achieved a maximum of 0.60. At this feed rate, this would result in 1141 lb/hr. Due to the significant differences of reported feed rates, RME selected the 1141 lb/hr as the feed rate for this modeling exercise.

(4) Production rate estimated based on last reported production in 1974.

TABLE 4: MODEL INPUT PARAMETERS FOR THE FORMER PCB MANUFACTURING PLANT AND FORMER WASTE INCINERATOR

CHARACTERISTIC	MODEL FILE NAME	PCB MANUFACTURING	INCINERATOR
Source Type	All	Volume	Point
Release/Stack Ht. (m)	Ending in a	30.48	30.48
	Ending in b	24.38	24.38
Side Length (m)	All	24.1	NA
Sigma Y (m)	All	5.60	NA
Sigma Z (m)	Ending in a	14.18	NA
	Ending in b	11.34	NA
Gas Temp. (K)	Ending in a	NA	324.82
	Ending in b	NA	297.04
Gas Exit Velocity (m/sec)	Ending in a	NA	8.85
	Ending in b	NA	13.82
Stack Inside Diameter (m)	Ending in a	NA	1.52
	Ending in b	NA	1.22

TABLE 5: LAND USE CATEGORIES FOR DEPOSITION MODELING

WIND DIRECTION SECTOR (deg)	LAND USE CATEGORY
5 - 15	3 - Rangeland
15 - 25	5 - Suburban, grassy
25 - 35	5 - Suburban, grassy
35 - 45	5 - Suburban, grassy
45 - 55	5 - Suburban, grassy
55 - 65	5 - Suburban, grassy
65 - 75	5 - Suburban, grassy
75 - 85	5 - Suburban, grassy
85 - 95	5 - Suburban, grassy
95 - 105	5 - Suburban, grassy
105 - 115	5 - Suburban, grassy
115 - 125	5 - Suburban, grassy
125 - 135	3 - Rangeland
135 - 145	3 - Rangeland
145 - 155	3 - Rangeland
155 - 165	3 - Rangeland
165 - 175	3 - Rangeland
175 - 185	3 - Rangeland
185 - 195	5 - Suburban, grassy
195 - 205	5 - Suburban, grassy
205 - 215	5 - Suburban, grassy
215 - 225	3 - Rangeland
225 - 235	3 - Rangeland
235 - 245	3 - Rangeland
245 - 255	3 - Rangeland
255 - 265	3 - Rangeland
265 - 275	3 - Rangeland
275 - 285	3 - Rangeland
285 - 295	3 - Rangeland
295 - 305	3 - Rangeland
305 - 315	3 - Rangeland
315 - 325	3 - Rangeland
325 - 335	3 - Rangeland
335 - 345	3 - Rangeland
345 - 355	3 - Rangeland
355 - 005	3 - Rangeland

FIGURES

APPENDICES

Appendix A – Former Chlorobenzene Storage Area Dust Re-suspension Emission Estimates

Appendix B – Meteorological Data and AERMET Processing Files

Appendix C – Deposition Modeling Input and Output Files

Appendix D – Soil Concentration Computations

Appendix E – Meteorological Data QA Files

APPENDIX A

Former Chlorobenzene Storage Area Dust Re-suspension Emission Estimates

(Electronic Files provided on CD)

APPENDIX B

Meteorological Data and AERMET Processing Files

(Electronic Files provided on CD)

APPENDIX C

Deposition Modeling Input and Output Files

(Electronic Files provided on CD)

APPENDIX D

Soil Concentration Computations

(Electronic Files provided on CD)

APPENDIX E

Meteorological Data QA Files

(Electronic Files provided on CD)