

# Exhibit 427

## Expert Report of Lisa A. Bailey, Ph.D.

### In the Case of: Jacqueline Tukes v. United States

Prepared by



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Prepared for  
United States Department of Justice  
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# Abbreviations

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|                                             |                                                  |
|---------------------------------------------|--------------------------------------------------|
| $\mu\text{g}/\text{m}^3$                    | Micrograms per Cubic Meter of Air                |
| $(\mu\text{g}/\text{m}^3)^{-1}$             | Per Micrograms per Cubic Meter of Air            |
| 1,2-cDCE                                    | <i>cis</i> -1,2-dichloroethylene                 |
| 1,2-tDCE                                    | <i>trans</i> -1,2-Dichloroethylene               |
| ACS                                         | American Cancer Society                          |
| ADAF                                        | Age-Dependent Adjustment Factor                  |
| ATSDR                                       | Agency for Toxic Substances and Disease Registry |
| BMD                                         | Benchmark Dose                                   |
| BMDL                                        | Lower Confidence Limit on the Benchmark Dose     |
| CSF                                         | Cancer Slope Factor                              |
| CTE                                         | Central Tendency Exposure                        |
| DEC                                         | Daily Exposure Concentration                     |
| DED                                         | Daily Exposure Dose                              |
| ELCR                                        | Excess Lifetime Cancer Risk                      |
| HB                                          | Holcomb Boulevard                                |
| HP                                          | Hadnot Point                                     |
| IARC                                        | International Agency for Research on Cancer      |
| IUR                                         | Inhalation Unit Risk                             |
| L                                           | Liter                                            |
| LADD                                        | Lifetime Average Daily Dose                      |
| LADE                                        | Lifetime Average Daily Exposure                  |
| LED                                         | Lower Confidence Limit of the Exposure Dose      |
| LNT                                         | Linear No Threshold                              |
| MCL                                         | Maximum Contaminant Level                        |
| MoE                                         | Margin of Exposure                               |
| mg/kg-day                                   | Milligrams per Kilogram Body Weight per Day      |
| $(\text{mg}/\text{kg}\cdot\text{day})^{-1}$ | Per Milligrams per Kilogram Body Weight per Day  |
| NHL                                         | Non-Hodgkin's Lymphoma                           |
| NRC                                         | National Research Council                        |
| NTP                                         | National Toxicology Program                      |
| PBPK                                        | Physiologically Based Pharmacokinetic            |
| PCE                                         | Tetrachloroethylene/Perchloroethylene            |
| POD                                         | Point of Departure                               |
| ppb                                         | Parts per Billion                                |
| RAGS                                        | Risk Assessment Guidance for Superfund           |
| RME                                         | Reasonable Maximum Exposure                      |
| SD                                          | Standard Deviation                               |
| SDWA                                        | Safe Drinking Water Act                          |
| TCE                                         | Trichloroethylene                                |
| TSCA                                        | Toxic Substances Control Act                     |
| TT                                          | Tarawa Terrace                                   |
| US DOJ                                      | United States Department of Justice              |
| US EPA                                      | United States Environmental Protection Agency    |

|     |                       |
|-----|-----------------------|
| WoE | Weight of Evidence    |
| WTP | Water Treatment Plant |

# 1 Qualifications

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I am a Principal at Gradient, an environmental and risk sciences consulting firm that specializes in toxicology, epidemiology, risk assessment, and other disciplines. I have more than 25 years of experience in toxicology and human health risk assessment. I received my Ph.D. in biochemistry from the Massachusetts Institute of Technology in 1996, and I was a post-doctoral fellow at the Harvard School of Public Health from 1996 to 1999. I have expertise in toxicology, molecular biology, genetic toxicology and mutagenesis, mechanisms of carcinogenesis, weight-of-evidence (WoE) evaluations and systematic review, and risk communication.

My expertise in WoE evaluations includes systematic review and in-depth evaluation and integration of all data relevant to a particular chemical and its potential association with human disease (*i.e.*, toxicokinetics data, animal toxicity data, epidemiology data, mechanistic data, and human exposure data). I have conducted in-depth WoE evaluations of many chemicals and have published several papers describing the results of my analyses.

I also have expertise in conducting human health risk assessments for environmental, consumer product, and occupational exposures. In order to assess whether exposure (*via* inhalation, dermal contact, or ingestion) to a particular substance may be associated with potential human health risk, both hazard and exposure (including the level, duration, and frequency of exposure) need to be considered, and only when the two combined are sufficient to cause disease in humans is there cause for concern. Therefore, my expertise in human health risk assessment consistently involves in-depth evaluation of the potential hazards of chemicals in addition to consideration of the extent to which humans are exposed to the chemicals of concern in the environment, consumer products, or the workplace.

I have authored many peer-reviewed articles and book chapters in the field of human health risk and toxicology and have presented my scientific findings and analyses at conferences, to community groups, and to regulatory agencies. I am also a full member of the Society of Toxicology and the Society for Risk Analysis.

Gradient is currently being compensated at the rate of \$595 per hour for my work in this matter. My *curriculum vitae* is attached as Appendix A. My testimony experience is attached as Appendix B. Appendix C lists all the materials I considered in the preparation of this report.

## 2 Introduction and Executive Summary

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This report was prepared at the request of the United States Department of Justice (US DOJ). As part of my engagement in this case, I have been asked to review materials relevant to the case *Jacqueline Tukes v. United States* and to develop opinions related to whether there is scientific support for the plaintiff's claim that exposure to chemicals in tap water (trichloroethylene [TCE], tetrachloroethylene [also known as perchloroethylene (PCE)], vinyl chloride, benzene, and *trans*-1,2-dichloroethylene [1,2-tDCE]) while employed and residing at Camp Lejeune is causally associated with the plaintiff's kidney cancer diagnosis.

My report includes:

- An executive summary (Section 2.1);
- An overview of the general risk assessment methodology I applied to evaluate risk for the plaintiff (Section 3);
- A brief discussion of the history of the Marine Corps Base Camp Lejeune Site (Section 4);
- Hazard evaluation summaries (based on the expert report by Dr. Julie Goodman [2025]) and summaries of the regulatory toxicity criteria used to calculate risks for TCE, PCE, vinyl chloride, benzene, and 1,2-tDCE (Section 5);
- A plaintiff-specific risk evaluation, based on exposure information provided in the expert report by Dr. Judy LaKind (2025) (Section 6);
- A comparison of the estimated exposures for the plaintiff to exposures from the animal or human studies that are the basis of the chemical-specific toxicity criteria (Section 7);
- A comparison of the estimated exposures for the plaintiff to exposure information from relevant epidemiology or animal studies (Section 8);
- A rebuttal of the plaintiff's experts' reports (Section 9); and
- A summary of my opinions related to the plaintiff's claim that exposures to chemicals in tap water while employed/residing at Camp Lejeune are related to plaintiff's diagnosis (Section 10).

### 2.1 Executive Summary

Section 3 of this report provides a discussion of the general approach to toxicology and risk assessment and regulatory risk assessment guidelines.

- Toxicology is the study of health effects resulting from exposure to chemical, biological, or physical agents. One of the most fundamental concepts in the field of toxicology is the dose-response relationship; dose is the amount of a chemical to which an organism is exposed, and a response is the effect on the organism resulting from the chemical exposure. A dose-response relationship occurs when the chemical exposure and the effect are correlated, and the effect (response) increases directly with increased exposure (dose). For most chemicals, biological effects (with a dose-response relationship) occur only when the dose exceeds a certain exposure level for a sufficient period of time. It is common for dose-response data from toxicology

investigations to be used in risk assessment, which is a tool used to predict adverse health effects based on knowledge of the effects of chemicals and exposures.

- Human health risk assessment is the systematic process of characterizing potential adverse human health effects resulting from exposure to environmental chemicals. Risk assessment generally involves four steps:
  - **Hazard Identification:** Identify the potential hazard (*i.e.*, determine whether a particular chemical is causally linked to any health effects).
  - **Dose-Response Assessment:** Determine the relationship between the nature and magnitude of exposure to the hazard and the probability of a health effect occurring.
  - **Exposure Assessment:** Estimate the level of human exposure to the hazard.
  - **Risk Characterization:** Compare the estimated human exposure level of concern to the dose-response assessment for the chemical and characterize the comparison as a risk estimate, then assess the magnitude of uncertainty in the risk estimate.
- The United States Environmental Protection Agency (US EPA) has derived toxicity criteria for many chemicals based on its **hazard and dose-response assessments** of those chemicals.
  - Toxicity criteria are quantitative estimates of risk of the adverse health effects associated with a given chemical exposure level. Toxicity criteria are typically derived from observations of chemical exposures and health effects reported in epidemiology or animal studies, and are conservatively based on the most sensitive endpoint reported in the health effect studies (*i.e.*, the health effect occurring at the lowest exposure level). They are also designed to be protective of the most sensitive populations (*e.g.*, children and the elderly). Therefore, US EPA's toxicity criteria reflect conservative estimates of the relationship between exposures and health effects (*i.e.*, overly protective assumptions about exposures and health effects), particularly for short exposure durations for healthy individuals in a population.
  - The cancer toxicity criteria derived by US EPA are referred to as the cancer slope factor (CSF), which is used to characterize risk from oral and dermal exposures, and the inhalation unit risk (IUR), which is used to characterize risk from inhalation exposure. These criteria are derived based on the most sensitive cancer endpoint evaluated in the available studies. CSFs are described as risks per milligrams per kilogram body weight per day (or  $[\text{mg/kg-day}]^{-1}$ ). IURs are described as risks per microgram per cubic meter of air (or  $[\mu\text{g/m}^3]^{-1}$ ). For example:
    - ▶ A CSF of  $0.01 (\text{mg/kg-day})^{-1}$  is equivalent to a risk of 1 in 100 or 1% (1 cancer case in 100 people exposed) from exposure to 1 milligram per kilogram body weight per day ( $\text{mg/kg-day}$ ) of a chemical over a lifetime (70 years) of oral or dermal exposure.
    - ▶ An IUR of  $0.01 (\mu\text{g/m}^3)^{-1}$  is equivalent to a risk of 1 in 100 or 1% (1 cancer case in 100 people exposed) from continuous exposure to 1 microgram per cubic meter of air ( $\mu\text{g/m}^3$ ) of a chemical over a lifetime (70 years) of inhalation exposure.
- In the **exposure assessment** step in the risk assessment, daily oral or dermal doses of a chemical taken into the body, averaged over the appropriate exposure period, and expressed in units of  $\text{mg/kg-day}$  are estimated for an individual. Similarly, inhalation exposure concentrations, averaged over the appropriate exposure period, and expressed in units of  $\mu\text{g/m}^3$  are estimated for an individual.
- In her expert report (LaKind, 2025), Dr. LaKind describes the daily exposure doses (DEDs) for oral and dermal exposures and daily exposure concentrations (DECs) for inhalation exposures calculated for the plaintiff for each chemical. Using the plaintiff-specific DED and DEC estimates from Dr. LaKind (2025), the exposure frequency (how often exposure occurs, in terms of days per

year), and exposure duration (how long the exposure was, in terms of years), for the plaintiff, and an averaging time (the period over which the exposure is averaged) of 70 years, or 25,550 days (consistent with US EPA regulatory guidelines for cancer risk estimates), I calculated the plaintiff's lifetime average daily doses (LADDs) for oral and dermal chemical exposures and the lifetime average daily exposures (LADEs) for inhalation chemical exposures for the plaintiff.

- I calculated the plaintiff's lifetime average daily doses (LADDs) as follows:

- ▶  $LADD = (DED \times EF \times ED) \div AT$ , where:

LADD = Lifetime Average Daily Dose (mg/kg-day)

DED = Daily Exposure Dose (mg/kg-day)

EF = Exposure Frequency (days/year)

ED = Exposure Duration (years)

AT = Averaging Time (25,550 days)

- I calculated the plaintiff's lifetime average daily exposures (LADEs) as follows:

- ▶  $LADE = (DEC \times EF \times ED) \div AT$ , where:

LADE = Lifetime Average Daily Exposure ( $\mu\text{g}/\text{m}^3$ )

DEC = Daily Exposure Concentration ( $\mu\text{g}/\text{m}^3$ )

EF = Exposure Frequency (days/year)

ED = Exposure Duration (years)

AT = Averaging Time (25,550 days)

- In the **risk characterization** step in the risk assessment, the estimated human exposure levels of concern (LADD or LADE, as described above) are combined with the dose-response assessment (toxicity criteria [CSF or IUR]) for each chemical to calculate risk estimates for each chemical and exposure pathway (*i.e.*, ingestion, dermal contact, or inhalation).
- Cancer toxicity criteria are used in regulatory risk evaluations to estimate the incremental risk of developing cancer following a specific chemical exposure, beyond the background cancer risk. US EPA refers to this risk as the excess lifetime cancer risk (ELCR), which is expressed as a unitless probability (*e.g.*, 1 cancer case in 1 million people exposed, or  $1 \times 10^{-6}$ ).
  - ▶ US EPA has established a target ELCR range of  $1 \times 10^{-6}$  (1 cancer case in 1,000,000 people exposed) to  $1 \times 10^{-4}$  (1 cancer case in 10,000 people exposed); an exposure that may result in an ELCR that falls within this range, that is calculated using conservative assumptions, is considered acceptable by US EPA (1990, 1991).
  - ▶ To provide perspective on what a target ELCR of 1 in 10,000 or 1 in 1,000,000 means, it is helpful to understand how these risks compare to the overall lifetime probability of being diagnosed with cancer. According to the American Cancer Society (ACS), the lifetime probability of developing any cancer (*i.e.*, background lifetime cancer risk for all cancers combined) is approximately 40% on average across the population (ACS, 2024). Individual risk will vary and is based on a number of different factors, including age, sex, race, lifestyle (*e.g.*, diet, exercise), and family history.
  - ▶ US EPA's acceptable ELCR range of  $1 \times 10^{-6}$  (1 cancer case in 1 million people exposed, or 0.0001% probability) to  $1 \times 10^{-4}$  (1 cancer case in 10,000 people exposed, or 0.01% probability) is well below the background lifetime probability of developing cancer (*i.e.*, ~40% overall in the population) – the equivalent of a total cancer risk range of 40.0001-

40.01%. Therefore, any exceedance of the regulatory cancer risk target should be interpreted carefully, and not be taken to mean that health effects are expected to occur for any particular individual as a result of that exceedance.

- Cancer risk (ELCR) from oral or dermal exposures to a chemical is calculated by multiplying the lifetime oral or dermal dose of that chemical (LADD) by the chemical-specific CSF, as follows:
  - ▶  $\text{ELCR from Oral or Dermal Exposure} = \text{LADD (mg/kg-day)} \times \text{CSF ([mg/kg-day]}^{-1})$
- Similarly, cancer risk (ELCR) from inhalation exposure to a chemical is calculated by multiplying the lifetime inhalation exposure concentration of that chemical (LADE) by the chemical-specific IUR, as follows:
  - ▶  $\text{ELCR from Inhalation Exposure} = \text{LADE } (\mu\text{g/m}^3) \times \text{IUR } ([\mu\text{g/m}^3]^{-1})$
- As an example risk calculation, applying a CSF of  $0.01 \text{ (mg/kg-day)}^{-1}$  to an LADD of  $0.005 \text{ mg/kg-day}$  would result in the following risk calculation:  $0.005 \text{ mg/kg-day} \times 0.01 \text{ (mg/kg-day)}^{-1} = \text{an excess risk (ELCR) of } 0.00005 \text{ (or 5 cancer cases in 100,000 people exposed, or } 5 \times 10^{-5} \text{, or 0.005\%)}$ . This ELCR falls within US EPA's target risk range and is considered acceptable by US EPA.

Section 4 briefly describes the history of the Marine Corps Base Camp Lejeune Site. Operations at Camp Lejeune started in late 1941. Multiple water treatment plants (WTPs)<sup>1</sup> have serviced the Camp Lejeune base, including Hadnot Point (HP), Tarawa Terrace (TT), and Holcomb Boulevard (HB). The HP WTP was the first plant to come online, in 1942, and it serviced the base until the TT and HB WTPs came online in 1952 and the summer of 1972, respectively (Hennet, 2024). In the early 1980s, the groundwater sources for two of the WTPs that serviced the Camp Lejeune base (HP and TT) were found to be contaminated with volatile organic compounds. Although the groundwater source for the HB WTP was not contaminated, the HB water system was contaminated when its drinking water was supplied by the HP WTP in the spring and summer months from 1972 through 1985 (ATSDR, 2017a). The contaminants identified in the drinking water at the HP WTP were TCE, PCE, vinyl chloride, 1,2-tDCE, and refined petroleum products (including benzene) (ATSDR, 2017a). The contaminants identified in the drinking water at the TT WTP were TCE, PCE, vinyl chloride, and 1,2-tDCE (ATSDR, 2017a).

As summarized in the hazard evaluations in Section 5, the Agency for Toxic Substances and Disease Registry (ATSDR), in its "Assessment of the Evidence for the Drinking Water Contaminants at Camp Lejeune" (ATSDR, 2017b), concluded that there was "sufficient evidence for causation" for TCE exposure and kidney cancer, and the evidence for causation was "below equipoise" for exposure to PCE and kidney cancer. ATSDR (2017b) provided no comment on whether there is a causal association between benzene, vinyl chloride, or 1,2-tDCE exposure and kidney cancer. As discussed in Section 5, US EPA, the International Agency for Research on Cancer (IARC), and the National Toxicology Program (NTP) have concluded that TCE can cause kidney cancer in humans at some doses, but these agencies do not conclude that there is an association between exposure to PCE, benzene, vinyl chloride, or 1,2-tDCE and kidney cancer. Dr. Goodman's review of the epidemiology and toxicology studies that evaluated potential associations between chemical exposures and kidney cancer concluded that overall, the scientific evidence does not support a causal association between PCE, benzene, vinyl chloride, or 1,2-tDCE exposure and

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<sup>1</sup> Hadnot Point (HP), Tarawa Terrace (TT), and Holcomb Boulevard (HB) supplied drinking water to residences and workplaces at Camp Lejeune (see Hennet [2024]). Additional Camp Lejeune water-distribution systems that were not contaminated include: Marine Corps Air Station New River, Onslow Beach, Courthouse Bay, Camp Geiger, Rifle Range, and Montford Point/Camp Johnson (Hennet, 2024).

kidney cancer (Goodman, 2025). Dr. Goodman concluded that the epidemiology evidence provides support for an association between kidney cancer and very high occupational TCE exposures (*e.g.*, >335 ppm-year).

Section 5 also summarizes the US EPA toxicity criteria used in the cancer risk evaluation for the plaintiff. The TCE toxicity criteria are based on kidney cancer as the most sensitive endpoint. Because the scientific evidence does not support, or only provides weak support for, an association between kidney cancer and exposure to PCE, benzene, or vinyl chloride,<sup>2</sup> the cancer toxicity criteria for these chemicals are not based on kidney cancer, and therefore are not predictive of, and are overly conservative for, kidney cancer risk from exposure to these chemicals. However, I conservatively apply the criteria for these chemicals to estimate the plaintiff's overall excess lifetime cancer risk.

In Section 6, I calculate cancer risks based on exposure estimates for Mrs. Tukes. Mrs. Tukes was at Camp Lejeune from June 1985 through January 1987 (~1.7 years). During this time, Mrs. Tukes lived with her husband and son at three locations: (1) the hostess house on-base at Hadnot Point (HP) for 1-2 months (June-July 1985),<sup>3</sup> (2) the Sherwood Mobile Home Park off-base for 4 months (August-November 1985), and (3) on-base residential housing in Tarawa Terrace (TT) for the remaining 1.2 years of her time at Camp Lejeune (December 1985-January 1987). For my risk calculations, I used TCE, PCE, benzene, vinyl chloride, and 1,2-tDCE exposure estimates for Mrs. Tukes from tap water (*via* ingestion of drinking water, and *via* dermal and inhalation exposure to shower vapor) calculated by Dr. LaKind (2025) (DED and DEC estimates, as discussed earlier) for the two main areas of concern for groundwater contamination at Camp Lejeune (HP and TT). I combined this information with the regulatory toxicity criteria summarized in Section 5 to conduct a conservative regulatory risk evaluation for Mrs. Tukes. Risks were calculated for the following exposure pathways and scenarios for the exposure period of concern (~1.7 years) for Mrs. Tukes:

▪ **Baseline Exposure Pathways:**

- **Drinking Water Ingestion** – For this exposure pathway, I evaluated two scenarios for the relevant time periods for HP and TT WTPs: (1) central tendency exposure (CTE), which assumes ingestion of 1.3 liters (L) of tap water per day; and (2) reasonable maximum exposure (RME), which assumes ingestion of 3.3 L of tap water per day. Based on Mrs. Tukes' deposition testimony that she often visited the main part of the base (which was serviced by the HP WTP) to run errands or meet Mr. Tukes for lunch while he was at work, I conservatively evaluated her drinking water exposure assuming 100% consumption from HP WTP during the June through November 1985 time period (*i.e.*, before she and her family moved to TT), and assuming a mix of consumption from both the HP and TT WTPs (12% HP and 88% TT, discussed in more detail in Section 6) for the December 1985 through January 1987 time period when the family resided in TT.
- **Dermal and Inhalation Exposures from Showering** – For these exposure pathways, I calculated risks based on dermal dose and inhalation concentration outputs from a residential exposure model that also includes exposures associated with household water uses other than drinking (*e.g.*, kitchen and utility sinks) (ATSDR, 2024a), and based on the plaintiff's locations of residence during her time at Camp LeJeune (HP from June to July 1985, TT from December 1985 through January 1987). The inhalation concentrations were provided by Dr. LaKind and are discussed further in her report (LaKind, 2025). The exposures from the shower model are

<sup>2</sup> Note that, as discussed in Section 5, US EPA does not consider *trans*-1,2-dichloroethylene (1,2-tDCE) to be carcinogenic. Therefore, there are no cancer toxicity criteria available for 1,2-tDCE.

<sup>3</sup> Mrs. Tukes initially testified that, after arriving at Camp Lejeune in June 1985, she and her family lived at the hostess house for 30 days (Tukes, 2025a). She later stated that they lived at the Sherwood Mobile Home Park from August to December 1985 (Tukes, 2025a). For this risk assessment, I have assumed that she resided at the hostess house in June and July 1985, for a total of 2 months.

estimated based on a daily shower duration of 20 minutes. Note that the residential shower model accounts for additional household water uses, including appliances, sinks, and toilets.

▪ **Exposure Scenarios Evaluated for Mrs. Tukes:**

- The CTE exposure scenario, which includes the following exposure pathways: CTE drinking water ingestion (TT and HP WTPs), and dermal and inhalation exposures from showering (TT and HP WTPs).
- The RME exposure scenario, which includes the following exposure pathways: RME drinking water ingestion (TT and HP WTPs), and RME dermal and inhalation exposures from showering (TT and HP WTPs).

Based on standard risk assessment methodology, which includes overly health-protective assumptions about exposure and risk, the maximum risk estimate calculated for Mrs. Tukes' estimated exposures ( $8 \times 10^{-7}$ , or 8 cancer cases in 10,000,000 exposed people, or 0.00008% risk), for all the exposure scenarios evaluated, is below the lower end of US EPA's target excess cancer risk range of 1 in 1,000,000 (*i.e.*, 1 cancer case in 1,000,000 exposed people, or 0.0001%). Further, the calculated cancer risk from the only chemical for which there is some evidence of an association between high levels of exposure and kidney cancer – TCE ( $1 \times 10^{-8}$ , or 1 cancer case in 100,000,000 exposed people, or 0.000001%) – falls well below US EPA's acceptable cancer risk range.

In Section 7, I compare the plaintiff-specific doses and exposure concentrations to the doses or exposure concentrations that are the basis of the toxicity criteria (predicted to be associated with no, or a very low, response from animal or human studies) before linear extrapolation to derive the toxicity criteria. These comparisons are called margins of exposure (MoEs), and are equal to the doses or exposure concentrations that are the basis of the toxicity criteria divided by the plaintiff-specific doses or exposure concentrations. MoEs above 1 provide support that adverse health effects would not be expected for the individual. Based on these comparisons for Mrs. Tukes' exposures, the MoEs range from 35,000 to 40,000,000, all of which are well above 1, providing additional support that Mrs. Tukes' exposures would not have been expected to lead to her kidney cancer.

Further, in Section 8, I consider comparisons of the plaintiff's exposure estimates to exposures in relevant epidemiology and animal studies. As discussed, Mrs. Tukes' exposure estimates are orders of magnitude below the exposure concentrations in these studies, providing additional support that Mrs. Tukes' exposures would not have been expected to lead to her kidney cancer.

Based on the results of my analysis described above, it is my opinion, to a reasonable degree of scientific certainty, that there is insufficient evidence to conclude that Mrs. Tukes' exposures to TCE, PCE, benzene, vinyl chloride, and 1,2-tDCE from tap water during the ~1.7 years that she lived and spent time at Camp Lejeune are causally associated with her kidney cancer.

I reserve the right to amend my opinion in the future should new information become available to me.

## 3 Methodology

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### 3.1 General Methodology

The opinions herein are based on my training and experience in toxicology and risk assessment, and on a review of documents available to me as of the date of this report. Specific documents I have reviewed are presented in the references section of this report. In addition, there are many documents that I have reviewed in my professional history that supported my understanding of this case but are not cited specifically in this report. The types of information I relied upon for my analyses include the following:

- Case-specific documents, including:
  - Expert report of Dr. Goodman (2025), which addresses general causation information regarding exposures to TCE, PCE, benzene, vinyl chloride, and 1,2-tDCE;
  - Expert report of Dr. LaKind (2025) regarding exposure information for the plaintiff;
  - Expert reports of Drs. Hennet (2024) and Spiliotopoulos (2024) regarding groundwater modeling for Camp Lejeune;
  - Expert reports submitted on behalf of Mrs. Tukes by Drs. Reynolds (2025a), Smith (2025), Josephson (2025), and Cooper (2025);
  - Plaintiff's depositions; and
  - Other Plaintiff materials, if available, as cited within (*e.g.*, declaration, housing records).
- Camp Lejeune evaluations conducted by ATSDR related to potential health effects from exposure to TCE, PCE, benzene, vinyl chloride, and 1,2-tDCE in groundwater.
- General toxicology and risk assessment guidance documents authored by agencies such as US EPA and ATSDR.
- Publicly available environmental and regulatory documents that are not case specific, but provide data and information relevant to my analyses. Such documents include chemical-specific toxicity criteria and toxicological reviews.
- Scientific literature specifically related to chemicals (TCE, PCE, vinyl chloride, benzene, and 1,2-tDCE) and exposures associated with the Camp Lejeune litigation.

The specific analyses I performed for my evaluation are briefly stated below.

- Reviewed the plaintiff's depositions, declaration, and housing records;
- Reviewed information related to possible associations between exposures to TCE, PCE, vinyl chloride, benzene, and 1,2-tDCE in tap water and the health effects alleged by the plaintiff, based on information provided in the expert report prepared by Dr. Goodman (2025);
- Applied standard risk assessment methodology to conduct a risk evaluation for the plaintiff using plaintiff-specific doses calculated and supplied to me by Dr. LaKind (2025), based on Dr. LaKind's and my agreement on exposure assumptions appropriate for the plaintiff;

- Conducted a margin of exposure (MoE) analysis, comparing the estimated exposures for the plaintiff to exposures from the animal or human studies that are the basis of the chemical-specific toxicity criteria; and
- Compared the estimated exposures for the plaintiff to exposure information from relevant epidemiology or animal studies.

The following sections provide more information about methodologies for toxicology, human health risk assessment, and regulatory risk evaluation.

## 3.2 Introduction to Toxicology

Toxicology is the study of health effects resulting from exposure to chemical, biological, or physical agents. An understanding of the scientific principles in the field of toxicology is necessary for evaluating the potential for a causal relationship between exposure to chemicals and health effects. One of the most fundamental concepts in the field of toxicology is the dose-response relationship; dose is the amount of a chemical to which an organism is exposed, and a response is the effect on the organism resulting from the chemical exposure. A dose-response relationship occurs when the chemical exposure and the effect are correlated, and the effect (response) increases directly with increased exposure (dose). However, for most chemicals, biological effects (with a dose-response relationship) occur only when the dose exceeds a threshold level for a certain period of time. At doses ranging between zero and the threshold, biochemical or physiological mechanisms can negate a chemical's effects, thereby preventing any adverse effects from occurring. As the magnitude and duration of exposure begin to exceed the threshold, these protective mechanisms can become less effective. Consequently, at exposure levels higher than the threshold for a given chemical, the effect begins to appear in a manner that corresponds to the increase in dose. It is common for dose-response data from toxicology investigations to be used in risk assessment, which is a tool used to predict adverse health effects based on knowledge of the effects of chemicals and exposures.

## 3.3 Introduction to Human Health Risk Assessment

Human health risk assessment is the systematic process of characterizing potential adverse human health effects resulting from exposure to environmental hazards (NRC, 1983). Risk assessment generally involves four steps that were first presented by the National Academy of Sciences in 1983 (NRC, 1983).

1. **Hazard Identification:** Identify the potential hazard (*i.e.*, determine whether a particular chemical is causally linked to any health effects).
2. **Dose-Response Assessment:** Determine the relationship between the nature and magnitude of exposure to the hazard and the probability of a health effect occurring.
3. **Exposure Assessment:** Estimate the level of human exposure to the hazard.
4. **Risk Characterization:** Compare the estimated human exposure level of concern to the dose-response assessment for the chemical and characterize the comparison as a risk estimate, then assess the magnitude of uncertainty in the risk estimate.

The hazard identification steps for TCE, PCE, benzene, vinyl chloride, and 1,2-tDCE are described in more detail in Dr. Goodman's expert report (Goodman, 2025), and are summarized in Section 5 of my report. The exposure assessment for the plaintiff is introduced below and described in more detail in Dr. LaKind's expert report (LaKind, 2025) and in Section 6 of my report.

Below, I provide more detail on the general approach for the dose-response assessment and risk characterization steps of a risk assessment, including discussion of US EPA's hazard and dose-response approach for the derivation of regulatory toxicity criteria. Because kidney cancer is the health effect of concern for this plaintiff, in this section, I have focused the dose-response and risk characterization methodology discussions on cancer risk evaluations.

### **3.3.1 Dose-Response Assessment**

A dose-response assessment characterizes the relationship between the nature and magnitude of exposure to a chemical of concern and the probability that one or more adverse health effects may result from that exposure. Regulatory agencies rely on dose-response assessments to derive chemical-specific toxicity criteria for use in evaluating potential cancer risks from oral, dermal, or inhalation exposures of concern (see Section 3.3.2).

The following section describes the derivation of cancer toxicity criteria used in regulatory risk assessments.

#### **3.3.1.1 Derivation of Cancer Toxicity Criteria**

Regulatory toxicity criteria for cancer and noncancer effects, such as those established by US EPA and ATSDR, are typically derived from observations of chemical exposures and health effects reported in epidemiology or animal studies, and are conservatively based on the most sensitive endpoint reported in the health effect studies (*i.e.*, the health effect occurring at the lowest exposure level). They are designed to be protective of the most sensitive populations (*e.g.*, children and the elderly). Therefore, toxicity criteria reflect conservative estimates of the relationship between exposures and health effects (*i.e.*, overly protective assumptions about exposures and health effects), particularly for short exposure durations for healthy individuals in a population.

US EPA and ATSDR apply standard risk assessment methodologies to estimate the dose-response relationship between chemical exposures and health effects in epidemiology or animal studies. Then, based on that relationship and an understanding of the mechanism of action for a particular chemical (if known) and the associated health effect, these regulatory agencies derive an exposure concentration or dose that is predicted to be associated with no (or a very low) response. This exposure concentration or dose is referred to as the point of departure (POD) (US EPA, 2021), from which cancer and noncancer toxicity criteria are typically derived. Because the plaintiff was diagnosed with kidney cancer, the process for deriving regulatory cancer toxicity criteria is described below.

The cancer toxicity criteria derived by US EPA are referred to as the cancer slope factor (CSF), which is used to characterize risk from oral and dermal exposures, and the inhalation unit risk (IUR), which is used to characterize risk from inhalation exposure. Dose-response information from studies used to derive toxicity criteria can be plotted graphically as the relationship between the magnitude of the response (*i.e.*, health effect) observed at each evaluated chemical dose (referred to as a "dose-response curve"). See Figure 3.1 for an example of a dose-response curve. CSF and IUR values are typically derived by drawing a line from the POD (the dose associated with no, or a very low, response in animal or human studies) on the dose-response curve down to the point of origin (or zero-response).

US EPA often uses a benchmark dose (BMD) modeling approach (US EPA, 2012a) to develop dose-response curves and PODs for the derivation of toxicity criteria. US EPA uses the 95% upper bound on the dose-response curves for these derivations, stating that "[t]he use of upper bounds generally is considered to be a health-protective approach for covering the risk to susceptible individuals" (US EPA, 2005). Using

the upper bound on the response results in a lower POD, called the lower confidence limit on the benchmark dose (BMDL). See Figure 3.2 for an example of linear extrapolation from a POD, based on a BMD/BMDL, for the derivation of toxicity criteria (*e.g.*, CSF or IUR). Depending on how the POD is derived, it can sometimes be referred to as a lower confidence limit of the exposure dose (LED). For cancer toxicity criteria, both the BMDL and LED values are typically associated with a cancer risk in the range of 1-10%.

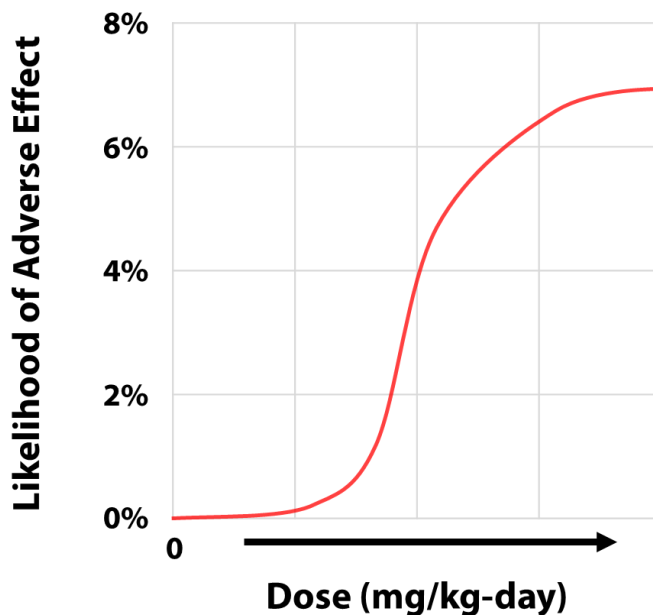


Figure 3.1 Dose-Response Curve

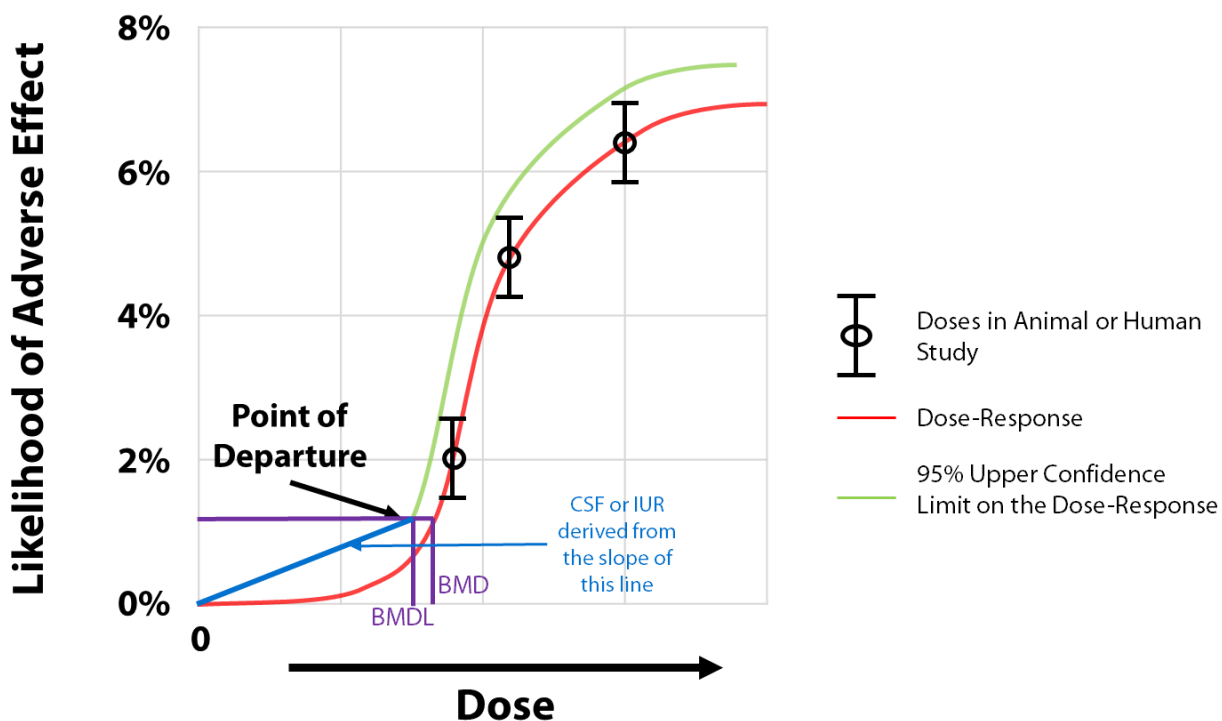


Figure 3.2 Approach for Cancer Slope Factor (CSF) or Inhalation Unit Risk (IUR) Development. BMD = Benchmark Dose; BMDL = Lower Confidence Limit on the Benchmark Dose.

CSFs are used to estimate the probability of an individual developing cancer as a result of a lifetime of oral or dermal exposure to a particular amount of a potential carcinogen, described as risks per mg/kg-day (*i.e.*,  $[\text{mg/kg-day}]^{-1}$ ). For example, a CSF of  $0.01 (\text{mg/kg-day})^{-1}$  is equal to a risk of 1 in 100 or 1% from exposure to 1 mg/kg-day of a substance over a lifetime. Similarly, US EPA defines the IUR as the probability of an individual developing cancer from continuous exposure to a particular amount of a potential carcinogen in air, described as risks per  $\mu\text{g}/\text{m}^3$  (or  $[\mu\text{g}/\text{m}^3]^{-1}$ ). For example, an IUR of  $0.01 (\mu\text{g}/\text{m}^3)^{-1}$  is equal to a risk of 1 in 100 or 1% from continuous exposure to 1  $\mu\text{g}/\text{m}^3$  of a substance in air over a lifetime.

Further, for some chemicals for which there is only reliable observational information (*i.e.*, a human or animal study) to derive either a CSF or an IUR, US EPA might conduct what is called a "route-to-route extrapolation" and derive an IUR from a CSF, or *vice versa*, using information about a chemical's absorption, distribution, metabolism, and excretion for the two exposure pathways, as well as assumptions about human and animal body weights and inhalation rates.

### 3.3.2 Exposure Assessment

Oral or dermal exposure estimates represent the daily dose of a chemical taken into the body, averaged over the appropriate exposure period and expressed in the units of milligram of chemical per kilogram of human body weight per day ( $\text{mg/kg-day}$ ). Inhalation exposure estimates represent the daily exposure concentration of a chemical taken into the body, averaged over the appropriate exposure period and expressed in the units of microgram of a chemical per cubic meter of air ( $\mu\text{g}/\text{m}^3$ ). The primary source for the exposure equations used in human health risk assessment is US EPA's "Risk Assessment Guidance for Superfund" (RAGS) (US EPA, 1989).

My risk calculations for the plaintiff, which are described in Section 6, start with Dr. LaKind's plaintiff-specific daily doses and daily inhalation exposure concentrations, which I have termed daily exposure doses (DEDs) and daily exposure concentrations (DECs), respectively. Dr. LaKind provides a detailed discussion of the plaintiff's DED and DEC estimates in her report (LaKind, 2025), including discussion of the dermal and shower inhalation exposure models applied and the exposure parameters used in those models. As described in her report, Dr. LaKind calculated plaintiff-specific daily dose and daily inhalation exposure concentration estimates from exposure point concentrations of chemicals in tap water at Camp Lejeune (LaKind, 2025).

The plaintiff's exposure frequency (EF, how often exposure to chemicals occurred) and exposure duration (ED, how long the exposure to chemicals was) are also considered in the risk calculations. A daily exposure frequency of 365 days per year is typically applied for tap water use (ingestion and showering). Exposure duration generally corresponds to the time period that the plaintiff lived or worked at Camp Lejeune. Finally, consistent with US EPA guidance (US EPA, 2014), an averaging time (the period over which the chemical exposures are averaged) was applied to derive the risk estimates. The averaging time that US EPA recommends using to calculate exposure estimates for cancer risk calculations is a 70-year lifetime (*i.e.*, 25,550 days), because the cancer toxicity criteria are based on a lifetime of exposure (US EPA, 2014).

For evaluating oral and dermal exposures for cancer risk estimates, the relevant dose metric is the lifetime average daily dose (LADD), which is defined as the amount of a chemical taken into the body *via* oral or dermal exposure during the exposure period, averaged over a 70-year life lifetime (*i.e.*, 25,550 days). Using

the DED estimates from Dr. LaKind, I calculate LADDs for oral and dermal exposures to the chemicals of interest as follows:

$$\text{LADD} = \frac{\text{DED} \times \text{EF} \times \text{ED}}{\text{AT}}$$

where:

LADD = Lifetime Average Daily Dose (mg/kg-day)  
DED = Daily Exposure Dose (mg/kg-day)  
EF = Exposure Frequency (days/year)  
ED = Exposure Duration (years)  
AT = Averaging Time (25,550 days)

For evaluating inhalation exposures for cancer risk estimates, the relevant dose metric is the lifetime average daily exposure (LADE), which is defined as the amount of chemical that someone is exposed to *via* inhalation during the exposure period, averaged over a 70-year lifetime (*i.e.*, 25,550 days). Using the DEC estimates from Dr. LaKind, I calculate LADEs for inhalation exposures to the chemicals of interest as follows:

$$\text{LADE} = \frac{\text{DEC} \times \text{EF} \times \text{ED}}{\text{AT}}$$

where:

LADE = Lifetime Average Exposure Concentration ( $\mu\text{g}/\text{m}^3$ )  
DEC = Daily Exposure Concentration ( $\mu\text{g}/\text{m}^3$ )  
EF = Exposure Frequency (days/year)  
ED = Exposure Duration (years)  
AT = Averaging Time (25,550 days)

See Appendix D for more details on these calculations.

### 3.3.3 Risk Characterization for Cancer Health Effects

In the risk characterization step of the risk assessment, the estimated human exposure levels of concern (LADD or LADE, as described above) are combined with the dose-response assessment (chemical-specific toxicity criteria [CSF or IUR]) for each chemical to calculate risk estimates for each chemical and exposure pathway.

#### 3.3.3.1 Cancer Toxicity Criteria Are Used to Estimate the Excess Lifetime Cancer Risk (ELCR) in a Population

Cancer risks are characterized as the incremental probability that an individual will develop cancer during their lifetime due to exposure to a chemical under the specific exposure scenarios evaluated. All individuals have a background risk of developing cancer at some point in their lifetimes. According to the American Cancer Society (ACS), the lifetime probability of developing any cancer (*i.e.*, background cancer risk for all cancers combined) is slightly less than 1 in 2 (41.6%) for men and slightly more than 1 in 3 (39.6%) for women (ACS, 2024). As described by ACS (2024), the lifetime probability of developing kidney cancer is 2.3% for men and 1.4% for women, in the population overall. Background cancer risk is based on cancer

incidence within the population and does not mean that all individuals are at 40% risk of developing cancer. Individual risk (background or above background) will vary and is based on a number of different factors, including age, sex, race, lifestyle (*e.g.*, diet, exercise), and family history (ACS, 2024; Mayo Clinic, 2024).

Cancer toxicity criteria are used in regulatory risk evaluations to estimate the incremental risk of developing cancer as a result of a specific chemical exposure, beyond the background cancer risk. This risk is termed the excess lifetime cancer risk (ELCR), which is expressed as a unitless probability (*e.g.*, 1 cancer case in 1 million people exposed, or  $1 \times 10^{-6}$ ). US EPA has established a target ELCR range of  $1 \times 10^{-6}$  (1 cancer case in 1,000,000 people exposed) to  $1 \times 10^{-4}$  (1 cancer case in 10,000 people exposed); an exposure that may result in an ELCR that falls within this range, that is calculated using conservative assumptions, is considered acceptable (US EPA, 1990, 1991). To provide perspective on what a target ELCR of 1 in 10,000 or 1 in 1,000,000 means, it is helpful to understand how these risks compare to the overall lifetime probability of being diagnosed with cancer. A risk of 1 in 1,000,000 is equivalent to a cancer risk of 0.000001, or an ELCR of 0.0001%. A risk of 1 in 10,000 is equivalent to a cancer risk of 0.0001, or an ELCR of 0.01%. Adding these risks to the background risk of developing any cancer over a lifetime (~40%, or about 400,000 cancer cases in a population of 1,000,000) results in total cancer risks of 40.0001-40.01%. Another way to think about these risks is as follows.

- A 40% background cancer risk is the same as 400,000 cancer cases occurring in a population of 1,000,000. Compare that to:
  - 400,001 cancer cases in a population of 1,000,000 (the same as a risk of 40.0001%, or a  $1 \times 10^{-6}$  ELCR), and
  - 400,100 cancer cases in a population of 1,000,000 (the same as a risk of 40.01%, or a  $1 \times 10^{-4}$  ELCR).

Therefore, US EPA's target ELCRs are well below the overall lifetime risk of getting cancer (including kidney cancer) and represent only very slight increases above the background risk of cancer, based on conservative assumptions of exposure and toxicity.

### 3.3.3.2 Cancer Risk Calculations

Per US EPA (1989) guidance, the excess lifetime cancer risk (ELCR) for oral or dermal exposure to a chemical is calculated by multiplying the lifetime average daily oral or dermal dose (LADD) of that chemical by the chemical-specific CSF, as follows:

$$\text{ELCR from Oral or Dermal Exposure} = \text{LADD (mg/kg-day)} \times \text{CSF (} [\text{mg/kg-day}]^{-1} \text{)}$$

Similarly, per US EPA (1989), the excess lifetime cancer risk (ELCR) from inhalation exposure to a chemical is calculated by multiplying the lifetime average daily inhalation exposure concentration (LADE) of that chemical by the chemical-specific IUR, as follows:

$$\text{ELCR from Inhalation Exposure} = \text{LADE (}\mu\text{g/m}^3\text{)} \times \text{IUR (} [\mu\text{g/m}^3]^{-1} \text{)}$$

US EPA does not derive toxicity criteria based specifically on dermal exposure toxicity studies. Instead, risk from dermal exposure to chemicals is assessed based on oral toxicity criteria, under the assumption that once a chemical is absorbed into the blood stream, the health effects caused by that chemical are similar regardless of whether the route of exposure was oral or dermal. Because oral toxicity criteria are based on the amount of a chemical *administered* per unit of time and body weight (*i.e.*, the chemical intake), and not

the amount absorbed systemically from the gastrointestinal tract, and because dermal exposures are expressed as absorbed intake levels, the oral criteria need to be adjusted to be applicable to *absorbed* doses before they can be used to assess risk from dermal exposure (US EPA, 1989, 1992, 2004).

This adjustment is made using the chemical's oral absorption efficiency (*i.e.*, the systemic absorption of the chemical following oral exposure). If a chemical's systemic absorption following oral exposure is very high (almost 100%), then the absorbed dose is virtually the same as the administered dose, and no adjustment of the oral toxicity factor is necessary for dermal risk calculations. If a chemical's systemic absorption following oral exposure is very low (*e.g.*, 5%), the chemical's oral toxicity criterion must be adjusted to account for the fact that the absorbed dose is much smaller than the administered dose before the criterion can be used to assess risk from dermal exposure to that chemical. US EPA recommends adjusting a chemical's oral toxicity criterion for use in evaluating dermal exposure and risks only when the systemic absorption of that chemical following oral exposure is less than 50%, to "obviate the need to make comparatively small adjustments in the toxicity value that would otherwise impart on the process a level of accuracy that is not supported by the scientific literature" (US EPA, 2004). Because the oral absorption efficiencies of TCE, PCE, benzene, vinyl chloride, and 1,2-tDCE are not less than 50%, their oral toxicity criteria can be used to assess risks posed by dermal exposure to these chemicals without any adjustment (US EPA, 2004).

For some chemicals that US EPA considers to be carcinogenic *via* a mutagenic mode of action (chemicals considered to react with DNA and lead to permanent changes in DNA, *i.e.*, mutations), such as TCE (for kidney cancer), US EPA (2011a) recommends applying age-dependent adjustment factors (ADAFs) to the cancer toxicity criteria to derive values protective of children in various age ranges. The current ADAFs are 10 for <2-year-olds (*i.e.*, an increase in the ELCR estimate by 10-fold is recommended for this age group), 3 for 2- to <16-year-olds (*i.e.*, an increase in the ELCR estimate by 3-fold is recommended for this age group), and 1 for ≥16-year-olds (no increase to the ELCR estimate is recommended for this age group) (US EPA, 2011a). US EPA recommends multiplying the CSF and IUR by the 10- and 3-fold ADAFs as part of the cancer risk calculations. US EPA does not recommend such adjustments when deriving cancer toxicity criteria for PCE or benzene, because the agency does not consider PCE or benzene to cause cancer by a mutagenic mode of action. As discussed in Section 5, US EPA has derived vinyl chloride cancer toxicity values for continuous lifetime exposure from birth that should be applied for early-life (from-birth) scenarios.

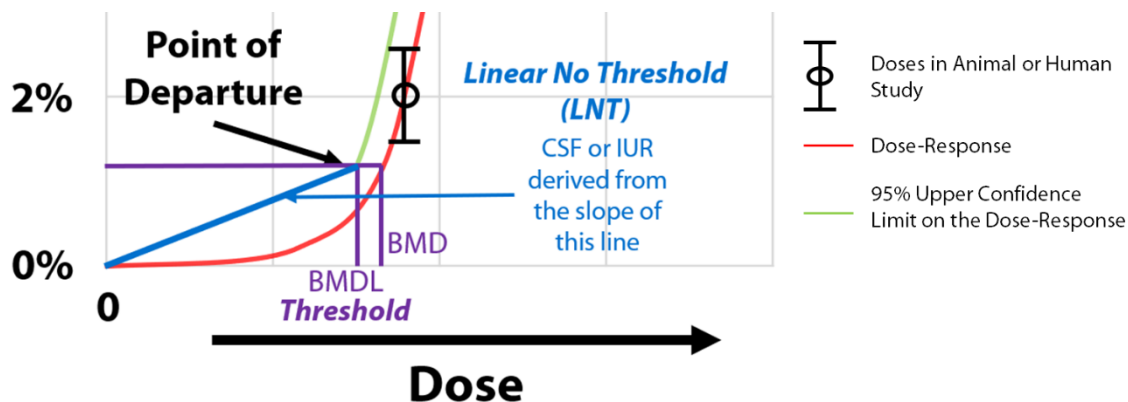
After calculating cancer risks from exposure to chemicals *via* each relevant exposure pathway, the ELCR is derived by summing the risks across chemicals and exposure pathways. If the ELCR falls within US EPA's acceptable risk range of  $1 \times 10^{-4}$  to  $1 \times 10^{-6}$  (or 1 additional cancer case in 10,000 people exposed to 1 additional cancer case in 1,000,000 people exposed), there is no need for further evaluation. If the ELCR is calculated to be greater than 1 in 10,000, the *potential* cancer risk from the evaluated chemical exposures requires further evaluation. However, because of the overly conservative nature of regulatory toxicity criteria, as discussed above, the exceedance of an estimated ELCR of  $1 \times 10^{-4}$  does not mean that adverse health effects will occur or are even likely to occur in any one individual.

### **3.4 The "Linear No-Threshold" Model and the Concept of "No Safe Dose" for Carcinogens**

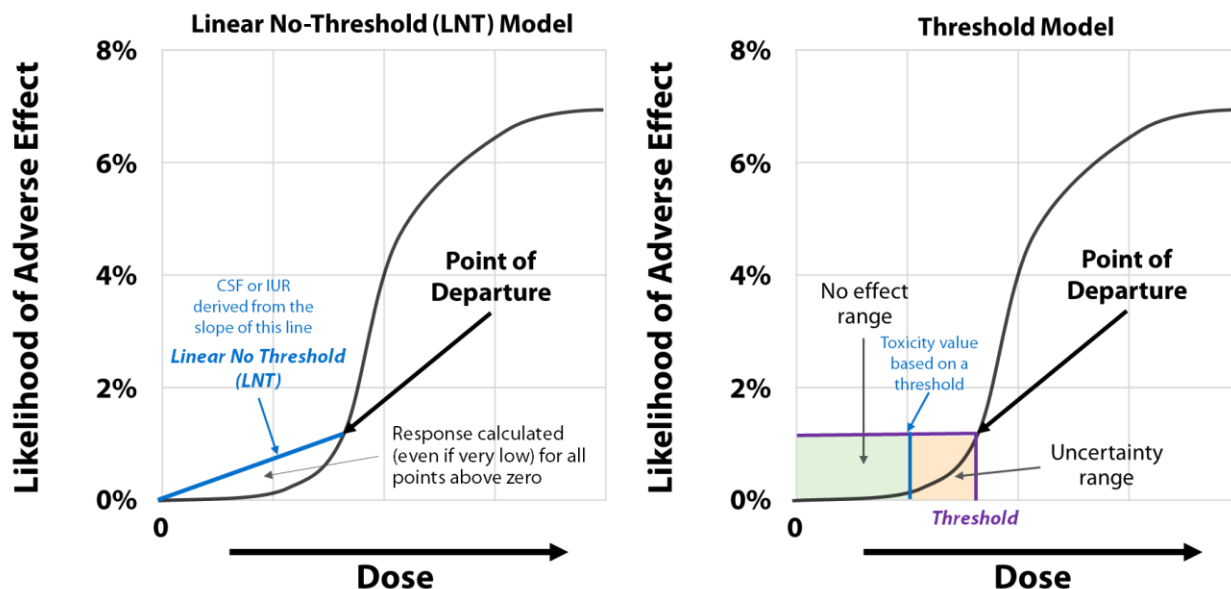
Carcinogenic compounds are often incorrectly described as having "no safe dose." The "no safe dose" concept can be described as meaning that any level of exposure to a carcinogen will lead to some level of increased cancer risk. This concept comes from the linear no-threshold (LNT) or "nonthreshold" mechanism of carcinogenesis that is often conservatively assumed to apply in regulatory cancer risk evaluations. As described by US EPA (and other regulatory agencies), the LNT mechanism of action is

applied when there is no known "threshold" dose below which exposure to a carcinogen is not expected to lead to some level of risk, even if it is very low. CSFs and IURs that are derived by extrapolating from the lowest doses in an animal or human study (or POD) down to a response of zero (as discussed above), are derived by applying the LNT approach. In contrast, a threshold model for deriving toxicity criteria is based on the concept that there is some dose below which no adverse effects are expected.

Figure 3.3 depicts a threshold (often the BMDL derived from the animal or human study) and a linear no-threshold (LNT) dose-response model that could be applied to a POD. Figure 3.4 provides a comparison of the LNT and threshold model extrapolations from the PODs. As shown, for a threshold model, US EPA typically applies uncertainty factors (*e.g.*, for sensitive subpopulations, or for the use of an animal study) to the POD to derive a toxicity value, at or below which adverse health effects are not expected. Non-cancer toxicity values are typically derived using a threshold approach.



**Figure 3.3 Linear No-Threshold (LNT) vs. Threshold Models.** CSF = Cancer Slope Factor; IUR = Inhalation Unit Risk.



**Figure 3.4 Linear No-Threshold (LNT) vs. Threshold Model Extrapolations from the Point of Departure (POD)**

Regulatory agencies often consider a nonthreshold approach to be the mechanism of carcinogenesis for genotoxic carcinogens (*i.e.*, carcinogens that directly interact with DNA), even when there is no reliable evidence of genotoxicity for these chemicals at low doses. Therefore, for chemicals that have been observed to be genotoxic only at high doses, a nonthreshold approach may be very conservative. Some carcinogens have been found to cause cancer through mechanisms that are not directly genotoxic. For example, some chemicals can cause cytotoxicity (cell death) at certain doses (usually high doses); cytotoxic conditions can result in oxidative stress that can result in the generation of toxic substances (*i.e.*, oxygen radicals) that can react with DNA and cause mutations and cancer. These carcinogens are considered to have a "threshold."

A nonthreshold mechanism of carcinogenesis implies that any level of exposure, even as low as a single molecule of a substance in a cell, potentially presents some level of response because of the possibility that (in theory) one molecule of the substance could react with DNA in a critical gene, and the consequent DNA damage could result in a mutation in that gene (permanent change in DNA) that could then result in carcinogenesis. However, this theoretical carcinogenic mechanism is not biologically plausible, even for carcinogens that are known to react directly with DNA. Several scientific reviews on this topic (*e.g.*, Cardarelli and Ulsh, 2018; Golden *et al.*, 2019; Calabrese, 2023) describe that there is no scientific consensus regarding the use of the nonthreshold approach for estimating cancer risk. Although a nonthreshold approach is reasonable to consider on a theoretical basis, the probability that it will occur in humans (*i.e.*, is it biologically plausible?) needs to be considered in the context of the high levels of DNA damage that human cells experience and efficiently repair on a daily basis.

DNA damage occurs daily in every cell in the human body as a result of normal daily living, and the body readily repairs that damage on a regular basis (Ames *et al.*, 1995). DNA damage from endogenous processes (*i.e.*, processes that naturally occur in the human body) are thought to result in a steady-state (*i.e.*, continuous, or any point in time) background level of about 50,000 damaged DNA bases in every human cell (Swenberg *et al.*, 2011). Although carcinogens have the potential to damage DNA either directly or indirectly, possibly resulting in mutations that may contribute to the development of cancer, these processes are more likely to happen when the body's normal cellular and molecular defense and repair mechanisms are damaged or overwhelmed by high concentrations of a mutagen or carcinogen. The body's normal defense mechanisms can efficiently eliminate low concentrations of a mutagenic or carcinogenic substance and repair DNA damage that exposure to the substance may have caused. Therefore, exposures to low levels of genotoxic carcinogens would be unlikely to lead to increases in genotoxicity, mutations, and carcinogenesis beyond what would be considered background levels. Therefore, the current scientific evidence supports a threshold mode of action even for substances that interact directly with DNA, as long as the exposure levels are low enough to not significantly overwhelm cells' normal defense mechanisms.

The National Research Council (NRC) report "Science and Decisions: Advancing Risk Assessment" described the need for an improved framework for dose-response analysis (NRC, 2009). The authors of this report discuss the nonthreshold (LNT) approach and address some of the points I have raised here. The authors state the following regarding the nonthreshold dose-response approach (referred to by NRC as the "low-dose linear" approach):

*Low-dose linear individual and population dose-response.* For this conceptual model, both individual risk and population risk have no threshold and are linear at low doses.... Note that low-dose linear means that at low doses "added risk" (above background) increases linearly with increasing dose; **it does not mean that the dose-response relationship is linear throughout the dose range between zero dose and high doses.** (NRC, 2009 [emphasis added]).

The NRC goes on to illustrate that the linear dose-response approach is based on an assumption of linearity above background from the hypothetical average of a number of different nonlinear (or threshold) dose-response curves in the population, showing that for a given individual, the dose-response is not linear throughout the dose range between zero and high doses. That is, for every individual, there is an exposure level, even for genotoxic substances, below which DNA damage and mutagenesis would not be expected to occur because of cellular defense mechanisms that are able to fully function at low exposures to exogenous (*i.e.*, environmental) substances. However, in the absence of information about the shape of the population dose-response curve in the low dose background range, regulators often conservatively assume the relationship is linear below the background level.

Therefore, the concept that there is "no safe dose" for carcinogens, or that there is no threshold below which increased cancer risk is unlikely, is not biologically plausible. Although US EPA and other regulatory agencies often apply the nonthreshold model (the basis of the "no safe dose" concept) to derive cancer toxicity criteria, the scientific evidence supports the conclusion that this approach is overly conservative when evaluating low exposures to genotoxic and mutagenic carcinogens in the population, and likely even more conservative when evaluating these exposures on an individual basis.

Further, based on the conservative derivations of cancer toxicity values using a nonthreshold approach, cancer risks calculated using these toxicity values are overly conservative, particularly at low doses; *i.e.*, for low exposures that typically occur in the population, a threshold approach is likely to be more scientifically appropriate.

### **3.5 Regulatory Toxicology and Risk Assessment vs. Risk Evaluation to Assess Potential Causation**

There are substantial differences between how toxicological data are used in a regulatory framework to protect public health *vs.* how they are used to evaluate the potential for causation between an individual's chemical exposures and health effects (Aleksunes and Eaton, 2019). The approach to regulatory decision-making is, in part, directed by policy. As practitioners of public health, regulatory toxicologists are more concerned with avoiding adverse health effects than with estimating the likelihood of health effects actually occurring in a population or an individual (Rodricks and Rieth, 1998; ATSDR, 2018a,b). This difference in perspective is important, because, as discussed above, regulators often use high-end estimates of exposure and toxicity (which can result in overprediction of potential health risks) to be protective of human health. The aim of US EPA and other public health agencies is not to precisely define which effects are expected to occur at any given exposure level, but to define the level at which health effects are *unlikely* to occur (US EPA, 1993; ATSDR, 2018a,b). Thus, regulatory criteria are designed to "protect the health of everyone in general and no one in particular" (Rodricks and Rieth, 1998, p. 23). As such, guidelines developed by US EPA and other agencies for deriving regulatory toxicity criteria state that such criteria are designed to be applicable to "susceptible groups," or sensitive subpopulations, which include life stages (*e.g.*, developing fetus) and other factors that may predispose certain individuals to experience a greater response to a given exposure (US EPA, 2002; ATSDR, 2018a,b). Thus, a regulatory risk assessment is designed to be protective of the population overall, and should not be the sole method used to evaluate risks on an individual basis. However, because of the conservative nature of regulatory toxicity criteria, if individual exposures are at or below those criteria, it can be concluded that the individual exposures do not pose concern for potential adverse health effects.

In contrast to risk assessments performed for regulatory or guidance purposes, assessing the likelihood of a chemical exposure causing health effects for an individual requires a risk evaluation specifically for that individual, based on an individual exposure assessment, dose characterization, and an understanding of the potential health effects that the chemical of interest may have on humans at the exposure levels relevant to

the individual (Olsen *et al.*, 2014). This type of evaluation can include a risk calculation, using regulatory toxicity criteria, based on the individual's exposure information, as a screening-level conservative first step in a causation analysis. However, as discussed above, it is important to consider the conservative nature of these regulatory criteria, and the fact that they often reflect exposure levels that are much lower than the exposure levels in the animal or human studies at which effects were reported. Therefore, application of regulatory risk calculations for an individual causation analysis is overly conservative and should not be used by itself in a causation analysis. However, if the conservative regulatory risk estimates fall at or below US EPA's acceptable risk range, those results provide strong support for the conclusion that the exposures of concern are not likely to be causally associated with the health effect of concern.

Further, given the conservative nature of the regulatory risk calculations, even if there is an exceedance of US EPA's risk target, that does not mean that health effects are likely to occur. Therefore, for a causation analysis, it is also useful to evaluate potential causal relationships by comparing the estimated doses for the individual to doses or exposure information from the health effect studies (animal or human) that are the basis of the toxicity criteria. These relationships are called margins of exposure (MoEs), as discussed in the next section.

In some cases, it is also helpful to compare plaintiff-specific exposure information to exposure information from reliable epidemiology studies that evaluated the potential relationships between exposures to the chemicals of concern and the disease of concern.

### 3.6 Margin of Exposure Estimates

As discussed above, the exposure levels at which health effects are predicted to be associated with no (or very low) responses in animal or human studies are the starting points (*i.e.*, PODs) used to derive regulatory toxicity criteria. PODs are the doses from which linear extrapolation is conducted to lower doses for the derivation of cancer toxicity criteria. I describe the PODs for TCE, PCE, benzene, and vinyl chloride in Section 5 of this report. In Section 7, I compare the plaintiff's exposure estimates for these chemicals to the appropriate POD. These types of comparisons provide what is called margins of exposure (MoE) between the exposure predicted for an individual and the lowest exposure levels at which health effects have been observed (or exposure levels at which no effects have been observed, for some chemicals) in human or animal studies. In comparison to the conservative regulatory risk calculations that are designed to assess risk for the most sensitive individual in a population, and for any concentration above zero (for carcinogens), MoEs provide a comparison of individual exposure estimates to concentrations much closer to those at which health effects have been reported in human studies (or extrapolated to humans from animal studies). The equation used to calculate MoEs is as follows:

$$\text{MoE} = \frac{\text{POD for the Cancer Toxicity Value}}{\text{Individual LADD or LADE}}$$

If the MoE is greater than 1, that indicates that the POD (*i.e.*, estimated to reflect exposures related to no or very low responses) is higher than exposures estimated for the individual, providing support that adverse health effects would not be expected for the individual.

These MoE calculations, in addition to comparisons of individual exposure information to exposure information from other relevant epidemiology studies, are important for causation analyses because they provide a more useful comparison of the plaintiff's exposures to exposures where health effects have been observed in people. If the plaintiff's exposures are well below exposures where effects have been observed in epidemiology or toxicology studies, even if there is a risk calculation greater than US EPA's targets,

these results provide support that the individual exposures are not likely to be associated with the health effect of concern.

## 4 Brief History of the US Marine Corps Base Camp Lejeune Site

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### 4.1 Site Description and History

In the early 1940s, the United States Marine Corps developed a water-distribution system at its Camp Lejeune base, which is located in Onslow County, North Carolina, approximately 70 miles northeast of Wilmington, North Carolina (ATSDR, 2013a). The sole source of drinking water at Camp Lejeune is groundwater wells that pump water from the Castle Hayne aquifer system (ATSDR, 2013a).

Operations at Camp Lejeune started in late 1941. Operations at Camp Lejeune started in late 1941. Multiple water treatment plants (WTPs)<sup>4</sup> have serviced Camp Lejeune, including Hadnot Point (HP), Tarawa Terrace (TT), and Holcomb Boulevard (HB) (the three at issue in this litigation). The HP WTP was the first plant to come online, in 1942, and it serviced the base until the TT and HB WTPs came online in 1952 and the summer of 1972, respectively (Hennet, 2024). Because the WTPs were connected to many more groundwater wells than were needed to supply drinking water to the base, the wells' service was rotated and water from different wells was sometimes mixed at the WTPs before being delivered to Camp Lejeune residences and facilities as tap water (ATSDR, 2013a).

### 4.2 Investigations of Groundwater Contamination

In 1974, the Safe Drinking Water Act (SDWA) was established to protect the quality of drinking water in the United States (US Congress, 1974). Under the SDWA, US EPA developed national drinking water regulations that included the derivation of maximum contaminant levels (MCLs), *i.e.*, the highest level of a contaminant that is allowed in drinking water.

In the early 1980s, the groundwater sources for two of the WTPs that serviced Camp Lejeune (HP and TT) were found to be contaminated with volatile organic compounds. Although the groundwater source for the HB WTP was not contaminated, the HB WTP was contaminated when HB drinking water was supplied by the HP WTP in the spring and summer months from 1972 through 1985 (ATSDR, 2017a). The contaminants identified in the drinking water at the HP WTP were TCE, PCE, vinyl chloride, and refined petroleum products (including benzene) (ATSDR, 2017a). The HP contamination is believed to have been related to historical base operations and disposal practices (ATSDR, 2017a). TCE was the primary contaminant identified at the HP WTP. Groundwater modeling conducted by ATSDR estimated that the maximum mean monthly reconstructed level of TCE was 783 parts per billion (ppb), in November 1983 (ATSDR, 2017a). The maximum reconstructed mean monthly concentrations of benzene and PCE were 12 ppb (in April 1984) and 39 ppb (in November 1983), respectively (ATSDR, 2017a). The maximum reconstructed mean monthly concentration of vinyl chloride was 67 ppb, in November 1983 (Maslia *et al.*,

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<sup>4</sup> Hadnot Point (HP), Tarawa Terrace (TT), and Holcomb Boulevard (HB) supplied drinking water to residences and workplaces at Camp Lejeune (see Hennet [2024]). Additional Camp Lejeune water-distribution systems that were not contaminated include: Marine Corps Air Station New River, Onslow Beach, Courthouse Bay, Camp Geiger, Rifle Range, and Montford Point/Camp Johnson (Hennet, 2024).

2016; ATSDR, 2017a). The maximum reconstructed mean monthly concentration of 1,2-tDCE was 435 ppb, in November 1983 (ATSDR, 2017a).<sup>5</sup>

Contamination of the TT WTP supply wells was found to be due to an off-site dry cleaner (Bove *et al.*, 2014), with PCE identified as the primary contaminant. TCE, vinyl chloride, and 1,2-tDCE were also detected at this WTP as PCE degradation products (ATSDR, 2017a; Bove *et al.*, 2014).<sup>6</sup> Groundwater modeling conducted by ATSDR, including a multispecies degradation model of PCE, estimated that the maximum reconstructed mean monthly concentration of PCE in the TT WTP was 158 ppb, in June 1984 (ATSDR, 2017a). Applying the same model, ATSDR estimated maximum reconstructed mean monthly concentrations of TCE and vinyl chloride of 7 and 12 ppb, respectively (ATSDR, 2017a). The maximum reconstructed mean monthly concentration of 1,2-tDCE was 22 ppb (ATSDR, 2017a).<sup>7</sup>

The wells directly serving the other Camp Lejeune water-distribution systems – Holcomb Boulevard (HB), Marine Corps Air Station, Courthouse Bay, Camp Johnson, Camp Geiger, and Rifle Range – were not contaminated with solvents. As stated previously, the HB WTP was largely uncontaminated except when HB drinking water was supplied by the HP WTP (ATSDR, 2017a).

By February 1985, the most highly contaminated wells servicing the HP and TT WTPs had been removed from service (ATSDR, 2017b).

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<sup>5</sup> Drs. Hennet and Spiliotopoulos explain in their expert reports that ATSDR's modeled groundwater concentrations are unreliable and likely biased high as a result of several conservative assumptions used in ATSDR's modeling (Hennet, 2024; Spiliotopoulos, 2024).

<sup>6</sup> Refined petroleum products were not contaminants of the TT WTP; therefore, benzene was not identified as a contaminant of concern at the TT WTP, and ATSDR did not model groundwater concentrations for benzene for the TT WTP (ATSDR, 2013b; Hennet, 2024).

<sup>7</sup> Drs. Hennet and Spiliotopoulos explain in their expert reports that ATSDR's modeled groundwater concentrations are unreliable and likely biased high as a result of several conservative assumptions used in ATSDR's modeling (Hennet, 2024; Spiliotopoulos, 2024).

## 5 Hazard Assessments and Toxicity Criteria

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This section summarizes the TCE, PCE, benzene, vinyl chloride, and 1,2-tDCE hazard assessments that have been conducted by regulatory agencies, and the hazard evaluations conducted by Dr. Goodman (2025) that are specifically focused on exposure to each of these chemicals and kidney cancer. In addition, I summarize the US EPA cancer toxicity criteria for TCE, PCE, benzene, and vinyl chloride that are applied in the plaintiff-specific risk evaluation (Section 6). Note that US EPA has not derived oral or inhalation toxicity criteria for 1,2-tDCE, because US EPA concluded that there was inadequate evidence with which to assess the carcinogenic potential of 1,2-tDCE (US EPA, 2010a,b).

### 5.1 Hazard Assessments

#### 5.1.1 Trichloroethylene (TCE)

To understand the potential association between TCE exposure and kidney cancer, I reviewed the expert report prepared by Dr. Goodman (2025). In addition, I reviewed the conclusions from several regulatory agency TCE toxicological reports. Overall, US EPA (2011a, 2020a), IARC (2014), ATSDR (2019a), and NTP (2015) concluded that the scientific evidence indicates that TCE can cause kidney cancer in humans at some doses. In its assessment of the evidence regarding drinking water contaminants at Camp Lejeune, ATSDR (2017b) concluded that there was "sufficient evidence for causation" for TCE exposure and kidney cancer. ATSDR (2017b) stated that its conclusion was based on the "overall consistent findings" from epidemiology studies, observations of increased incidences of kidney tumors in rats following oral exposure to TCE, and "strong" supportive mechanistic evidence for a mutagenic and cytotoxic mode of action.

Based on the available epidemiology studies and agency reviews that evaluated TCE exposure and kidney cancer, Dr. Goodman concluded that "the epidemiology evidence provides some support for associations between kidney cancer and very high occupational TCE exposures (*e.g.*, >335 ppm-yr in Charbotel *et al.*, 2006)" (Goodman, 2025). Based on a lack of significant findings of treatment related kidney tumors in chronic bioassays, Dr. Goodman concluded, "Collectively, chronic animal bioassays do not support a causal association between TCE exposure and kidney cancer in humans." In summary, Dr. Goodman's review of the epidemiology and toxicology studies that evaluated potential associations between TCE exposure and kidney cancer concluded that overall, "epidemiology evidence provides support for an association between kidney cancer and very high occupational TCE exposures (*e.g.*, >335 ppm-yr in Charbotel *et al.*, 2006)" (Goodman, 2025).

#### 5.1.2 Tetrachloroethylene (PCE)

To understand the potential association between PCE exposure and kidney cancer, I reviewed the expert report prepared by Dr. Goodman (2025). In addition, I reviewed the conclusions from several regulatory agency PCE toxicological reports (ATSDR, 2019b; US EPA, 2012b, 2020b) and IARC (2014); none of the agency documents concluded that PCE exposure is a known cause of kidney cancer in humans. In its assessment of the evidence regarding drinking water contaminants at Camp Lejeune, ATSDR (2017b) concluded that the evidence for causation is "below equipoise" for exposure to PCE and kidney cancer based on inconsistent epidemiology evidence.

Based on the available epidemiology studies and agency reviews that evaluated PCE exposure and kidney cancer, Dr. Goodman concluded, "the epidemiology evidence does not support a causal association between PCE exposure and kidney cancer" (Goodman, 2025). Dr. Goodman also concluded, "Collectively, chronic animal bioassays do not support a causal association between PCE exposure and kidney cancer in humans" (Goodman, 2025). In summary, Dr. Goodman's review of the epidemiology and toxicology studies that evaluated potential associations between PCE exposure and kidney cancer concluded that overall, "scientific evidence does not support a causal association between PCE and kidney cancer" (Goodman, 2025).

### **5.1.3 Benzene**

To understand the potential association between benzene exposure and kidney cancer, I reviewed the expert report prepared by Dr. Goodman (2025). In addition, I reviewed the conclusions from several regulatory agency benzene toxicological reports. Overall, US EPA (2003a), ATSDR (2007a, 2015), and IARC (2018) did not conclude that there is a causal association between exposure to benzene and kidney cancer in humans. In its assessment of the evidence regarding drinking water contaminants at Camp Lejeune, ATSDR (2017b) did not comment on whether there is a causal association between benzene exposure and kidney cancer.

Based on the available epidemiology studies and agency reviews that evaluated benzene exposure and kidney cancer, Dr. Goodman concluded, "the epidemiology evidence does not support an association. Most epidemiology studies reported risk estimates around 1 and, while some statistically significant associations were reported in a few studies, they were based on indirect or non-specific exposure measurements with no clear or compelling evidence that supports an exposure-response relationship" (Goodman, 2025). Dr. Goodman also concluded, "There is no evidence that benzene causes kidney cancer in animal models" (Goodman, 2025). In summary, Dr. Goodman's review of the epidemiology and toxicology studies that evaluated potential associations between benzene exposure and kidney cancer concluded that "the evidence does not support a causal association between benzene and kidney cancer" (Goodman, 2025).

### **5.1.4 Vinyl Chloride**

To understand the potential association between vinyl chloride exposure and kidney cancer, I reviewed the expert report prepared by Dr. Goodman (2025). In addition, I reviewed the conclusions from regulatory agency vinyl chloride toxicological reports. Overall, ATSDR (2024b) and US EPA (2003b) did not conclude that vinyl chloride exposure is a known cause of kidney cancer in humans. In its assessment of the evidence regarding drinking water contaminants at Camp Lejeune, ATSDR (2017b) did not comment on whether there is a causal association between vinyl chloride exposure and kidney cancer.

Based on the available epidemiology studies and agency reviews that evaluated vinyl chloride exposure and kidney cancer, Dr. Goodman concluded that "the epidemiology evidence does not support a causal association between vinyl chloride exposure and kidney cancer" (Goodman, 2025). Dr. Goodman also concluded, "Vinyl chloride does not cause kidney cancer in animal models" (Goodman, 2025). In summary, Dr. Goodman's review of the epidemiology and toxicology studies that evaluated potential associations between vinyl chloride exposure and kidney cancer concluded that overall, "the evidence does not support a causal association between vinyl chloride and kidney cancer" (Goodman, 2025).

### 5.1.5 *trans*-1,2-Dichloroethylene (1,2-tDCE)

To understand the potential association between 1,2-tDCE exposure and kidney cancer, I reviewed the expert report prepared by Dr. Goodman (2025). In addition, I reviewed the conclusions from regulatory agency 1,2-tDCE toxicological reports. Dr. Goodman concluded that currently available scientific evidence is too limited to address whether there is a causal association between 1,2-tDCE and kidney cancer (Goodman, 2025). Overall, US EPA (2010a,b) and ATSDR (2023) have not concluded that 1,2-tDCE is associated with increased kidney cancer risk in humans. In its assessment of the evidence regarding drinking water contaminants at Camp Lejeune, ATSDR (2017b) did not comment on whether *cis*-1,2-dichloroethylene (1,2-cDCE), 1,2-tDCE, or their mixtures are carcinogenic.

## 5.2 Toxicity Criteria

This section summarizes the cancer toxicity criteria that US EPA derived for TCE, PCE, benzene, and vinyl chloride based on the methodology described in Section 3, and US EPA's hazard assessment of these chemicals as described in the documents cited below.

### 5.2.1 Trichloroethylene (TCE)

Table 5.1 summarizes the cancer types, points of departure (PODs), and oral cancer toxicity criteria (cancer slope factors [CSFs]) that US EPA derived for TCE (US EPA, 2011b). Table 5.2 summarizes the cancer types, PODs, and inhalation cancer toxicity criteria (inhalation unit risks [IURs]) that US EPA derived for TCE (US EPA, 2011b). Note that US EPA does not provide TCE oral PODs for renal cell carcinoma (kidney cancer), non-Hodgkin's lymphoma (NHL), or liver cancer, or TCE inhalation PODs for NHL or liver cancer. Because PODs are used in the MoE analyses in Section 7, I estimated PODs for these pathways and endpoints as described in Appendix E.

Based on its hazard assessment for TCE, US EPA first derived the TCE IURs for renal cell carcinoma, NHL, and liver cancer based on two human occupational TCE inhalation studies (Charbotel *et al.*, 2006; Raaschou-Nielsen *et al.*, 2003; US EPA, 2011b) (Table 5.2). US EPA then applied a TCE physiologically based pharmacokinetic (PBPK) model to conduct a route-to-route (inhalation-to-oral) extrapolation to derive the TCE CSFs from the IURs (US EPA, 2011b) (Table 5.1).

Table 5.3 summarizes the TCE toxicity criteria used in the risk evaluation for the plaintiff. Because the plaintiff is claiming kidney cancer from exposure to TCE, I chose to use the CSF and IUR that US EPA derived specifically for renal cell carcinoma.

**Table 5.1 US EPA TCE Oral Cancer Toxicity Values (Cancer Slope Factors [CSFs])**

| Chemical | Oral CSF <sup>a,b</sup><br>[(mg/kg-day) <sup>-1</sup> ] | POD<br>(mg/kg-day)                    | Cancer Type                                    | Sources          |
|----------|---------------------------------------------------------|---------------------------------------|------------------------------------------------|------------------|
| TCE      | $4.6 \times 10^{-2}$                                    | LED <sub>01</sub> = 0.21 <sup>c</sup> | Renal cell carcinoma, NHL,<br>and liver cancer | US EPA (2011a,b) |
|          | $9.33 \times 10^{-3}$                                   | LED <sub>01</sub> = 1.07 <sup>d</sup> | Renal cell carcinoma                           |                  |
|          | $2.16 \times 10^{-2}$                                   | LED <sub>01</sub> = 0.46 <sup>d</sup> | NHL                                            |                  |
|          | $1.55 \times 10^{-2}$                                   | LED <sub>01</sub> = 0.65 <sup>d</sup> | Liver cancer                                   |                  |

Notes:

IUR = Inhalation Unit Risk; LED<sub>01</sub> = Lower Confidence Limit of the Exposure Dose at an Extra Risk Level of 1%; mg/kg-day = Milligrams per Kilogram Body Weight per Day; (mg/kg-day)<sup>-1</sup> = Per Milligrams per Kilogram Body Weight per Day; NHL = Non-Hodgkin's Lymphoma; PBPK = Physiologically Based Pharmacokinetic; POD = Point of Departure; ppm = Parts per Million; (ppm)<sup>-1</sup> = Per Parts per Million; TCE = Trichloroethylene; US EPA = United States Environmental Protection Agency.

(a) Individual CSFs for the three cancers were derived by US EPA (2011a) by extrapolating from the IURs for these cancers. Each IUR was multiplied by a cancer-specific PBPK model-derived adjustment for route-to-route extrapolation (from inhalation to oral exposure) (US EPA, 2011a), as follows. Renal Cell Carcinoma:  $5.49 \times 10^{-3}$  (ppm)<sup>-1</sup>  $\times$  1.7 ppm per mg/kg-day =  $9.33 \times 10^{-3}$  (mg/kg-day)<sup>-1</sup>. NHL:  $1.10 \times 10^{-2}$  (ppm)<sup>-1</sup>  $\times$  1.97 ppm per mg/kg-day =  $2.16 \times 10^{-2}$  (mg/kg-day)<sup>-1</sup>. Liver Cancer:  $5.49 \times 10^{-3}$  (ppm)<sup>-1</sup>  $\times$  2.82 ppm per mg/kg-day =  $1.55 \times 10^{-2}$  (mg/kg-day)<sup>-1</sup>.

(b) The CSF for the three cancer types combined was derived by US EPA (2011a) as follows:  $(5.49 \times 10^{-3}$  [ppm]<sup>-1</sup>  $\times$  1.7 ppm per mg/kg-day)  $\times$  5 =  $4.6 \times 10^{-2}$  (mg/kg-day)<sup>-1</sup>. The factor of 5 is equal to the total risks summed across all three endpoints ( $4.6 \times 10^{-2}$  [mg/kg-day]<sup>-1</sup>) divided the by the kidney cancer risk ( $9.33 \times 10^{-3}$  [mg/kg-day]<sup>-1</sup>).

(c) US EPA (2011a) calculated the LED<sub>01</sub> in mg/kg-day for the three cancers combined using the following equation: LED<sub>01</sub> = (kidney cancer LED<sub>01</sub> in ppm  $\div$  1.70 ppm per mg/kg-day)  $\div$  5 =  $(1.82 \div 1.70) \div 5 = 0.21$  mg/kg-day.

(d) See Appendix E for derivation.

**Table 5.2 US EPA TCE Inhalation Cancer Toxicity Values (Inhalation Unit Risks [IURs])**

| Chemical | IUR<br>[( $\mu\text{g}/\text{m}^3$ ) <sup>-1</sup> ; (ppm) <sup>-1</sup> ]                                    | POD<br>( $\mu\text{g}/\text{m}^3$ [ppb])       | Cancer Type                                    | Sources                                                                                          |
|----------|---------------------------------------------------------------------------------------------------------------|------------------------------------------------|------------------------------------------------|--------------------------------------------------------------------------------------------------|
| TCE      | $4.1 \times 10^{-6}$ ( $\mu\text{g}/\text{m}^3$ ) <sup>-1</sup> ;<br>$2.2 \times 10^{-2}$ (ppm) <sup>-1</sup> | LEC <sub>01</sub> = 2,445 <sup>a</sup> (455)   | Renal cell carcinoma,<br>NHL, and liver cancer | Charbotel <i>et al.</i> (2006);<br>Raaschou-Nielsen <i>et al.</i><br>(2003);<br>US EPA (2011a,b) |
|          | $1.0 \times 10^{-6}$ ( $\mu\text{g}/\text{m}^3$ ) <sup>-1</sup> ;<br>$5.5 \times 10^{-3}$ (ppm) <sup>-1</sup> | LEC <sub>01</sub> = 9,781 (1,820)              | Renal cell carcinoma                           |                                                                                                  |
|          | $2.0 \times 10^{-6}$ ( $\mu\text{g}/\text{m}^3$ ) <sup>-1</sup> ;<br>$1.1 \times 10^{-2}$ (ppm) <sup>-1</sup> | LEC <sub>01</sub> = 4,890 <sup>b</sup> (910)   | NHL                                            |                                                                                                  |
|          | $1.0 \times 10^{-6}$ ( $\mu\text{g}/\text{m}^3$ ) <sup>-1</sup> ;<br>$5.5 \times 10^{-3}$ (ppm) <sup>-1</sup> | LEC <sub>01</sub> = 9,781 <sup>b</sup> (1,820) | Liver cancer                                   |                                                                                                  |

Notes:

$\mu\text{g}/\text{m}^3$  = Micrograms per Cubic Meter; ( $\mu\text{g}/\text{m}^3$ )<sup>-1</sup> = Per Micrograms per Cubic Meter; LEC<sub>01</sub> = Lower Confidence Limit of the Exposure Concentration at an Extra Risk Level of 1%; POD = Point of Departure; ppb = Parts per Billion; ppm = Parts per Million; (ppm)<sup>-1</sup> = Per Parts per Million; NHL = Non-Hodgkin's Lymphoma; TCE = Trichloroethylene; US EPA = United States Environmental Protection Agency.

(a) US EPA (2011a) calculated the LEC<sub>01</sub> for all three cancers combine using the following equation and the LEC<sub>01</sub> for kidney cancer of 1.82 ppm: LEC<sub>01</sub> = kidney cancer LEC<sub>01</sub>  $\div$  4 =  $1.82 \text{ ppm} \div 4 = 0.455 \text{ ppm}$  (equivalent to 2,445  $\mu\text{g}/\text{m}^3$ ). The factor of 4 is equal to the total risks summed across all three endpoints ( $4.1 \times 10^{-6}$  [ $\mu\text{g}/\text{m}^3$ ]<sup>-1</sup>) divided by the kidney cancer risk ( $1.0 \times 10^{-6}$  [ $\mu\text{g}/\text{m}^3$ ]<sup>-1</sup>).

(b) See Appendix E for derivation.

**Table 5.3 TCE Toxicity Criteria Applied in the Risk Calculations**

| Chemical | Criteria | Cancer Type          | Value                                                           |
|----------|----------|----------------------|-----------------------------------------------------------------|
| TCE      | Oral CSF | Renal cell carcinoma | $9.33 \times 10^{-3}$ (mg/kg-day) <sup>-1</sup>                 |
|          | IUR      | Renal cell carcinoma | $1.0 \times 10^{-6}$ ( $\mu\text{g}/\text{m}^3$ ) <sup>-1</sup> |

Notes:

( $\mu\text{g}/\text{m}^3$ )<sup>-1</sup> = Per Microgram per Cubic Meter; CSF = Cancer Slope Factor; IUR = Inhalation Unit Risk;

(mg/kg-day)<sup>-1</sup> = Per Milligrams per Kilogram Body Weight per Day; TCE = Trichloroethylene.

Source: US EPA (2011b).

### 5.2.2 Tetrachloroethylene (PCE)

Table 5.4 summarizes the cancer type, point of departure (POD), and oral cancer toxicity criterion (CSF) that US EPA derived for PCE (US EPA, 2012b). Table 5.5 summarizes the cancer type, POD, and inhalation cancer toxicity criterion (IUR) that US EPA derived for PCE (US EPA, 2012b).

Based on its hazard assessment for PCE, US EPA (2012b) first derived a PCE IUR based on an inhalation tumor bioassay conducted in mice that reported hepatocellular adenomas and carcinomas (liver cancer) (JISA, 1993) and applying a PCE PBPK model to extrapolate from animal to human doses (Table 5.4). US EPA then applied the same PBPK model to conduct a route-to-route (inhalation-to-oral) and animal-to-human extrapolation to derive the PCE CSF from the IUR (US EPA, 2012b) (Table 5.5).

Table 5.6 summarizes the PCE toxicity criteria used in the cancer risk evaluation for the plaintiff. Because the evidence overall is weak for an association between PCE exposure and kidney cancer, increased kidney cancer risk is not expected from PCE exposure and PCE cancer toxicity values specific to kidney cancer are not available. Further, using US EPA's PCE cancer toxicity criteria that are based on liver cancer is not predictive of kidney cancer risk. However, I conservatively apply the criteria to estimate cancer risk for the plaintiff.

**Table 5.4 US EPA PCE Oral Cancer Toxicity Value (Cancer Slope Factor [CSF])**

| Chemical | Oral CSF<br>([mg/kg-day] <sup>-1</sup> ) | POD<br>(mg/kg-day) | Cancer Type<br>(Sex/Species)                            | Sources          |
|----------|------------------------------------------|--------------------|---------------------------------------------------------|------------------|
| PCE      | $2.1 \times 10^{-3}$                     | 50                 | Hepatocellular adenomas<br>or carcinomas<br>(male mice) | US EPA (2012b,c) |

Notes:

mg/kg-day = Milligrams per Kilogram Body Weight per Day; (mg/kg-day)<sup>-1</sup> = Per Milligrams per Kilogram Body Weight per Day; PCE = Tetrachloroethylene; POD = Point of Departure; US EPA = United States Environmental Protection Agency.

**Table 5.5 US EPA PCE Inhalation Cancer Toxicity Value (Inhalation Unit Risk [IUR])**

| Chemical | IUR<br>([μg/m <sup>3</sup> ] <sup>-1</sup> ; [ppm] <sup>-1</sup> )                                    | POD<br>(μg/m <sup>3</sup> [ppb]) | Cancer Type<br>(Sex/Species)                            | Source                           |
|----------|-------------------------------------------------------------------------------------------------------|----------------------------------|---------------------------------------------------------|----------------------------------|
| PCE      | $2.6 \times 10^{-7}$ (μg/m <sup>3</sup> ) <sup>-1</sup> ;<br>$1.8 \times 10^{-3}$ (ppm) <sup>-1</sup> | 390,000 (60,000)                 | Hepatocellular adenomas<br>or carcinomas<br>(male mice) | JISA (1993);<br>US EPA (2012b,c) |

Notes:

μg/m<sup>3</sup> = Micrograms per Cubic Meter; (μg/m<sup>3</sup>)<sup>-1</sup> = Per Micrograms per Cubic Meter; ppb = Parts per Billion; (ppm)<sup>-1</sup> = Per Parts per Million; PCE = Tetrachloroethylene; POD = Point of Departure; US EPA = United States Environmental Protection Agency.

**Table 5.6 PCE Toxicity Criteria Applied in the Risk Calculations**

| Chemical | Criteria | Cancer Type<br>(Sex/Species)                         | Value                                                   |
|----------|----------|------------------------------------------------------|---------------------------------------------------------|
| PCE      | Oral CSF | Hepatocellular adenomas or carcinomas<br>(male mice) | $2.1 \times 10^{-3}$ (mg/kg-day) <sup>-1</sup>          |
|          | IUR      |                                                      | $2.6 \times 10^{-7}$ (μg/m <sup>3</sup> ) <sup>-1</sup> |

Notes:

(μg/m<sup>3</sup>)<sup>-1</sup> = Per Micrograms per Cubic Meter; CSF = Cancer Slope Factor; IUR = Inhalation Unit Risk; (mg/kg-day)<sup>-1</sup> = Per Milligrams per Kilogram Body Weight per Day; PCE = Tetrachloroethylene.

Source: US EPA (2012b).

### 5.2.3 Benzene

Table 5.7 summarizes the cancer type, point of departure (POD), and oral cancer toxicity criterion (CSF) that US EPA derived for benzene (US EPA, 2003a). Table 5.8 summarizes the cancer type, POD, and inhalation cancer toxicity criterion (IUR) that US EPA derived for benzene (US EPA, 2003a).

Based on its hazard assessment for benzene, US EPA (2003a) first derived a benzene IUR based on two sets of benzene exposure estimates derived from the Rinsky *et al.* (1981, 1987) Pliofilm rubber worker cohort studies that evaluated leukemia: (1) exposure estimates from Paustenbach *et al.* (1992), and (2) exposure estimates from Crump and Allen (1984) (Table 5.7). US EPA then conducted route-to-route (inhalation-to-oral) extrapolation to derive the benzene CSF from the IUR (US EPA, 2003a) (Table 5.8).

Table 5.9 summarizes the benzene toxicity criteria used in the risk evaluation for the plaintiff. I chose to use the higher end of the range of benzene CSFs and IURs provided by US EPA (2003a) in my risk calculations. Because the evidence overall does not support an association between benzene exposure and kidney cancer, increased kidney cancer risk is not expected from benzene exposure and benzene cancer toxicity values specific to kidney cancer are not available. Further, using US EPA's benzene cancer toxicity criteria that are based on leukemia is not predictive of kidney cancer risk. However, I conservatively apply the criteria to estimate cancer risk for the plaintiff.

**Table 5.7 US EPA Benzene Oral Cancer Toxicity Values (Cancer Slope Factors [CSFs])**

| Chemical | Oral CSF<br>[(mg/kg-day) <sup>-1</sup> ]     | POD<br>(mg/kg-day) | Cancer Type | Sources                                                    |
|----------|----------------------------------------------|--------------------|-------------|------------------------------------------------------------|
| Benzene  | $1.5 \times 10^{-2}$ to $5.5 \times 10^{-2}$ | 0.055              | Leukemia    | Rinsky <i>et al.</i> (1981, 1987);<br>US EPA (1999, 2003a) |

Notes:

mg/kg-day = Milligrams per Kilogram Body Weight per Day; (mg/kg-day)<sup>-1</sup> = Per Milligrams per Kilogram Body Weight per Day;  
POD = Point of Departure; US EPA = United States Environmental Protection Agency.

**Table 5.8 US EPA Benzene Inhalation Cancer Toxicity Values (Inhalation Unit Risks [IURs])**

| Chemical | IUR<br>[(μg/m <sup>3</sup> ) <sup>-1</sup> ; [ppm] <sup>-1</sup> ]                                                                                    | POD<br>(μg/m <sup>3</sup> [ppb]) | Cancer Type | Sources                                                    |
|----------|-------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|-------------|------------------------------------------------------------|
| Benzene  | $2.2 \times 10^{-6}$ to $7.8 \times 10^{-6}$ (μg/m <sup>3</sup> ) <sup>-1</sup> ;<br>$7.1 \times 10^{-3}$ to $2.5 \times 10^{-2}$ (ppm) <sup>-1</sup> | 383 (120)                        | Leukemia    | Rinsky <i>et al.</i> (1981, 1987);<br>US EPA (1998, 2003a) |

Notes:

μg/m<sup>3</sup> = Micrograms per Cubic Meter; (μg/m<sup>3</sup>)<sup>-1</sup> = Per Micrograms per Cubic Meter; POD = Point of Departure; ppb = Parts per Billion; (ppm)<sup>-1</sup> = Per Parts per Million; US EPA = United States Environmental Protection Agency.

**Table 5.9 Benzene Toxicity Criteria Applied in the Risk Calculations**

| Chemical | Criteria | Cancer Type | Value                                                   |
|----------|----------|-------------|---------------------------------------------------------|
| Benzene  | Oral CSF | Leukemia    | $5.5 \times 10^{-2}$ (mg/kg-day) <sup>-1</sup>          |
|          | IUR      |             | $7.8 \times 10^{-6}$ (μg/m <sup>3</sup> ) <sup>-1</sup> |

Notes:

(μg/m<sup>3</sup>)<sup>-1</sup> = Per Micrograms per Cubic Meter; CSF = Cancer Slope Factor; IUR = Inhalation Unit Risk;  
(mg/kg-day)<sup>-1</sup> = Per Milligrams per Kilogram Body Weight per Day.

Source: US EPA (2003a).

## 5.2.4 Vinyl Chloride

Table 5.10 summarizes the cancer type, points of departure (PODs), and oral cancer toxicity criteria (CSFs) that US EPA derived for vinyl chloride (US EPA, 2000, 2003b). Table 5.11 summarizes the cancer type and inhalation cancer toxicity criteria (IURs) that US EPA derived for vinyl chloride (US EPA, 2003b). Note that US EPA does not provide vinyl chloride oral or inhalation PODs. Because PODs are used in the MoE analyses in Section 7, I estimated PODs for these pathways as described in Appendix E.

Based on its hazard assessment for vinyl chloride, US EPA (2000, 2003b) derived a vinyl chloride CSF for continuous lifetime exposure during adulthood based on an increased incidence of liver angiosarcoma, hepatocellular carcinoma, and neoplastic nodules in female rats in the oral study by Feron *et al.* (1981) and applying a vinyl chloride PBPK model to extrapolate from animal to human doses. US EPA derived two very similar CSFs using two extrapolation methods and they recommend using the lower of the two values for risk calculations (US EPA, 2000, 2003b). US EPA (2000, 2003b) also recommends a two-fold higher CSF to account for continuous lifetime exposure from birth. Values are summarized in Table 5.10.

US EPA (2000, 2003b) derived a vinyl chloride IUR for continuous lifetime exposure during adulthood based on an increased incidence of liver angiosarcomas, angiomas, hepatomas, and neoplastic nodules in female rats in the inhalation studies by Popper *et al.* (1981) and Maltoni *et al.* (1984) and applying a vinyl chloride PBPK model to extrapolate from animal to human doses. US EPA (2000, 2003b) also recommends a two-fold higher CSF to account for continuous lifetime exposure from birth. Values are summarized in Table 5.11.

Table 5.12 summarizes the vinyl chloride toxicity criteria used in the risk evaluation for the plaintiff. Because the evidence overall does not support an association between vinyl chloride exposure and kidney cancer, increased kidney cancer risk is not expected from vinyl chloride exposure and vinyl chloride cancer toxicity values specific to kidney cancer are not available. Further, use of US EPA's vinyl chloride cancer toxicity criteria that are based on liver cancer is not predictive of kidney cancer risk. However, I conservatively apply the criteria to estimate cancer risk for the plaintiff.

**Table 5.10 US EPA Vinyl Chloride Oral Cancer Toxicity Values (Cancer Slope Factors [CSFs])**

| Chemical       | Oral CSF<br>([mg/kg-day] <sup>-1</sup> )             | POD <sup>a</sup><br>(mg/kg-day) | Cancer Type<br>(Sex/Species)                                                                       | Sources                                             |
|----------------|------------------------------------------------------|---------------------------------|----------------------------------------------------------------------------------------------------|-----------------------------------------------------|
| Vinyl Chloride | <b>Continuous Lifetime Exposure During Adulthood</b> |                                 |                                                                                                    |                                                     |
|                | 7.2 × 10 <sup>-1</sup> ;<br>7.5 × 10 <sup>-1</sup>   | LED <sub>10</sub> = 0.133       | Liver angiosarcomas,<br>hepatocellular carcinomas,<br>and neoplastic liver nodules<br>(female rat) | Feron <i>et al.</i> (1981);<br>US EPA (2000, 2003b) |
|                | <b>Continuous Lifetime Exposure from Birth</b>       |                                 |                                                                                                    |                                                     |
|                | 1.4;<br>1.5                                          | LED <sub>10</sub> = 0.067       | Liver angiosarcomas,<br>hepatocellular carcinomas,<br>and neoplastic liver nodules<br>(female rat) | Feron <i>et al.</i> (1981);<br>US EPA (2000, 2003b) |

Notes:

LED<sub>10</sub> = Lower Confidence Limit of the Exposure Dose at an Extra Risk Level of 10%; mg/kg-day = Milligrams per Kilogram Body Weight per Day; (mg/kg-day)<sup>-1</sup> = Per Milligrams per Kilogram Body Weight per Day; POD = Point of Departure; US EPA = United States Environmental Protection Agency.

(a) See Appendix E for derivation.

**Table 5.11 US EPA Vinyl Chloride Inhalation Cancer Toxicity Values (Inhalation Unit Risks [IURs])**

| Chemical       | IUR<br>[( $\mu\text{g}/\text{m}^3$ ) <sup>-1</sup> ] | POD <sup>a</sup><br>( $\mu\text{g}/\text{m}^3$ [ppb]) | Cancer Type<br>(Sex/Species)                                                                 | Sources                                                                               |
|----------------|------------------------------------------------------|-------------------------------------------------------|----------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| Vinyl Chloride | <b>Continuous Lifetime Exposure During Adulthood</b> |                                                       |                                                                                              |                                                                                       |
|                | $4.4 \times 10^{-6}$                                 | LEC <sub>10</sub> =<br>22,727 (8,900)                 | Liver angiosarcomas,<br>angiomas, hepatomas, and<br>neoplastic liver nodules<br>(female rat) | Popper <i>et al.</i> (1981);<br>Maltoni <i>et al.</i> (1984);<br>US EPA (2000, 2003b) |
|                | <b>Continuous Lifetime Exposure from Birth</b>       |                                                       |                                                                                              |                                                                                       |
|                | $8.8 \times 10^{-6}$                                 | LEC <sub>10</sub> =<br>11,364 (4,445)                 | Liver angiosarcomas,<br>angiomas, hepatomas, and<br>neoplastic liver nodules<br>(female rat) | Popper <i>et al.</i> (1981);<br>Maltoni <i>et al.</i> (1984);<br>US EPA (2000, 2003b) |

Notes:

$\mu\text{g}/\text{m}^3$  = Micrograms per Cubic Meter; ( $\mu\text{g}/\text{m}^3$ )<sup>-1</sup> = Per Micrograms per Cubic Meter; LEC<sub>10</sub> = Lower Confidence Limit of the Exposure Concentration at an Extra Risk Level of 10%; ppb = Parts per Billion; POD = Point of Departure; US EPA = United States Environmental Protection Agency.

(a) See Appendix E for derivation.

**Table 5.12 Vinyl Chloride Toxicity Criteria Applied in the Risk Calculations**

| Chemical       | Criteria | Cancer Type                                                                                  | Value                                                                                 |
|----------------|----------|----------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| Vinyl Chloride | Oral CSF | Liver angiosarcomas,<br>angiomas, hepatomas, and<br>neoplastic liver nodules<br>(female rat) | $7.2 \times 10^{-1}$ (mg/kg-day) <sup>-1</sup><br>(adult continuous)                  |
|                | IUR      |                                                                                              | $4.4 \times 10^{-6}$ ( $\mu\text{g}/\text{m}^3$ ) <sup>-1</sup><br>(adult continuous) |

Notes:

( $\mu\text{g}/\text{m}^3$ )<sup>-1</sup> = Per Microgram per Cubic Meter; CSF = Cancer Slope Factor; IUR = Inhalation Unit Risk;  
(mg/kg-day)<sup>-1</sup> = Per Milligrams per Kilogram Body Weight per Day.

Source: US EPA (2003b).

## 5.2.5 *trans*-1,2-Dichloroethylene (1,2-tDCE)

US EPA (2010a,b) concluded that there was inadequate evidence from which to assess the carcinogenic potential of 1,2-cDCE, 1,2-tDCE, or their mixtures. Therefore, US EPA has not derived a CSF or IUR for 1,2-cDCE, 1,2-tDCE, or their mixtures. ATSDR (2017a) did not evaluate cancer risk from exposure to 1,2-tDCE.

## 6 Plaintiff-Specific Regulatory Risk Evaluation

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This section summarizes the plaintiff's residential history, including the duration of time the plaintiff lived and spent time at Camp Lejeune, and a risk evaluation for the plaintiff based on the plaintiff's estimated exposures. I perform regulatory risk calculations based on exposure estimates for the plaintiff from the expert report of Dr. LaKind (2025), plaintiff-specific information about exposure duration (*i.e.*, time spent on-base), information about exposure frequency for the activities evaluated (*e.g.*, number of times per week), and US EPA's toxicity criteria for the chemicals of interest (when available), as summarized in Section 5, and applying standard risk assessment methodology as summarized in Section 3.

### 6.1 Plaintiff Background

According to Mrs. Tukes' deposition and supporting exhibits (Tukes, 2024), she lived and spent time at Camp Lejeune from June 1985 through January 1987 (~1.7 years). Mrs. Tukes testified that she and her family lived in the hostess house (located off of Holcomb Boulevard in the Hadnot Point [HP] part of the base) when they first arrived on-base for a period of 1-2 months<sup>8</sup> before moving off-base to the Sherwood Mobile Home Park (Tukes, 2025a). Mrs. Tukes testified that while living at the Sherwood Mobile Home Park, she would frequently visit the base to shop for groceries, obtain medical care for her son, and have lunch with Mr. Tukes, who was working on-base (Tukes, 2025a). In December 1985, the Tukes family moved to an apartment on Inchon Street in Tarawa Terrace (TT), where they resided until January 1987. Mrs. Tukes testified that she was pregnant with her second son from the middle of 1986 (when the family was living in TT) until after they left Camp Lejeune; her son was born in February 1987 (Tukes, 2024). With respect to water consumption, Mrs. Tukes testified to drinking tap water and using it for cooking while at home, and drinking from water fountains while visiting the main part of the base, but did not provide an estimate of the amount of water she consumed per day (Tukes, 2025a). With respect to showering, Mrs. Tukes stated that she showered 1-3 times per day for 15-20 minutes each time (and periodically took a bath instead of a shower), and she also helped her son bathe (Tukes, 2025a,b). Mrs. Tukes further stated that she spent multiple hours each day cooking, washing dishes, and/or mopping at her house (Tukes, 2025b).

Mrs. Tukes is claiming that her exposure to the water at Camp Lejeune is the cause of her kidney cancer, which she states she was diagnosed with in June 2010 (Tukes, 2024).

### 6.2 Plaintiff Exposure Estimates

Exposure estimates for the plaintiff were calculated based on the average of the monthly average concentrations of TCE, PCE, benzene, vinyl chloride, and 1,2-tDCE over the duration of the plaintiff's exposure period from modeled treatment plant finished water concentrations for both the HP and TT WTPs, which are available in ATSDR's "Public Health Assessment for Camp Lejeune Drinking Water" (ATSDR, 2017a), as described in Dr. LaKind's report (LaKind, 2025). As described above, Mrs. Tukes and her family resided at the hostess house located in Hadnot Point in June and July 1985; lived off-base

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<sup>8</sup> Mrs. Tukes initially testified that, after arriving at Camp Lejeune in June 1985, she and her family lived at the hostess house for 30 days (Tukes, 2025a). She later stated that they lived at the Sherwood Mobile Home Park from August to December 1985 (Tukes, 2025a). For this risk assessment, I have assumed that she resided at the hostess house in June and July 1985, for a total of 2 months.

for several months; and then lived in TT from December 1985 through January 1987. Therefore, I evaluated Mrs. Tukes' shower exposures from HP WTP for the 2 months when the Tukes family resided at the hostess house (June-July 1985), and her shower exposures from TT WTP for the 1.2 years when she and her family resided in TT (December 1985-January 1987). Based on Mrs. Tukes' testimony (as discussed above) that she frequently visited the commissary, hospital, and concession stands in the main part of the base (which were serviced by HP WTP), I evaluated her drinking water exposures as follows:

- From June 1985 through November 1985, I assumed that Mrs. Tukes obtained 100% of her drinking water from the HP WTP; *i.e.*, during the first 2 months that she lived on-base, and conservatively assuming she spent the majority of her time on-base at HP while living off-base.
- From December 1985 through January 1987, I assumed Mrs. Tukes consumed 88% of her drinking water at her home, which was serviced by the TT WTP, and the remaining 12% at the main part of the base, which was serviced by the HP WTP. This is reflective of a scenario in which Mrs. Tukes spent approximately 2 hours each day visiting the main part of base and the remainder of each day at home.

Plaintiff-specific TCE, PCE, benzene, vinyl chloride, and 1,2-tDCE daily tap water exposure estimates from drinking water (ingestion exposure pathway) and showering (dermal and inhalation exposure pathways) are described in more detail in Dr. LaKind's expert report (LaKind, 2025). Risks were calculated for the following baseline exposure pathways and scenarios for the exposure period of concern (1.7 years in total) for the plaintiff:

- **Drinking Water Ingestion:** For this exposure pathway, I evaluated two scenarios for the relevant time periods for HP and TT WTPs: (1) central tendency exposure (CTE), which assumes ingestion of 1.3 liters (L) of tap water per day; and (2) reasonable maximum exposure (RME), which assumes ingestion of 3.3 L of tap water per day.
  - Mrs. Tukes did not specify the amount of water she typically drank per day, but she testified that she was pregnant with her younger child from the middle of 1986 until they left Camp Lejeune in January 1987 (Tukes, 2024). Dr. LaKind provided drinking water dose estimates for several receptors, including a standard adult and a pregnant or breastfeeding woman (LaKind, 2025). Because the dose estimates for the standard adult are higher than those for a pregnant or breastfeeding woman, I conservatively used the adult doses for this evaluation.
- **Dermal and Inhalation Exposures from Showering:** For these exposure pathways, I calculated risks from a residential shower/bathing model (ATSDR, 2024a) to represent Mrs. Tukes' exposures at her residences, the first of which was serviced by the HP WTP and the second of which was serviced by the TT WTP, and both of which she shared with her husband and son. This model estimates average daily dermal and inhalation exposures from showering for a three-person household. Exposure estimates were provided by Dr. LaKind, and details about this model are further described in her report (LaKind, 2025). Note that the residential shower model accounts for additional household water uses, including appliances, sinks, and toilets
  - Mrs. Tukes stated that she typically showered after Mr. Tukes and after giving her son a 15-minute shower, and that her own showers took 15-20 minutes (Tukes, 2024, 2025a,b). Mrs. Tukes also stated that she took 1-3 showers per day. For this risk evaluation, the showering/bathing model assumes that all three members of the house took 20-minute showers, and that Person #3, which represents Mrs. Tukes, showered twice, once in the morning (after the other two household members had showered) and once in the evening. Mrs. Tukes stated that her showering habits were the same when she lived at the hostess house and in TT (Tukes, 2025a).

- As discussed in Dr. LaKind's report (LaKind, 2025), the residential shower model includes exposures associated with use of a washing machine and dishwasher, as well as the use of a kitchen sink and a utility sink. Therefore, household water use activities in addition to bathroom activities are incorporated into the shower model exposure estimates for Mrs. Tukes.

In summary, the following exposure scenarios are evaluated for Mrs. Tukes:

- The CTE exposure scenario, which includes the following exposure pathways: CTE drinking water ingestion (TT and HP WTPs), and dermal and inhalation exposures from showering (TT and HP WTPs).
- The RME exposure scenario, which includes the following exposure pathways: RME drinking water ingestion (TT and HP WTPs), and dermal and inhalation exposures from showering (TT and HP WTPs).

### 6.3 Regulatory Risk Calculations

Risk calculations for the plaintiff based on the estimates of oral and dermal daily exposure doses (DEDs) and daily inhalation exposure concentrations (DECs), which were based on Dr. LaKind's expert report (LaKind, 2025), considering the exposure duration for the plaintiff (~1.7 years) and applying the toxicity values summarized in Section 5, are shown in Table 6.1. More detail on the risk calculations (including chemical- and pathway-specific calculations) is presented in Appendix D. As shown, the ELCRs calculated for Mrs. Tukes' estimated exposures are below the lower end of US EPA's acceptable cancer risk range of  $1 \times 10^{-6}$  to  $1 \times 10^{-4}$  for all of the exposure pathways/scenarios and both water sources evaluated.

**Table 6.1 ELCRs by Exposure Pathway for the Plaintiff<sup>a</sup>**

| Exposure Pathway                                                                                                        | Water Source   | Excess Lifetime Cancer Risks |                    |
|-------------------------------------------------------------------------------------------------------------------------|----------------|------------------------------|--------------------|
|                                                                                                                         |                | Central Tendency             | Reasonable Maximum |
| Ingestion of drinking water while living in HP and spending time visiting HP while living off-base (June-November 1985) | HP WTP         | $2 \times 10^{-8}$           | $5 \times 10^{-8}$ |
| Ingestion of drinking water while living in TT (88%) and spending time on-base in HP (12%) (December 1985-January 1987) | HP and TT WTPs | $2 \times 10^{-7}$           | $4 \times 10^{-7}$ |
| Dermal contact from showering while living in HP (June-July 1985)                                                       | HP WTP         | $2 \times 10^{-9}$           | $2 \times 10^{-9}$ |
| Inhalation from showering while living in HP (June-July 1985)                                                           | HP WTP         | $8 \times 10^{-8}$           | $8 \times 10^{-8}$ |
| Dermal contact from showering while living in TT (December 1985-January 1987)                                           | TT WTP         | $3 \times 10^{-8}$           | $3 \times 10^{-8}$ |
| Inhalation from showering while living in TT (December 1985-January 1987)                                               | TT WTP         | $2 \times 10^{-7}$           | $2 \times 10^{-7}$ |
| <b>Total ELCRs (All Pathways):</b>                                                                                      |                | $5 \times 10^{-7}$           | $8 \times 10^{-7}$ |

Notes:

ELCR = Excess Lifetime Cancer Risk; HP = Hadnot Point; TT = Tarawa Terrace; WTP = Water Treatment Plant.

(a) All ELCRs are rounded to 1 significant digit and are based on values from tables in Appendix D.

As shown in Table 6.1, the maximum ELCR calculated for Mrs. Tukes' estimated exposures (*i.e.*, RME scenario) is  $8 \times 10^{-7}$  (or 8 cancer cases in 10,000,000 exposed people, or 0.00008% increased risk), which is below US EPA's target excess cancer risk range. The cancer risk estimate is for all cancer types for all chemical exposures evaluated. As discussed in Section 5, none of the regulatory agency documents concluded that PCE, benzene, or vinyl chloride exposures are known causes of kidney cancer in humans. US EPA's cancer toxicity criteria, and cancer risk estimates, for PCE and vinyl chloride are based on liver cancer and, those for benzene are based on leukemia. Thus, estimates of cancer risk from these chemicals are overly protective for kidney cancer risk. As shown in Appendix D, most of the RME cancer risk estimate is driven by vinyl chloride exposure *via* drinking water consumption. The estimated cancer risks for TCE (which are based on kidney cancer) are lower than the total risk, with a maximum ELCR of  $1 \times 10^{-8}$  (or 1 kidney cancer case in 100,000,000 exposed people, or 0.000001% increased risk of kidney cancer) from the RME scenario (see Appendix D, Table D.2), which is well below US EPA's acceptable risk range.

It is also important to keep in mind that, as discussed in Section 3, these risk estimates are protective of the whole population (including sensitive individuals). Therefore, they are based on conservative assumptions about exposures and health effects, and, consequently, are likely overestimates for healthy individuals. In addition, some of the toxicity criteria that are based on inhalation studies are extrapolated to toxicity criteria that can be applied to oral and dermal exposure pathways (or *vice versa*). These extrapolations include conservative assumptions, and therefore, the toxicity values derived based on these extrapolations likely overpredict exposures and risks.

It is also important to note that there is some uncertainty in the modeled finished water concentrations of TCE, PCE, benzene, vinyl chloride, and 1,2-tDCE from the two WTPs that are available from ATSDR (2007b, 2013b). As described in the expert reports by Dr. Hennes (2024) and Dr. Spiliotopoulos (2024), ATSDR's modeled finished water concentrations are likely to be biased high as a result of several conservative assumptions in the modeling. These results suggest that exposures and risks calculated based on ATSDR's modeled concentrations may be overestimated.

## 6.4 Risk Evaluation Conclusion

Overall, the regulatory risk calculations support the conclusion that Mrs. Tukes was not exposed to TCE, PCE, benzene, vinyl chloride, and 1,2-tDCE in tap water at Camp Lejeune at levels that are of concern for human health. Even at the highest potential exposure for Mrs. Tukes, and applying conservative, health-protective assumptions, her exposures to chemicals in Camp Lejeune tap water did not increase her overall cancer risk by more than 0.00008% (*i.e.*,  $8 \times 10^{-7}$ , or 8 cancer cases in 10,000,000 exposed people) over her background cancer risk. This ELCR is below US EPA's acceptable risk range. The maximum calculated cancer risk from the only chemical for which there is some evidence of an association between high levels of exposure and kidney cancer – TCE ( $1 \times 10^{-8}$ , or 1 cancer case in 100,000,000 exposed people, or 0.000001%) – falls well below US EPA's acceptable cancer risk range. Therefore, one cannot reasonably conclude that Mrs. Tukes' exposures to chemicals in Camp Lejeune water are causally associated with her kidney cancer.

Because the cancer risks presented in Table 6.1 are based on the application of conservative exposure assumptions and toxicity values, in Section 7, I have also conducted margin of exposure (MoE) comparisons between the exposures predicted for the plaintiff and the lowest exposure levels at which health effects have been observed (or exposure levels at which no effects have been observed, for some chemicals) in the human or animal studies that are the basis of the toxicity criteria. In Section 8, I have also conducted a comparison of the plaintiff's estimated exposures to exposures reported in epidemiology and animal studies relevant to kidney cancer.

## 7 Plaintiff-Specific Margins of Exposure

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As discussed in Section 3, the exposure levels at which health effects are predicted to be associated with no (or a very low) response from animal or human studies are the starting points (*i.e.*, points of departure [PODs]) used to derive regulatory toxicity criteria. PODs are the doses from which linear extrapolation is conducted to lower doses for the derivation of cancer toxicity criteria. In this section, I compare the plaintiff's exposure estimates for the chemicals evaluated in this report to the chemical-specific PODs. These types of comparisons provide what is called margins of exposure (MoEs) between the exposure predicted for an individual and the lowest exposure levels at which health effects have been observed (or exposure levels at which no effects have been observed, for some chemicals) in human or animal studies. In comparison to the conservative regulatory risk calculations (described in Section 6) that are designed to assess risk for the most sensitive individual in a population, and for any concentration above zero (for carcinogens), MoEs provide a comparison of individual exposure estimates to concentrations much closer to those at which health effects have been reported in human studies (or in animal studies used to extrapolate to humans). As discussed in Section 3, the equation used to calculate MoEs is as follows:

$$\text{MoE} = \frac{\text{POD for the Cancer Toxicity Value}}{\text{Individual LADD or LADE}}$$

If the MoE is greater than 1, that indicates that the POD (*i.e.*, estimated to reflect exposures related to no or very low responses) is higher than exposures estimated for the individual, providing support that adverse health effects would not be expected for the individual.

The PODs for the ingestion (or dermal) and inhalation pathways for each chemical assessed herein are presented in Section 5.2. The plaintiff-specific exposure levels and MoEs are presented in Appendix D. As shown in Table D.1, the MoEs for the plaintiff range from 35,000 to 40,000,000. For TCE exposure (*i.e.*, the only chemical for which the toxicity values are based on kidney cancer) *via* all exposure pathways, the MoEs range from 920,000 to 40,000,000. Therefore, the MoEs are orders of magnitude above 1, indicating that the plaintiff's estimated exposure levels to TCE, PCE, benzene, vinyl chloride, and 1,2-tDCE in tap water (*via* inhalation, ingestion, and dermal exposure) at Camp Lejeune were well below the exposure doses and concentrations used to derive the toxicity criteria for these chemicals, providing additional support that the plaintiff's exposures would not have been expected to lead to adverse health effects.

## 8 Consideration of Epidemiology and Animal Studies Relevant to Kidney Cancer

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In this section, I compare the exposure estimates for the plaintiff to exposure information I identified from epidemiology and toxicology studies summarized in Dr. Goodman's expert report that evaluated the possible association between TCE, PCE, benzene, vinyl chloride, or 1,2-tDCE exposure and kidney cancer risk (Goodman, 2025).

Although Dr. Goodman reviewed epidemiology studies that evaluated potential correlations between chemical exposures and kidney cancer in study participants who were stationed at Camp Lejeune, I did not consider exposure estimates from those studies because of the methodological limitations in the studies (*e.g.*, high likelihood of exposure misclassification) as discussed by Dr. Goodman (2025). Further, as discussed by Dr. Goodman with regard to these studies:

Overall, there were no consistent associations reported between either working or living at Camp Lejeune or TCE, PCE, benzene, or vinyl chloride exposures at Camp Lejeune and kidney cancer. Almost all risk estimates were statistically null and close to 1. The few reported statistically significant risk estimates were not reported across other analyses of the Camp Lejeune population. (Goodman, 2025).

### 8.1 TCE

As summarized in Section 5, ATSDR, in its "Assessment of the Evidence for the Drinking Water Contaminants at Camp Lejeune" (ATSDR, 2017b), concluded that there is "sufficient evidence for causation" for TCE exposure and kidney cancer. US EPA, IARC, and NTP have concluded that TCE can cause kidney cancer in humans at some doses (see Section 5). Dr. Goodman (2025) concluded that the epidemiology evidence provides support for an association between kidney cancer and very high occupational TCE exposures (*e.g.*, >335 ppm-year), based on the Charbotel *et al.* (2006) study. Mrs. Tukes' exposure estimates are all well below 335 ppm-years.

For my exposure comparisons, I relied on the kidney cancer epidemiology study conducted by Charbotel *et al.* (2006) that is considered by US EPA to be the most reliable study for quantifying a potential association between TCE exposure and kidney cancer and deriving TCE cancer toxicity criteria (US EPA, 2011b) (see Section 5). These cancer toxicity criteria were applied in the recent US EPA final risk management rule for TCE under its Toxic Substances Control Act (TSCA) (US EPA, 2024a). A comparison of the exposure information from this study to the plaintiff's exposure estimates is described in Section 7; *i.e.*, Mrs. Tukes' TCE exposure estimates (over all exposure pathways) are 920,000 to 40,000,000 times lower than the kidney cancer PODs for TCE that are based on the Charbotel *et al.* (2006) study, and thus are well below 335 ppm-years.

## 8.2 PCE

As summarized in Section 5, ATSDR (2017b) concluded that the evidence for causation is "below equipoise" for exposure to PCE and kidney cancer. US EPA, IARC, and NTP do not conclude that there is an association between exposure to PCE and kidney cancer (see Section 5). Dr. Goodman concluded that overall, the scientific evidence does not support a causal association between PCE exposure and kidney cancer (Goodman, 2025). There are no PCE kidney cancer epidemiology studies discussed in Dr. Goodman's report that include participant exposure estimates; however, below I discuss the PCE exposure information from the PCE animal bioassay studies discussed by Dr. Goodman (2025).

Mrs. Tukes' PCE exposure estimates are well below those reported in the animal bioassays discussed by Dr. Goodman (2025). Dr. Goodman's report indicates that there are no significant increases or trends in kidney tumors in 2-year chronic animal bioassays at oral PCE doses up to 1,072 mg/kg-day and PCE inhalation concentrations as high as 600 ppm (Goodman, 2025). These exposures are orders of magnitude higher than Mrs. Tukes' maximum estimated PCE oral LADD of 0.0000035 mg/kg-day and inhalation LADE of 0.000022 ppm (0.15  $\mu\text{g}/\text{m}^3$ ).<sup>9</sup>

Mrs. Tukes' oral and inhalation exposure estimates are presented in Appendix D.

## 8.3 Benzene

As summarized in Section 5, ATSDR (2017b) provided no comment on whether there is a causal association between benzene exposure and kidney cancer. US EPA, IARC, and NTP do not conclude that there is an association between exposure to benzene and kidney cancer (see Section 5). Dr. Goodman concluded that, overall, the scientific evidence does not support a causal association between benzene exposure and kidney cancer (Goodman, 2025). There are no benzene kidney cancer epidemiology studies discussed in Dr. Goodman's report that include participant exposure estimates; however, below I discuss the benzene exposure information from the benzene animal bioassay studies discussed by Dr. Goodman (2025).

Mrs. Tukes' benzene exposure estimates are well below those reported in the animal bioassays discussed by Dr. Goodman (2025). Dr. Goodman's report indicates that there are no significant increases or trends in kidney tumors in 2-year chronic animal bioassays at oral benzene doses up to 200 mg/kg-day and benzene inhalation concentrations as high as 300 ppm (Goodman, 2025). These exposures are orders of magnitude higher than Mrs. Tukes' maximum estimated benzene oral LADD of 0.00000086 mg/kg-day and inhalation LADE of 0.0000016 ppm (0.011  $\mu\text{g}/\text{m}^3$ ).<sup>10</sup>

Mrs. Tukes' oral and inhalation exposure estimates are presented in Appendix D.

## 8.4 Vinyl Chloride

As summarized in Section 5, ATSDR (2017b) provided no comment on whether there is a causal association between vinyl chloride exposure and kidney cancer. US EPA, IARC, and NTP do not conclude that there is an association between exposure to vinyl chloride and kidney cancer (see Section 5). Dr. Goodman concluded that, overall, the scientific evidence does not support a causal association between vinyl chloride exposure and kidney cancer (Goodman, 2025). There are no vinyl chloride kidney cancer epidemiology studies discussed in Dr. Goodman's report that include participant exposure estimates; however, below I

<sup>9</sup> 1 ppm PCE = 6,780  $\mu\text{g}/\text{m}^3$  (CDC, 2019a).

<sup>10</sup> 1 ppm benzene = 3,190  $\mu\text{g}/\text{m}^3$  (CDC, 2019b).

discuss the vinyl chloride exposure information from the vinyl chloride animal bioassay studies discussed by Dr. Goodman (2025).

Mrs. Tukes' vinyl chloride exposure estimates are well below those reported in the animal bioassays discussed by Dr. Goodman (2025). Dr. Goodman's report indicates that there are no significant increases or trends in kidney tumors in 2-year chronic animal bioassays at oral vinyl chloride doses up to 300 mg/kg-day and vinyl chloride inhalation concentrations as high as 30,000 ppm (Goodman, 2025). These exposures are orders of magnitude higher than Mrs. Tukes' maximum estimated vinyl chloride oral LADD of 0.00000053 mg/kg-day and inhalation LADE of 0.0000044 ppm (0.03  $\mu\text{g}/\text{m}^3$ ).<sup>11</sup>

Mrs. Tukes' oral and inhalation exposure estimates are presented in Appendix D.

## **8.5 1,2-tDCE**

As summarized in Section 5, Dr. Goodman concluded that, overall, the scientific evidence (including epidemiology and toxicology studies) is too limited to address whether there is a causal association between 1,2-tDCE and kidney cancer (Goodman, 2025). ATSDR (2017b) provided no comment on whether there is a causal association between 1,2-tDCE exposure and kidney cancer. US EPA, IARC, and NTP do not conclude that there is an association between exposure to 1,2-tDCE and kidney cancer (see Section 5). Therefore, exposure comparisons cannot be made for 1,2-tDCE.

## **8.6 Conclusions from Epidemiology and Toxicology Studies**

The results described above provide additional support that Mrs. Tukes' exposures to TCE, PCE, benzene and vinyl chloride were well below levels of concern for kidney cancer (TCE) or well below levels at which there were no significant increases in kidney tumors in animals (PCE, benzene, and vinyl chloride). Therefore, Mrs. Tukes' estimated exposures during the time that she lived and spent time at Camp Lejeune would not have been expected to lead to her kidney cancer.

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<sup>11</sup> 1 ppm vinyl chloride = 2,560  $\mu\text{g}/\text{m}^3$  (CDC, 2019c).

## 9 Rebuttal of the Plaintiff's Experts' Reports

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I reviewed the reports of the plaintiff's experts Dr. Kelly Reynolds (2025a), who provided exposure estimates for the plaintiff, and Drs. Armine Smith (2025), David Josephson (2025), Matthew Cooper (2025), and Timothy Mallon (2025), who provided opinions on specific causation for Mrs. Tukes. Below, I note the methodological flaws in their analyses, with respect to risk assessment.

### 9.1 Dr. Reynolds

Dr. Reynolds' report (Reynolds, 2025a) does not provide reliable estimates of TCE, PCE, vinyl chloride, and benzene exposures for Mrs. Tukes from which to evaluate potential adverse health effects.

Dr. Reynolds relies on ATSDR's monthly modeled concentrations (in  $\mu\text{g/L}$ ) of TCE, PCE, vinyl chloride, and benzene to calculate total cumulative amounts (in  $\mu\text{g}$ ) of each chemical summed over time, based on plaintiff-specific drinking water ingestion rates and exposure durations for the total time the plaintiff spent at Camp Lejeune (Reynolds, 2025a). Dr. Reynolds describes that her exposure scenarios are based on military field manuals and plaintiff depositions. Dr. Reynolds provides these estimates in plaintiff-specific "exposure assessment charts" in her report (Reynolds, 2025a).

Although Dr. Reynolds' calculations are not clearly explained, it appears that she first calculates a cumulative  $\mu\text{g/L}$ -month concentration for the plaintiff based on the chemical concentrations and the number of months the plaintiff resided at Camp Lejeune. She also calculates a total chemical mass (in  $\mu\text{g}$ ) for each plaintiff based on the water concentration and the daily ingestion rate; these calculations were further explained in her calculation summary (Reynolds, 2025b). With respect to Dr. Reynolds' use of total amount ( $\mu\text{g}$ ) as an oral exposure estimate – this is not a standard exposure metric used in risk assessment. As previously discussed in Section 3.3.2, oral and dermal exposure estimates are represented by the daily dose of a chemical taken into the body, averaged over the appropriate exposure period and expressed in units of milligram of chemical per kilogram of human body weight per day ( $\text{mg/kg-day}$ ). Inhalation exposure estimates represent the daily exposure concentration of a chemical taken into the body, averaged over the appropriate exposure period and expressed in units of microgram of a chemical per cubic meter of air ( $\mu\text{g/m}^3$ ). As discussed in Section 3, doses and inhalation exposure estimates can then be used to calculate excess lifetime cancer risks (ELCRs) using US EPA's chemical-specific toxicity criteria, and then the results can be compared to US EPA guidelines for acceptable ELCRs. Therefore, Dr. Reynolds' representation of exposure as total ingested amount of chemical ( $\mu\text{g}$ ) cannot be used directly to evaluate potential health effects for the plaintiff. That is, the mass of ingested chemical needs to be divided by body weight for the plaintiff and averaged over the appropriate averaging time, as described in Section 3, and as presented in my report for the plaintiff (Section 6), so that the oral doses can be used to calculate ELCRs per US EPA risk assessment guidelines.

Further, total mass is not a useful metric for comparison to exposure estimates in most reliable animal or epidemiology studies. Doses ( $\text{mg/kg-day}$ ) or inhalation concentrations ( $\mu\text{g/m}^3$ ) are typically used in animal bioassays for evaluating potential health effects from chemical exposures. Most reliable epidemiology studies provide cumulative exposure estimates in  $\text{ppm-year}$  (*i.e.*, inhalation exposure concentration  $\times$  number of years exposed) and  $\text{ppb-month}$  or  $\text{ppb-year}$  (*i.e.*, ingested water concentration  $\times$  number of months or years exposed). Thus, there is no risk-based comparison that can be made between total ingested mass and exposure information from relevant animal or epidemiology studies.

## 9.2 Drs. Smith, Josephson, Cooper, and Mallon

The reports of Drs. Smith (2025), Josephson (2025), Cooper (2025), and Mallon (2025) do not provide a reliable analysis of specific causation or risk of kidney cancer with regard to Mrs. Tukes' alleged exposures.

- Dr. Smith concludes that Mrs. Tukes' exposures while at Camp Lejeune were "substantial" and "causally related to the development of her kidney cancer" (Smith, 2025)
- Dr. Josephson concludes that "more likely than not, her exposure to carcinogens at Camp Lejeune known to cause kidney cancer, primarily PCE, amplified by her genetic susceptibility, caused her kidney cancers. Her exposure to TCE, VC [vinyl chloride] and benzene during these exposures likely added to or worked synergistically to cause her kidney cancer" (Josephson, 2025).
- Dr. Cooper concludes that Mrs. Tukes' exposures to toxins at Camp Lejeune were "substantial" and "more likely than not did cause her kidney cancer" (Cooper, 2025).
- Dr. Mallon concludes that Mrs. Tukes' PCE exposure "more likely than not" is a cause of her kidney cancer (Mallon, 2025).

All four experts make these conclusions without providing a robust analysis of the best available scientific information relevant to the potential specific causal association between exposure to these chemicals and kidney cancer, or any consideration of the very short duration of Mrs. Tukes' exposure to water at Camp Lejeune (1.7 years). In addition, all four experts' reliance on Dr. Reynolds' exposure estimates is seriously flawed and not consistent with US EPA risk assessment guidelines. Therefore, these experts cannot use these exposure estimates to determine Mrs. Tukes' risks. Below I describe several flaws in the analyses of these four experts:

- Dr. Smith's, Dr. Josephson's, Dr. Cooper's, and Dr. Mallon's risk evaluations are not consistent with US EPA's risk assessment guidelines, which consider not only exposure concentrations, but also exposure frequency and duration.
  - As discussed in Sections 3 and 5, exposure frequency and duration are critical components of US EPA's risk assessment methodology. It is only when the exposure concentrations, in combination with exposure frequencies and durations, result in doses exceeding US EPA's toxicity criteria (*i.e.*, result in a risk estimate that exceeds US EPA's acceptable targets) that there is concern for potential adverse health effects. And even with slight exceedances of US EPA's conservative risk targets, health effects are not necessarily expected to occur (as discussed in Section 3).
- Dr. Smith's, Dr. Josephson's, Dr. Cooper's, and Dr. Mallon's reports refer to Mrs. Tukes' increased susceptibility to chemical exposures because of a potential genetic mutation. Even assuming Mrs. Tukes is more susceptible to chemical exposures because of a genetic mutation (which Dr. Gail Vance explains is not the case [Vance, 2025]), any increased susceptibility is already factored into my analysis. As explained in Section 3, the toxicity criteria I apply are designed to be applicable to susceptible groups and other sensitive subpopulations.
- Drs. Smith, Josephson, Cooper, and Mallon all rely on Dr. Reynolds' exposure charts as support for their conclusion that Mrs. Tukes' exposures were "substantial," but provide no basis for this conclusion other than simply pointing to the total mass values reported by Dr. Reynolds'. As discussed in the previous section, estimates of total chemical mass exposure over time cannot be used directly to evaluate potential health effects for the plaintiff, because there are no total mass

exposure estimates from relevant animal or epidemiology studies against which to make reliable risk-based comparisons. Exposures need to be estimated as oral doses of mg/kg-day or inhalation doses of  $\mu\text{g}/\text{m}^3$ , per US EPA risk assessment guidelines. Adding up mass over many days and months will, undoubtedly, result in a very large number. But it is an incorrect value for the purpose of risk evaluation. Therefore, Dr. Smith's, Dr. Cooper's, Dr. Josephson's, and Dr. Mallon's conclusions based on estimates of total chemical mass exposure for Mrs. Tukes are meaningless and misleading and cannot be relied upon for risk evaluation for Mrs. Tukes.

- Drs. Smith, Cooper, and Mallon also incorrectly refer to the total masses from Dr. Reynolds' report (in  $\mu\text{g}$ ) as drinking water concentrations (ppb or  $\mu\text{g}/\text{L}$ ). All three state that Mrs. Tukes would have ingested "5,875 ppb of PCE" (Smith, 2025; Cooper, 2025; Mallon, 2025). However, the value of 5,875 (in  $\mu\text{g}$ ) discussed by Dr. Reynolds *is a total mass of PCE over time, and not a concentration (ppb or  $\mu\text{g}/\text{L}$ ) of PCE in drinking water*. According to Dr. Reynolds' report (Reynolds 2025a), the concentrations of PCE in the water that Mrs. Tukes' is assumed to have been exposed to range from 3.6 to 8.3 ppb or 8.3 to 17.8 ppb (depending on what model is used), which are orders of magnitude lower than what Drs. Smith, Cooper, and Mallon incorrectly state to be Mrs. Tukes' PCE exposure concentration levels. Therefore, Dr. Smith's, Dr. Cooper's, and Dr. Mallon's statements that Mrs. Tukes would have been exposed to 5,875 ppb PCE in drinking water is grossly incorrect and misleading. Dr. Cooper also incorrectly makes similar statements regarding the total masses of TCE, benzene, and vinyl chloride.
- Dr. Smith's, Dr. Josephson's, and Dr. Mallon's comparisons to US EPA Maximum Contaminant Levels (MCLs) for allowable chemical concentrations in drinking water are not reliable risk evaluation methods.
  - US EPA does not use MCLs to evaluate potential risks to human health.
  - MCLs are derived to be acceptable (health-protective) daily drinking water concentrations over a lifetime of exposure (~70 years) (US EPA, 2024b), which is much longer than Mrs. Tukes' ~1.7 years of exposure during her time at Camp Lejeune.
  - Per US EPA guidance for cancer risk assessment, it is the cumulative dose averaged over a lifetime that is critical for evaluating cancer risk. As shown in equations in Section 3, estimated doses are averaged over a 70-year lifetime before calculating risks. Therefore, once averaged over a lifetime, it is possible to have a dose based on a higher exposure concentration for a shorter exposure duration (which is the case for some of the plaintiffs at Camp Lejeune) that would not exceed a dose based on a lower exposure concentration for a longer exposure duration (like ingesting water at the MCL every day for a lifetime). In both cases, the calculated risks would be considered acceptable under US EPA guidelines. Therefore, a simple comparison of drinking water concentrations to MCLs, without considering exposure duration, is not consistent with standard risk assessment practice and is misleading.
- Dr. Smith's, Dr. Josephson's, Dr. Cooper's, and Dr. Mallon's reports also fail to mention that the concentrations of TCE, vinyl chloride, and benzene reported in Dr. Reynolds' report for Mrs. Tukes were consistently below the MCLs, suggesting that exposure to these chemicals would not have been expected to result in health effects, even after a lifetime of exposure.
- Dr. Smith's, Dr. Josephson's, Dr. Cooper's, and Dr. Mallon's reports refer to exposure information from several Camp Lejeune studies to support their conclusions. However, as discussed in Dr. Goodman's report (Goodman, 2025), there are methodological limitations in these studies (*e.g.*, high likelihood of exposure misclassification). In addition, with regard to the Camp Lejeune studies, overall, Dr. Goodman states the following:

Overall, there were no consistent associations reported between either working or living at Camp Lejeune or TCE, PCE, benzene, or vinyl chloride exposures at

Camp Lejeune and kidney cancer. Almost all risk estimates were statistically null and close to 1. The few reported statistically significant risk estimates were not reported across other analyses of the Camp Lejeune population. (Goodman, 2025).

- In addition, as discussed in Section 5, based on a comprehensive review of the best available and most current epidemiology and animal studies, Dr. Goodman (2025) concludes that the scientific evidence does not support a causal association between PCE, benzene, vinyl chloride, or 1,2-tDCE exposure and kidney cancer, and only provides support for an association between occupational exposure to high concentrations of TCE (much higher than Mrs. Tukes' estimated exposures) and kidney cancer.
- As shown in Dr. Reynolds' report, the TCE concentrations in drinking water during the time that Mrs. Tukes lived and spent time at Camp Lejeune were very low, ranging from nondetect to 0.36 µg/L, well below the current TCE MCL of 5 µg/L, supporting the conclusion that Mrs. Tukes' TCE exposures (in addition to her PCE, benzene, and vinyl chloride exposures) are unrelated to her kidney cancer. However, none of the plaintiff's experts discuss this point.

As discussed in my report (Section 6), applying standard risk assessment methodology (*i.e.*, considering exposure concentrations in addition to exposure frequency and duration for the plaintiff), the excess lifetime cancer risks (ELCRs) estimated for Mrs. Tukes' exposures do not exceed US EPA's acceptable cancer risk range.

Therefore, Dr. Reynolds', Dr. Smith's, Dr. Josephson's, Dr. Cooper's, and Dr. Mallon's expert reports do not change my opinions, as discussed throughout my report and summarized in Section 10, regarding Mrs. Tukes' claim that exposures from Camp Lejeune are the cause of her kidney cancer.

## 10 Conclusion and Summary of Opinions

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Based on the conservative regulatory risk calculations discussed in Section 6, the MoE calculations discussed in Section 7, and consideration of the kidney cancer epidemiology and toxicology studies discussed in Section 8, it is my opinion, to a reasonable degree of scientific certainty, that there is insufficient evidence to conclude that Mrs. Tukes' exposures to TCE, PCE, benzene, vinyl chloride, and 1,2-tDCE from tap water during the ~1.7 years that she lived and spent time at Camp Lejeune are causally associated with her kidney cancer.

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# Appendix A

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## *Curriculum Vitae* Lisa A. Bailey, Ph.D.

**Lisa Bailey, Ph.D.**

**Principal**

Lisa.Bailey@gradientcorp.com

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## Areas of Expertise

Human health risk assessment, exposure assessment, toxicology, DNA repair, mutagenesis, carcinogenesis.

## Education

Ph.D., Biochemistry, Massachusetts Institute of Technology, 1995

B.A., *cum laude*, Chemistry, Skidmore College, 1989

## Professional Experience

2006 – Present GRADIENT, Boston, MA

Principal. Provides expertise in human exposure assessment and toxicology in support of human health risk assessment and toxic tort litigation projects. Evaluates chemical toxicology data and reviews specific environmental chemical exposures to assess potential human health risks. Special emphasis on exposure assessment, toxicology, mode of action, genotoxicity, and carcinogenesis.

1999 – 2006 MENZIE-CURA & ASSOCIATES, INC., Winchester, MA

Senior Scientist. Managed human health risk assessments under the Massachusetts Contingency Plan and the US Environmental Protection Agency Superfund Program.

1996 – 1999 HARVARD SCHOOL OF PUBLIC HEALTH, Boston, MA

Post-Doctoral Fellow, Department of Molecular and Cellular Toxicology. Investigated the contribution of spontaneously generated abasic site DNA damage to spontaneous mutagenesis in the yeast *Saccharomyces cerevisiae* system. Compiled data regarding the origin of spontaneous mutations to better understand their role in the carcinogenesis process.

1989 – 1995 MASSACHUSETTS INSTITUTE OF TECHNOLOGY, Cambridge, MA

Ph.D. Student, Department of Biochemistry and Division of Toxicology. Investigated the mutational specificity of aflatoxin B<sub>1</sub> (AFB<sub>1</sub>), a potent mutagen and carcinogen, in *Escherichia coli* through the use of an M13 genome containing the AFB<sub>1</sub>-N7-Gua adduct in a defined position. Compared the mutational specificity observed in *E. coli* to that found in human liver cancers believed to be caused by aflatoxin.

## Professional Affiliations

Society of Toxicology (Full Member); Society for Risk Analysis

2/14/2025

## Select Projects

Confidential Client: In support of toxic tort litigation, reviewed toxicology, epidemiology, mechanistic, and exposure information related to claims of causal associations between trichloroethylene and perchloroethylene inhalation exposures and health effects (e.g., pancreatic cancer and fetal heart malformation).

Confidential Client: In support of toxic tort litigation, reviewed toxicology, epidemiology, and exposure information related to claims of causal associations between exposures to chemicals associated with employment as an oil spill response worker and health effects (e.g., respiratory and dermal effects).

Confidential Client: In support of toxic tort litigation, conducted an in-depth review of toxicology, epidemiology, mechanistic, and biomonitoring data related to claims of a causal association between exposure to glyphosate-based herbicides and Non-Hodgkin's Lymphoma.

Industrial Client: Performed an evaluation of occupational exposure and toxicity information for trichloroethylene to provide support in responding to US EPA's request for information under the 2016 Toxic Substances Control Act (TSCA).

Confidential Client: In support of toxic tort litigation, reviewed toxicology, epidemiology, and exposure information related to claims of causal associations between exposure to diesel exhaust, diesel fuel, silica, asbestos, and cancer endpoints (e.g., lung cancer, colon cancer, and hematological cancers).

Consumer Product Company: Assessed toxicity and human health risk related to potential leaching of chemicals (i.e., nitrosamines) into a household appliance and into consumer tap water.

Consumer Product Company: Assessed toxicity and human health risk related to potential leaching of chemicals from a medical device.

Trade Association: Assessed the current state of the science on neurotoxicity from exposure to manganese in welding fumes and proposed a manganese occupational exposure limit for welders.

Consumer Product Company: Assessed toxicity and human health risk information related to exposure to mold and bacterial species identified in a children's toy product.

Trade Association: Performed in-depth evaluation of naphthalene toxicity and exposure data available in US EPA's ToxCast and ExpoCast programs in comparison to toxicity information from *in vivo* toxicity studies and ambient naphthalene exposure information.

Industrial Client: Performed an evaluation of occupational exposure and toxicity information for carbon tetrachloride, methylene chloride, and perchloroethylene to provide support in responding to US EPA's request for information under the 2016 Toxic Substances Control Act (TSCA).

Industrial Client: In support of toxic tort litigation, performed in-depth toxicological and risk evaluation for hexavalent chromium exposure for stainless steel welders.

Confidential Client: In support of toxic tort litigation, reviewed exposure information and medical records related to a claim of a causal association between inhalation exposure to naphthalene in mothballs and hemolytic anemia for the Plaintiffs.

Insurance Company: In support of toxic tort litigation, reviewed exposure information and medical records related to a claim of a causal association between formaldehyde inhalation exposure and acute myeloid leukemia.

Industrial Clients: In support of toxic tort litigation, assessed the current state of science on manganese neurotoxicity and human health, from exposure to manganese in air and soil, for workers and the general population.

Industrial Client: In support of toxic tort litigation, assessed the weight of epidemiological and toxicological evidence regarding the association between nitrosamine/amide inhalation and brain cancer.

Consumer Product Company: In support of toxic tort litigation, assessed the weight of epidemiological evidence regarding a causal association between inhalation exposures to trichloroethylene and perchloroethylene and cancer and non-cancer health effects.

Industrial Client: In support of toxic tort litigation, performed an extensive review of the mode-of-action data for asbestos and the epidemiology literature on vehicle brake repair and lung cancer and mesothelioma to assess whether there is a causal association.

Industrial Client: In support of toxic tort litigation, evaluated human health risk from exposure to chlorinated volatiles, including trichloroethylene and perchloroethylene, in groundwater *via* drinking water and showering.

Trade Association: Performed in-depth analysis of trichloroethylene and tetrachloroethylene toxicology and mechanistic data to evaluate whether the weight of the evidence supports the plausibility of trichloroethylene and tetrachloroethylene as a human renal carcinogen.

Trade Association: Performed in-depth analysis of methyl methacrylate toxicology and mechanistic data to evaluate the weight of evidence and propose an occupational exposure level.

Trade Association: Through Toxicology Excellence for Risk Assessment (TERA), participated in a peer review process of our proposed manganese reference concentration (RfC) (Bailey *et al.*, 2009), which resulted in the values being posted on the National Library of Medicine's National Institute of Health TOXNET compilation of databases as an ITER (International Toxicity Estimates for Risk Assessment) value for manganese dioxide.

Industrial Client(s): For several industrial clients, reviewed current status of manganese inhalation toxicity criteria (reference concentration [RfC], American Conference of Governmental Industrial Hygienists Threshold Limit Value [ACGIH TLV]), and current manganese inhalation toxicity literature, in support of regulatory comment/communication and public communication regarding potential health effects from both occupational and residential exposure to manganese in air.

Trade Association: Performed in-depth analysis of methanol toxicology and mechanistic data to evaluate whether the weight of evidence supports the plausibility that methanol exposure is associated with human lymphoma.

Trade Association: Performed in-depth analysis of naphthalene toxicology and mechanistic data to evaluate whether the weight of evidence supports the plausibility of naphthalene as a human carcinogen.

Trade Association: Performed in-depth analysis of formaldehyde toxicology and mechanistic data to evaluate whether the weight of the evidence supports the plausibility of formaldehyde as a human leukemogen.

Chemical Company: Provided comments on US EPA's 2009 trichloroethylene draft reassessment, focusing on the use of novel methods for reference concentration (RfC) and reference dose (RfD) determination, such as US EPA's use of physiologically based pharmacokinetic (PBPK) modeling.

Industrial Client: Reviewed toxicity data and various agency derivations of perchlorate toxicity criteria.

Pharmaceutical Company: Performed in-depth analysis of the toxicology data of a specific drug to determine whether the company could have anticipated potential adverse side effects in humans.

Confidential Client: Performed literature review of health effects from inhalation of mercury vapor, focusing on reversibility and latency of effects.

Medical Device Manufacturing Company: Participated in evaluation of potential for adverse side effects from residual contamination on medical implant device.

Industrial Company: Reviewed current status of US EPA's manganese inhalation toxicity value, and current manganese inhalation toxicity literature, in support of litigation regarding claims of elevated manganese air concentrations.

Industrial Client: Managed a Superfund risk assessment for US EPA Region I, including a number of chemicals and human exposure pathways for children and adults: direct contact with sediment and soil, direct contact with surface water and groundwater, ingestion of fish, inhalation of indoor air and trench vapor, and inhalation of asbestos in resuspended sediment and soil. This risk assessment required application of US EPA's "Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens" for carcinogenic polycyclic aromatic hydrocarbons (PAHs) in all media.

Industrial Client: Performed a human health Superfund risk assessment for residential exposure to chlorinated volatile organic compounds (VOCs) and metals in drinking water and indoor air, and from potential exposure to metals in sediment and surface water. Part of the project involved participating in public meetings to address concerned citizen groups.

Industrial Client: Performed a risk assessment for the state of Connecticut, for potential residential risk from lead in sediment and blue crab. The risk assessment involved use of the Integrated Exposure Uptake Biokinetic (IEUBK) Model for lead and the Adult Lead Model.

Municipal Facility: Helped design a sampling plan and performed a risk evaluation for an asbestos site that was developed into an urban park. This project was carried out in conjunction with the Massachusetts Department of Environmental Protection (MassDEP), and was used as a model for development of the Draft MassDEP Asbestos in Soil Regulations.

## **Awards and Honors**

Best Overall Abstract Award, "Evaluation of US EPA's Proposed Rule for the Occupational use of Carbon Tetrachloride and Proposal for a Revised Occupational Exposure Value," Risk Assessment Specialty Section (RASS), Society of Toxicology (SOT) 64th Annual Meeting and ToxExpo, 2025

Best Abstract Award, "Hypothesis-Based Weight-of-Evidence Evaluation and Risk Assessment for Naphthalene Carcinogenesis," Risk Assessment Specialty Section (RASS), Society of Toxicology (SOT) 54<sup>th</sup> Annual Meeting and ToxExpo, 2015

One of the Top Ten Abstracts, "Health-Protective Manganese Guideline for Welding and Other Occupations," Risk Assessment Specialty Section (RASS), Society of Toxicology (SOT) 53<sup>rd</sup> Annual Meeting and ToxExpo, 2014

One of the Best Published Papers, "Hypothesis-Based Weight-of-evidence Evaluation of Methyl Methacrylate Olfactory Effects in Humans and Derivation of an Occupational Exposure Level," Risk Assessment Specialty Section (RASS), Society of Toxicology (SOT), 2013

One of the Top Ten Best Published Papers, "Hypothesis-Based Weight-of-Evidence Evaluation of Methanol as a Human Carcinogen," Risk Assessment Specialty Section (RASS), Society of Toxicology (SOT), 2012

DNA Damage and Repair NASA Conference Travel Award, Antalya, Turkey, 1997

Mutagenesis Gordon Conference Travel Award, Plymouth, NH, 1996.

## Publications and Book Chapters

Bailey, L; Marchitti, S. 2024 (Spring). "Evolving chemical risk evaluation and management under the Toxic Substances Control Act: Trichloroethylene as an example." *Gradient Trends* 90.

Mayfield, DB; Bailey, LA; Cohen, JM; Beck, BD. 2022. "Properties and effects of metals." In *Principles of Toxicology: Environmental and Industrial Applications (Fourth Edition)*. (Eds.: Roberts, SM; James, RC; Williams, PL), John Wiley & Sons, Inc., Hoboken, NJ. p357-380.

Bailey LA, Boomhower SR. 2021. "Potential implications of new information concerning manganese Ohio community health effects studies." *Regul. Toxicol. Pharmacol.* doi: 10.1016/j.yrtph.2021.105069.

Langseth, D; Chien, J; Bailey, L. 2021 (Spring). "Opening the Malden River for recreational boating." *Gradient Trends - Risk Science & Application* 81:1-2.

Bailey, L. 2021 (Spring) "Collaborating to promote chemical safety and animal welfare." *Gradient Trends - Risk Science & Application* 81:6.

Bailey, L. 2020 (Fall). "Worker risk evaluations under TSCA: What we know so far." *Gradient Trends - Risk Science & Application* 79:3,7.

Bailey, LA; Rhomberg, LR. 2020. "Incorporating ToxCast™ data into naphthalene human health risk assessment." *Toxicol. In Vitro.* doi: 10.1016/j.tiv.2020.104913.

Bailey, LA; Zu, K; Beck, BD. 2018. "Comment on 'Impact of air manganese on child neurodevelopment in East Liverpool, Ohio' by Haynes *et al.* (2018)." *Neurotoxicology* 68:A1-A2. doi: 10.1016/j.neuro.2018.07.017.

Bailey, LA; Beck, BD. 2017. "Comment on 'Environmental exposure to manganese in air: Associations with tremor and motor function' by Bowler *et al.* (2016)." *Sci. Total Environ.* 595:839-841. doi: 10.1016/j.scitoenv.2017.03.277.

Bailey, LA; Kerper, LE; Goodman, JE. 2017. "Derivation of an occupational exposure level for manganese in welding fumes." *Neurotoxicology* 64:166-176. doi: 10.1016/j.neuro.2017.06.009.

Bailey, L; Nascarella, M; Kerper, L; Rhomberg, L. 2015. "Hypothesis-based weight-of-evidence evaluation and risk assessment for naphthalene carcinogenesis." *Crit. Rev. Toxicol.* 46(1):1-42. doi: 10.3109/10408444.2015.1061477.

Bailey, LA; Kerper, LE; Rhomberg, LR. [Gradient]. 2015. "Naphthalene." In *Hamilton and Hardy's Industrial Toxicology (Sixth Edition)*. (Eds.: Harbison, RD; Bourgeois, MM; Johnson, GT), John Wiley & Sons, Inc., Hoboken, NJ, p663-668.

Goodman, JE; Peterson, MK; Bailey, LA; Kerper, LE; Dodge, DG. 2014. "Electricians' chrysotile asbestos exposure from electrical products and risks of mesothelioma and lung cancer." *Regul. Toxicol. Pharmacol.* 68(1):8-15.

Pemberton, M; Bailey, LA; Rhomberg, LR. 2013. "Hypothesis-based weight-of-evidence evaluation of methyl methacrylate olfactory effects in humans and derivation of an occupational exposure level." *Regul. Toxicol. Pharmacol.* 66:217-233.

Goodman, JE; Prueitt, RL; Sax, SN; Bailey, LA; Rhomberg, LR. 2013. "Evaluation of the causal framework used for setting National Ambient Air Quality Standards." *Crit. Rev. Toxicol.* 43(10):829-849.

Rhomberg, LR; Goodman, JE; Bailey, LA; Prueitt, RL; Beck, NB; Bevan, C; Honeycutt, M; Kaminski, NE; Paoli, G; Pottenger, LH; Scherer, RW; Wise, KC; Becker, RA. 2013. "A survey of frameworks for best practices in weight-of-evidence analyses." *Crit. Rev. Toxicol.* 43(9):753-784.

Mayfield, DB; Lewis, AS; Bailey, LA; Beck, BD. 2015. "Properties and effects of metals." In *Principles of Toxicology: Environmental and Industrial Applications (Third Edition)*. (Eds.: Roberts, SM; James, RC; Williams, PL), John Wiley & Sons, Inc., Hoboken, NJ, p283-307.

Bailey, LA; Prueitt, RL; Rhomberg, LR. 2012. "Hypothesis-based weight-of-evidence evaluation of methanol as a human carcinogen." *Regul. Toxicol. Pharmacol.* 62:278-291.

Rhomberg, LR; Bailey, LA; Goodman, JE; Hamade, A; Mayfield, D. 2011. "Is exposure to formaldehyde in air causally associated with leukemia? - A hypothesis-based weight-of-evidence analysis." *Crit. Rev. Toxicol.* 41(7):555-621.

Prueitt, RL; Goodman, JE; Bailey, LA; Rhomberg, LR. 2011. "Hypothesis-based weight of evidence evaluation of the neurodevelopmental effects of chlorpyrifos." *Crit. Rev. Toxicol.* 42(10):822-903.

Rhomberg, LR; Bailey, LA; Goodman, JE. 2010. "Hypothesis-based weight of evidence – A tool for evaluating and communicating uncertainties and inconsistencies in the large body of evidence in proposing a carcinogenic mode of action – Naphthalene as an example." *Crit. Rev. Toxicol.* 40(8):671-696.

Goodman, JE; Dodge, DG; Bailey, LA. 2010. "A framework for assessing adverse effects in humans with a case study of sulfur dioxide." *Regul. Toxicol. Pharmacol.* 58:308-322.

Bailey, LA; Goodman, JE; Beck BD. 2009. "Proposal for a revised Reference Concentration (RfC) for manganese based on recent epidemiological studies." *Regul. Toxicol. Pharmacol.* 55:330-339.

Baird, SJS; Bailey, EA; Vorhees, DJ. 2007. "Evaluating human risk from exposure to alkylated polycyclic aromatic hydrocarbons in an aquatic system." *Hum. Ecol. Risk Assess.* 13:322-338.

Auerbach, P; Bennett, RAO; Bailey, EA; Krokan, HE; Demple, B. 2005. "Mutagenic specificity of endogenously generated abasic sites in *Saccharomyces cerevisiae* chromosomal DNA." *Proc. Natl. Acad. Sci. USA* 102:17711-17716.

Bailey, L. 2005. "Evaluating risk from asbestos in soil under the MCP." *LSP Assoc. Newsl.* 12(Oct.):7.

Smela, ME; Currier, SS; Bailey, EA; Essigmann, JM. 2001. "The chemistry and biology of aflatoxin B(1): From mutational spectrometry to carcinogenesis." *Carcinogenesis* 22(4):535-545.

Demple, B; Bailey, EA; Bennett, RAO; Masuda, Y; Wong, D; Xu, Y. 1998. *DNA Damage and Repair: Oxygen Radical Effects, Cellular Protection and Biological Consequences*. (Ed.: Dizdaroglu, M), Plenum Press, NY.

Bailey, EA; Iyer, RS; Stone, MP; Harris, TM; Essigmann, JM. 1996. "Mutational properties of the primary aflatoxin B1-DNA adduct." *Proc. Natl. Acad. Sci. USA* 93:1535-1539.

Bailey, EA; Iyer, RS; Harris, TM; Essigmann, JM. 1996. "A viral genome containing an unstable aflatoxin B1-N7 Gua adduct situated at a unique site." *Nucleic Acids Res.* 24:2821-2828.

## Poster Presentations

Marchitti, SA; Bailey, LA. 2025. "Evaluation of US EPA's Proposed Rule for the Occupational Use of Carbon Tetrachloride and Proposal for a Revised Occupational Exposure Value." Abstract/Poster #4237/P751. Presented at the Society of Toxicology (SOT) 64<sup>th</sup> Annual Meeting and ToxExpo, Orlando, FL, March 16-20.

**\*\*Best Overall Abstract Award Winner, Risk Assessment Specialty Section**

Zu, K; Bailey, LA; Prueitt, RL; Beck, BD; Seeley, M. 2019. "Comparison of Lung Cancer Risks from Environmental Exposures to Arsenic and from Those Associated with Medical Monitoring Criteria for Smokers." Poster # 2776/P262. Presented at the Society of Toxicology (SOT) 58<sup>th</sup> Annual Meeting, Baltimore, MD, March 10-14.

Bailey, LA. 2019. "Evaluation of the Carcinogenic Mode of Action and Proposal for an Occupational Exposure Limit for Tetrachloroethylene." Poster # 1872/P255. Presented at the Society of Toxicology (SOT) 58<sup>th</sup> Annual Meeting, Baltimore, MD, March 10-14.

Bailey, LA; Rhomberg, LR. 2018. "Incorporating ToxCast Data into Naphthalene Human Health Risk Assessment." Poster # 2858/P381. Presented at the Society of Toxicology (SOT) 57<sup>th</sup> Annual Meeting, San Antonio, TX, March 11-15.

Bailey, LA; Lam, T; Peterson, MK; Beck, BD. 2017. "Does Hexavalent Chromium in Welding Fumes Cause Increased Lung Cancer Risk in Stainless Steel Welders?" Presented at the Society of Toxicology (SOT) 56<sup>th</sup> Annual Meeting, Baltimore, MD, March 12-16.

Bailey, L; Kerper, L; Goodman, J. 2016. "Occupational Exposure Level for Manganese in Welding Fumes Based on the Best Available Science." Presented at the Manganese 2016 Conference, New York, NY, September 25-28.

Bailey, L; Nascarella, M; Kerper, L; Rhomberg, L. 2015. "Hypothesis-based Weight-of-Evidence Evaluation and Risk Assessment for Naphthalene Carcinogenesis." Presented at the Society of Toxicology 54<sup>th</sup> Annual Meeting, San Diego, CA, March 22-26.

Bailey, L; Kerper, L; 2014. "Health-Protective Manganese Guideline for Welding and Other Occupations." Presented at the American Industrial Hygiene Association Fall Meeting, Washington, DC, October 20-21.

Bailey, L; Kerper, L; Beck, B. 2014. "Health-Protective Manganese Guideline for Welding and Other Occupations." Presented at the Society of Toxicology 53<sup>rd</sup> Annual Meeting, Phoenix, AZ, March 23-27.

Pemberton, M; Bailey, LA; Rhomberg, LR. 2013. "Weight-of-Evidence Evaluation of Methyl Methacrylate Olfactory Effects in Humans and Derivation of an Occupational Exposure Level." Presented at the Society of Toxicology 52<sup>nd</sup> Annual Meeting, San Antonio, TX. *Toxicologist* 132(1):473. Abstract No. 2216.

Prueitt, RL; Goodman, JE; Bailey, LA; Rhomberg, LR. 2012. "Hypothesis-Based Weight-of-Evidence Evaluation of the Neurodevelopmental Effects of Chlorpyrifos." Presented at the Society of Toxicology 51<sup>st</sup> Annual Meeting, San Francisco, CA. *Toxicologist* 126(1):309. Abstract No. 1430.

Bailey, LA; Goodman, JE; Beck, BD. 2012. "Revised Reference Concentration for Manganese Oxide Based on Recent Epidemiology and Pharmacokinetic Studies." Presented at the Society of Toxicology 51<sup>st</sup> Annual Meeting, San Francisco, CA, March. *Toxicologist* 126(1):213. Abstract No. 995.

Bailey, LA; Goodman, JE; Rhomberg, LR. 2011. "Hypothesis-based Weight-of-Evidence Evaluation of Naphthalene: Carcinogenic Hazard Assessment and Mode of Action." Presented at the Society of Environmental Toxicology and Chemistry (SETAC) North America 32<sup>nd</sup> Annual Meeting, Boston, MA, November 14, 1p.

Bailey, L; Hamade, AK; Rhomberg, LR. 2011. "Weight-of-Evidence Evaluation of a Plausible Mode of Action for Leukemogenesis from Inhalation Exposure to Formaldehyde." Presented at the Society of Toxicology 50<sup>th</sup> Annual Meeting, Washington, DC. *Toxicologist - Supplement to Toxicological Sciences* 120(Suppl. 2):417.

Peterson, MK; Bailey, L; Dodge, DG; Goodman, JE; Valberg, PA. 2011. "A weight-of-evidence evaluation of asbestos exposure and mesothelioma risk among electricians." *Toxicologist - Supplement to Toxicological Sciences* 120(Suppl. 2):414.

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## **Appendix B**

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### **Testimony Experience of Lisa A. Bailey, Ph.D.**

**Lisa A. Bailey, Ph.D.**

Last 4 Years of Expert Testimony Experience

Dr. Bailey has provided expert testimony as follows:

1. Steven Halvorsen *vs.* Union Pacific Railroad Company regarding a claim of causal association between occupational exposure to diesel exhaust, benzene, and herbicides and chronic lymphocytic leukemia. For defendant. Deposition on March 12, 2021.
2. Earl Neal *et al.* *vs.* Monsanto Company and Nathaniel Evans *vs.* Monsanto Company regarding claims of causal association between exposure to glyphosate-based herbicides and Non-Hodgkin Lymphoma. For defendant. Deposition on February 18, 2022.
3. Charles E. Adams, *et al.* *vs.* Adient US LLC regarding claims of exposure and health risks from TCE in indoor air and drinking water. For defendant. Deposition on September 10, 2024.
4. Charles A. Boggs *vs.* BP Exploration and Production, Inc. and BP America Production Company related to the Deepwater Horizon spill and claims of respiratory health effects from exposure to particulate matter and benzene in ambient air. For defendant. October 2, 2024.

# Appendix C

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## Materials Considered

# Appendix D

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## Plaintiff Risk Calculations

Table D.1 Risk Calculations for the Baseline Daily Drinking Water and Shower Exposures for Jacqueline Tukes

| Exposure Scenario                                        | Exposure Point                | Exposure Medium | Exposure Route | Analyte                     | Daily Exposure Dose (DED) or Concentration (DEC) |                   | Lifetime Average Daily Dose (LADD) or Exposure (LADE) <sup>a</sup> |                   | Toxicity Reference Value |                                    | Excess Lifetime Cancer Risk <sup>a</sup> | Point of Departure (POD) |                   | Margin of Exposure <sup>b</sup> | Exposure Exceeds POD? (Y/N) |
|----------------------------------------------------------|-------------------------------|-----------------|----------------|-----------------------------|--------------------------------------------------|-------------------|--------------------------------------------------------------------|-------------------|--------------------------|------------------------------------|------------------------------------------|--------------------------|-------------------|---------------------------------|-----------------------------|
|                                                          |                               |                 |                |                             | Value                                            | Units             | Value                                                              | Units             | Value                    | Units                              |                                          | Value                    | Units             |                                 |                             |
| Central Tendency Exposure (CTE)                          |                               |                 |                |                             |                                                  |                   |                                                                    |                   |                          |                                    |                                          |                          |                   |                                 |                             |
| CTE                                                      | Hadnot Point                  | Drinking water  | Ingestion      | Benzene                     | 4.9E-05                                          | mg/kg-day         | 3.5E-07                                                            | mg/kg-day         | 5.5E-02                  | (mg/kg-day) <sup>-1</sup>          | 1.9E-08                                  | 5.5E-02                  | mg/kg-day         | 1.6E+05                         | N                           |
|                                                          |                               |                 |                | trans -1,2-Dichloroethylene | NA                                               | NA                | NA                                                                 | NA                | NA                       | NA                                 | NA                                       | NA                       | NA                | NA                              |                             |
|                                                          |                               |                 |                | Tetrachloroethylene         | NA                                               | NA                | NA                                                                 | NA                | 2.1E-03                  | (mg/kg-day) <sup>-1</sup>          | NA                                       | 5.0E+01                  | mg/kg-day         | NA                              | NA                          |
|                                                          |                               |                 |                | Trichloroethylene           | NA                                               | NA                | NA                                                                 | NA                | 9.3E-03                  | (mg/kg-day) <sup>-1</sup>          | NA                                       | 1.1E+00                  | mg/kg-day         | NA                              | NA                          |
|                                                          |                               |                 |                | Vinyl Chloride              | NA                                               | NA                | NA                                                                 | NA                | 7.2E-01                  | (mg/kg-day) <sup>-1</sup>          | NA                                       | 1.3E-01                  | mg/kg-day         | NA                              | NA                          |
| Total for Hadnot Point Ingestion (CTE):                  |                               |                 |                |                             |                                                  |                   |                                                                    |                   |                          |                                    | 2E-08                                    |                          |                   |                                 |                             |
| CTE                                                      | Hadnot Point                  | Shower water    | Dermal         | Benzene                     | 1.6E-05                                          | mg/kg-day         | 3.8E-08                                                            | mg/kg-day         | 5.5E-02                  | (mg/kg-day) <sup>-1</sup>          | 2.1E-09                                  | 5.5E-02                  | mg/kg-day         | 1.5E+06                         | N                           |
|                                                          |                               |                 |                | trans -1,2-Dichloroethylene | NA                                               | NA                | NA                                                                 | NA                | NA                       | NA                                 | NA                                       | NA                       | NA                | NA                              | NA                          |
|                                                          |                               |                 |                | Tetrachloroethylene         | NA                                               | NA                | NA                                                                 | NA                | 2.1E-03                  | (mg/kg-day) <sup>-1</sup>          | NA                                       | 5.0E+01                  | mg/kg-day         | NA                              | NA                          |
|                                                          |                               |                 |                | Trichloroethylene           | NA                                               | NA                | NA                                                                 | NA                | 9.3E-03                  | (mg/kg-day) <sup>-1</sup>          | NA                                       | 1.1E+00                  | mg/kg-day         | NA                              | NA                          |
|                                                          |                               |                 |                | Vinyl Chloride              | NA                                               | NA                | NA                                                                 | NA                | 7.2E-01                  | (mg/kg-day) <sup>-1</sup>          | NA                                       | 1.3E-01                  | mg/kg-day         | NA                              | NA                          |
| Total for Hadnot Point Dermal (CTE):                     |                               |                 |                |                             |                                                  |                   |                                                                    |                   |                          |                                    | 2E-09                                    |                          |                   |                                 |                             |
| CTE                                                      | Hadnot Point                  | Indoor air      | Inhalation     | Benzene                     | 4.6E+00                                          | µg/m <sup>3</sup> | 1.1E-02                                                            | µg/m <sup>3</sup> | 7.8E-06                  | (µg/m <sup>3</sup> ) <sup>-1</sup> | 8.4E-08                                  | 3.8E+02                  | µg/m <sup>3</sup> | 3.5E+04                         | N                           |
|                                                          |                               |                 |                | trans -1,2-Dichloroethylene | NA                                               | NA                | NA                                                                 | NA                | NA                       | NA                                 | NA                                       | NA                       | NA                | NA                              | NA                          |
|                                                          |                               |                 |                | Tetrachloroethylene         | NA                                               | NA                | NA                                                                 | NA                | 2.6E-07                  | (µg/m <sup>3</sup> ) <sup>-1</sup> | NA                                       | 4.0E+05                  | µg/m <sup>3</sup> | NA                              | NA                          |
|                                                          |                               |                 |                | Trichloroethylene           | NA                                               | NA                | NA                                                                 | NA                | 1.0E-06                  | (µg/m <sup>3</sup> ) <sup>-1</sup> | NA                                       | 9.8E+03                  | µg/m <sup>3</sup> | NA                              | NA                          |
|                                                          |                               |                 |                | Vinyl Chloride              | NA                                               | NA                | NA                                                                 | NA                | 4.4E-06                  | (µg/m <sup>3</sup> ) <sup>-1</sup> | NA                                       | 2.3E+04                  | µg/m <sup>3</sup> | NA                              | NA                          |
| Total for Hadnot Point Inhalation (CTE):                 |                               |                 |                |                             |                                                  |                   |                                                                    |                   |                          |                                    | 8E-08                                    |                          |                   |                                 |                             |
| CTE                                                      | Tarawa Terrace + Hadnot Point | Drinking water  | Ingestion      | Benzene                     | 5.9E-06                                          | mg/kg-day         | 9.8E-08                                                            | mg/kg-day         | 5.5E-02                  | (mg/kg-day) <sup>-1</sup>          | 5.4E-09                                  | 5.5E-02                  | mg/kg-day         | 5.6E+05                         | N                           |
|                                                          |                               |                 |                | trans -1,2-Dichloroethylene | 1.8E-05                                          | mg/kg-day         | 3.1E-07                                                            | mg/kg-day         | NA                       | NA                                 | NA                                       | NA                       | NA                | NA                              | NA                          |
|                                                          |                               |                 |                | Tetrachloroethylene         | 8.5E-05                                          | mg/kg-day         | 1.4E-06                                                            | mg/kg-day         | 2.1E-03                  | (mg/kg-day) <sup>-1</sup>          | 3.0E-09                                  | 5.0E+01                  | mg/kg-day         | 3.5E+07                         | N                           |
|                                                          |                               |                 |                | Trichloroethylene           | 4.3E-06                                          | mg/kg-day         | 7.2E-08                                                            | mg/kg-day         | 9.3E-03                  | (mg/kg-day) <sup>-1</sup>          | 6.7E-10                                  | 1.1E+00                  | mg/kg-day         | 1.5E+07                         | N                           |
|                                                          |                               |                 |                | Vinyl Chloride              | 1.3E-05                                          | mg/kg-day         | 2.2E-07                                                            | mg/kg-day         | 7.2E-01                  | (mg/kg-day) <sup>-1</sup>          | 1.6E-07                                  | 1.3E-01                  | mg/kg-day         | 6.0E+05                         | N                           |
| Total for Tarawa Terrace + Hadnot Point Ingestion (CTE): |                               |                 |                |                             |                                                  |                   |                                                                    |                   |                          |                                    | 2E-07                                    |                          |                   |                                 |                             |
| CTE                                                      | Tarawa Terrace                | Shower water    | Dermal         | Benzene                     | NA                                               | NA                | NA                                                                 | NA                | 5.5E-02                  | (mg/kg-day) <sup>-1</sup>          | NA                                       | 5.5E-02                  | mg/kg-day         | NA                              | NA                          |
|                                                          |                               |                 |                | trans -1,2-Dichloroethylene | 5.8E-06                                          | mg/kg-day         | 9.7E-08                                                            | mg/kg-day         | NA                       | NA                                 | NA                                       | NA                       | NA                | NA                              | NA                          |
|                                                          |                               |                 |                | Tetrachloroethylene         | 1.3E-04                                          | mg/kg-day         | 2.2E-06                                                            | mg/kg-day         | 2.1E-03                  | (mg/kg-day) <sup>-1</sup>          | 4.6E-09                                  | 5.0E+01                  | mg/kg-day         | 2.3E+07                         | N                           |
|                                                          |                               |                 |                | Trichloroethylene           | 1.6E-06                                          | mg/kg-day         | 2.7E-08                                                            | mg/kg-day         | 9.3E-03                  | (mg/kg-day) <sup>-1</sup>          | 2.5E-10                                  | 1.1E+00                  | mg/kg-day         | 4.0E+07                         | N                           |
|                                                          |                               |                 |                | Vinyl Chloride              | 2.3E-06                                          | mg/kg-day         | 3.8E-08                                                            | mg/kg-day         | 7.2E-01                  | (mg/kg-day) <sup>-1</sup>          | 2.8E-08                                  | 1.3E-01                  | mg/kg-day         | 3.5E+06                         | N                           |
| Total for Tarawa Terrace Dermal (CTE):                   |                               |                 |                |                             |                                                  |                   |                                                                    |                   |                          |                                    | 3E-08                                    |                          |                   |                                 |                             |
| CTE                                                      | Tarawa Terrace                | Indoor air      | Inhalation     | Benzene                     | NA                                               | NA                | NA                                                                 | NA                | 7.8E-06                  | (µg/m <sup>3</sup> ) <sup>-1</sup> | NA                                       | 3.8E+02                  | µg/m <sup>3</sup> | NA                              | NA                          |
|                                                          |                               |                 |                | trans -1,2-Dichloroethylene | 2.2E+00                                          | µg/m <sup>3</sup> | 3.7E-02                                                            | µg/m <sup>3</sup> | NA                       | NA                                 | NA                                       | NA                       | NA                | NA                              | NA                          |
|                                                          |                               |                 |                | Tetrachloroethylene         | 9.1E+00                                          | µg/m <sup>3</sup> | 1.5E-01                                                            | µg/m <sup>3</sup> | 2.6E-07                  | (µg/m <sup>3</sup> ) <sup>-1</sup> | 3.9E-08                                  | 4.0E+05                  | µg/m <sup>3</sup> | 2.6E+06                         | N                           |
|                                                          |                               |                 |                | Trichloroethylene           | 6.4E-01                                          | µg/m <sup>3</sup> | 1.1E-02                                                            | µg/m <sup>3</sup> | 1.0E-06                  | (µg/m <sup>3</sup> ) <sup>-1</sup> | 1.1E-08                                  | 9.8E+03                  | µg/m <sup>3</sup> | 9.2E+05                         | N                           |
|                                                          |                               |                 |                | Vinyl Chloride              | 1.8E+00                                          | µg/m <sup>3</sup> | 3.0E-02                                                            | µg/m <sup>3</sup> | 4.4E-06                  | (µg/m <sup>3</sup> ) <sup>-1</sup> | 1.3E-07                                  | 2.3E+04                  | µg/m <sup>3</sup> | 7.6E+05                         | N                           |
| Total for Tarawa Terrace Inhalation (CTE):               |                               |                 |                |                             |                                                  |                   |                                                                    |                   |                          |                                    | 2E-07                                    |                          |                   |                                 |                             |

| Exposure Scenario                                        | Exposure Point                | Exposure Medium | Exposure Route | Analyte                     | Daily Exposure Dose (DED) or Concentration (DEC) |                   | Lifetime Average Daily Dose (LADD) or Exposure (LADE) <sup>a</sup> |                   | Toxicity Reference Value |                                    | Excess Lifetime Cancer Risk <sup>a</sup> | Point of Departure (POD) |                   | Margin of Exposure <sup>b</sup> | Exposure Exceeds POD? (Y/N) |
|----------------------------------------------------------|-------------------------------|-----------------|----------------|-----------------------------|--------------------------------------------------|-------------------|--------------------------------------------------------------------|-------------------|--------------------------|------------------------------------|------------------------------------------|--------------------------|-------------------|---------------------------------|-----------------------------|
|                                                          |                               |                 |                |                             | Value                                            | Units             | Value                                                              | Units             | Value                    | Units                              |                                          | Value                    | Units             |                                 |                             |
| Reasonable Maximum Exposure (RME)                        |                               |                 |                |                             |                                                  |                   |                                                                    |                   |                          |                                    |                                          |                          |                   |                                 |                             |
| RME                                                      | Hadnot Point                  | Drinking water  | Ingestion      | Benzene                     | 1.2E-04                                          | mg/kg-day         | 8.6E-07                                                            | mg/kg-day         | 5.5E-02                  | (mg/kg-day) <sup>-1</sup>          | 4.7E-08                                  | 5.5E-02                  | mg/kg-day         | 6.4E+04                         | N                           |
|                                                          |                               |                 |                | trans -1,2-Dichloroethylene | NA                                               | NA                | NA                                                                 | NA                | NA                       | NA                                 | NA                                       | NA                       | NA                |                                 |                             |
|                                                          |                               |                 |                | Tetrachloroethylene         | NA                                               | NA                | NA                                                                 | NA                | 2.1E-03                  | (mg/kg-day) <sup>-1</sup>          | NA                                       | 5.0E+01                  | mg/kg-day         | NA                              | NA                          |
|                                                          |                               |                 |                | Trichloroethylene           | NA                                               | NA                | NA                                                                 | NA                | 9.3E-03                  | (mg/kg-day) <sup>-1</sup>          | NA                                       | 1.1E+00                  | mg/kg-day         | NA                              | NA                          |
|                                                          |                               |                 |                | Vinyl Chloride              | NA                                               | NA                | NA                                                                 | NA                | 7.2E-01                  | (mg/kg-day) <sup>-1</sup>          | NA                                       | 1.3E-01                  | mg/kg-day         | NA                              | NA                          |
| Total for Hadnot Point Ingestion (RME):                  |                               |                 |                |                             |                                                  |                   |                                                                    |                   |                          |                                    | 5E-08                                    |                          |                   |                                 |                             |
| RME                                                      | Hadnot Point                  | Shower water    | Dermal         | Benzene                     | 1.6E-05                                          | mg/kg-day         | 3.8E-08                                                            | mg/kg-day         | 5.5E-02                  | (mg/kg-day) <sup>-1</sup>          | 2.1E-09                                  | 5.5E-02                  | mg/kg-day         | 1.5E+06                         | N                           |
|                                                          |                               |                 |                | trans -1,2-Dichloroethylene | NA                                               | mg/kg-day         | NA                                                                 | mg/kg-day         | NA                       | NA                                 | NA                                       | NA                       | NA                | NA                              | NA                          |
|                                                          |                               |                 |                | Tetrachloroethylene         | NA                                               | mg/kg-day         | NA                                                                 | mg/kg-day         | 2.1E-03                  | (mg/kg-day) <sup>-1</sup>          | NA                                       | 5.0E+01                  | mg/kg-day         | NA                              | NA                          |
|                                                          |                               |                 |                | Trichloroethylene           | NA                                               | mg/kg-day         | NA                                                                 | mg/kg-day         | 9.3E-03                  | (mg/kg-day) <sup>-1</sup>          | NA                                       | 1.1E+00                  | mg/kg-day         | NA                              | NA                          |
|                                                          |                               |                 |                | Vinyl Chloride              | NA                                               | mg/kg-day         | NA                                                                 | mg/kg-day         | 7.2E-01                  | (mg/kg-day) <sup>-1</sup>          | NA                                       | 1.3E-01                  | mg/kg-day         | NA                              | NA                          |
| Total for Hadnot Point Dermal (RME):                     |                               |                 |                |                             |                                                  |                   |                                                                    |                   |                          |                                    | 2E-09                                    |                          |                   |                                 |                             |
| RME                                                      | Hadnot Point                  | Indoor air      | Inhalation     | Benzene                     | 4.6E+00                                          | µg/m <sup>3</sup> | 1.1E-02                                                            | µg/m <sup>3</sup> | 7.8E-06                  | (µg/m <sup>3</sup> ) <sup>-1</sup> | 8.4E-08                                  | 3.8E+02                  | µg/m <sup>3</sup> | 3.5E+04                         | N                           |
|                                                          |                               |                 |                | trans -1,2-Dichloroethylene | NA                                               | NA                | NA                                                                 | NA                | NA                       | NA                                 | NA                                       | NA                       | NA                | NA                              | NA                          |
|                                                          |                               |                 |                | Tetrachloroethylene         | NA                                               | NA                | NA                                                                 | NA                | 2.6E-07                  | (µg/m <sup>3</sup> ) <sup>-1</sup> | NA                                       | 4.0E+05                  | µg/m <sup>3</sup> | NA                              | NA                          |
|                                                          |                               |                 |                | Trichloroethylene           | NA                                               | NA                | NA                                                                 | NA                | 1.0E-06                  | (µg/m <sup>3</sup> ) <sup>-1</sup> | NA                                       | 9.8E+03                  | µg/m <sup>3</sup> | NA                              | NA                          |
|                                                          |                               |                 |                | Vinyl Chloride              | NA                                               | NA                | NA                                                                 | NA                | 4.4E-06                  | (µg/m <sup>3</sup> ) <sup>-1</sup> | NA                                       | 2.3E+04                  | µg/m <sup>3</sup> | NA                              | NA                          |
| Total for Hadnot Point Inhalation (RME):                 |                               |                 |                |                             |                                                  |                   |                                                                    |                   |                          |                                    | 8E-08                                    |                          |                   |                                 |                             |
| RME                                                      | Tarawa Terrace + Hadnot Point | Drinking water  | Ingestion      | Benzene                     | 1.4E-05                                          | mg/kg-day         | 2.4E-07                                                            | mg/kg-day         | 5.5E-02                  | (mg/kg-day) <sup>-1</sup>          | 1.3E-08                                  | 5.5E-02                  | mg/kg-day         | 2.3E+05                         | N                           |
|                                                          |                               |                 |                | trans -1,2-Dichloroethylene | 4.6E-05                                          | mg/kg-day         | 7.6E-07                                                            | mg/kg-day         | NA                       | NA                                 | NA                                       | NA                       | NA                | NA                              | NA                          |
|                                                          |                               |                 |                | Tetrachloroethylene         | 2.1E-04                                          | mg/kg-day         | 3.5E-06                                                            | mg/kg-day         | 2.1E-03                  | (mg/kg-day) <sup>-1</sup>          | 7.4E-09                                  | 5.0E+01                  | mg/kg-day         | 1.4E+07                         | N                           |
|                                                          |                               |                 |                | Trichloroethylene           | 1.1E-05                                          | mg/kg-day         | 1.8E-07                                                            | mg/kg-day         | 9.3E-03                  | (mg/kg-day) <sup>-1</sup>          | 1.6E-09                                  | 1.1E+00                  | mg/kg-day         | 6.1E+06                         | N                           |
|                                                          |                               |                 |                | Vinyl Chloride              | 3.2E-05                                          | mg/kg-day         | 5.3E-07                                                            | mg/kg-day         | 7.2E-01                  | (mg/kg-day) <sup>-1</sup>          | 3.8E-07                                  | 1.3E-01                  | mg/kg-day         | 2.5E+05                         | N                           |
| Total for Tarawa Terrace + Hadnot Point Ingestion (RME): |                               |                 |                |                             |                                                  |                   |                                                                    |                   |                          |                                    | 4E-07                                    |                          |                   |                                 |                             |
| RME                                                      | Tarawa Terrace                | Shower water    | Dermal         | Benzene                     | NA                                               | NA                | NA                                                                 | NA                | 5.5E-02                  | (mg/kg-day) <sup>-1</sup>          | NA                                       | 5.5E-02                  | mg/kg-day         | NA                              | NA                          |
|                                                          |                               |                 |                | trans -1,2-Dichloroethylene | 5.8E-06                                          | mg/kg-day         | 9.7E-08                                                            | mg/kg-day         | NA                       | NA                                 | NA                                       | NA                       | NA                | NA                              | NA                          |
|                                                          |                               |                 |                | Tetrachloroethylene         | 1.3E-04                                          | mg/kg-day         | 2.2E-06                                                            | mg/kg-day         | 2.1E-03                  | (mg/kg-day) <sup>-1</sup>          | 4.6E-09                                  | 5.0E+01                  | mg/kg-day         | 2.3E+07                         | N                           |
|                                                          |                               |                 |                | Trichloroethylene           | 1.6E-06                                          | mg/kg-day         | 2.7E-08                                                            | mg/kg-day         | 9.3E-03                  | (mg/kg-day) <sup>-1</sup>          | 2.5E-10                                  | 1.1E+00                  | mg/kg-day         | 4.0E+07                         | N                           |
|                                                          |                               |                 |                | Vinyl Chloride              | 2.3E-06                                          | mg/kg-day         | 3.8E-08                                                            | mg/kg-day         | 7.2E-01                  | (mg/kg-day) <sup>-1</sup>          | 2.8E-08                                  | 1.3E-01                  | mg/kg-day         | 3.5E+06                         | N                           |
| Total for Tarawa Terrace Dermal (RME):                   |                               |                 |                |                             |                                                  |                   |                                                                    |                   |                          |                                    | 3E-08                                    |                          |                   |                                 |                             |

| Exposure Scenario                          | Exposure Point | Exposure Medium | Exposure Route | Analyte                            | Daily Exposure Dose (DED) or Concentration (DEC) |                   | Lifetime Average Daily Dose (LADD) or Exposure (LADE) <sup>a</sup> |                   | Toxicity Reference Value |                                    | Excess Lifetime Cancer Risk <sup>a</sup> | Point of Departure (POD) |                   | Margin of Exposure <sup>b</sup> | Exposure Exceeds POD? (Y/N) |
|--------------------------------------------|----------------|-----------------|----------------|------------------------------------|--------------------------------------------------|-------------------|--------------------------------------------------------------------|-------------------|--------------------------|------------------------------------|------------------------------------------|--------------------------|-------------------|---------------------------------|-----------------------------|
|                                            |                |                 |                |                                    | Value                                            | Units             | Value                                                              | Units             | Value                    | Units                              |                                          | Value                    | Units             |                                 |                             |
| RME                                        | Tarawa Terrace | Indoor air      | Inhalation     | Benzene                            | NA                                               | NA                | NA                                                                 | NA                | 7.8E-06                  | (µg/m <sup>3</sup> ) <sup>-1</sup> | NA                                       | 3.8E+02                  | µg/m <sup>3</sup> | NA                              | NA                          |
|                                            |                |                 |                | <i>trans</i> -1,2-Dichloroethylene | 2.2E+00                                          | µg/m <sup>3</sup> | 3.7E-02                                                            | µg/m <sup>3</sup> | NA                       | NA                                 | NA                                       | NA                       | NA                | NA                              | NA                          |
|                                            |                |                 |                | Tetrachloroethylene                | 9.1E+00                                          | µg/m <sup>3</sup> | 1.5E-01                                                            | µg/m <sup>3</sup> | 2.6E-07                  | (µg/m <sup>3</sup> ) <sup>-1</sup> | 3.9E-08                                  | 4.0E+05                  | µg/m <sup>3</sup> | 2.6E+06                         | N                           |
|                                            |                |                 |                | Trichloroethylene                  | 6.4E-01                                          | µg/m <sup>3</sup> | 1.1E-02                                                            | µg/m <sup>3</sup> | 1.0E-06                  | (µg/m <sup>3</sup> ) <sup>-1</sup> | 1.1E-08                                  | 9.8E+03                  | µg/m <sup>3</sup> | 9.2E+05                         | N                           |
|                                            |                |                 |                | Vinyl Chloride                     | 1.8E+00                                          | µg/m <sup>3</sup> | 3.0E-02                                                            | µg/m <sup>3</sup> | 4.4E-06                  | (µg/m <sup>3</sup> ) <sup>-1</sup> | 1.3E-07                                  | 2.3E+04                  | µg/m <sup>3</sup> | 7.6E+05                         | N                           |
| Total for Tarawa Terrace Inhalation (RME): |                |                 |                |                                    |                                                  |                   |                                                                    |                   |                          |                                    | 2E-07                                    |                          |                   |                                 |                             |

Notes:

µg/m<sup>3</sup> = Micrograms per Cubic Meter; (µg/m<sup>3</sup>)<sup>-1</sup> = Per Micrograms per Cubic Meter; mg/kg-day = Milligrams per Kilogram Body Weight per Day; (mg/kg-day)<sup>-1</sup> = Per Milligrams per Kilogram Body Weight per Day; N = No; NA = Not Applicable; POD = Point of Departure; Y = Yes.

(a) Lifetime average daily doses (LADDs), lifetime average daily exposures (LADEs), and excess lifetime cancer risks (ELCRs) are calculated using the following equations:

Ingestion:

$$LADD = \frac{DED \times EF \times ED_{Ingest}}{AT}$$

$$ELCR = LADD \times CSF$$

Dermal Contact:

$$LADD = \frac{DED \times EF \times ED_{Shower}}{AT}$$

$$ELCR = LADD \times CSF$$

Inhalation:

$$LADE = \frac{DEC \times EF \times ED_{Shower}}{AT}$$

$$ELCR = LADE \times IUR$$

where:

| Variable                   | Definition                                                         | Units                              | Value             | Source/Notes                        |
|----------------------------|--------------------------------------------------------------------|------------------------------------|-------------------|-------------------------------------|
| LADD                       | Lifetime Average Daily Dose (Oral and Dermal)                      | mg/kg-day                          | Chemical specific | Calculated                          |
| LADE                       | Lifetime Average Daily Exposure (Inhalation)                       | µg/m <sup>3</sup>                  | Chemical specific | Calculated                          |
| DED                        | Daily Exposure Dose                                                | mg/kg-day                          | Chemical specific | LaKind (2025)                       |
| DEC                        | Daily Exposure Concentration                                       | µg/m <sup>3</sup>                  | Chemical specific | LaKind (2025)                       |
| EF                         | Exposure Frequency                                                 | days/year                          | 365               | Assumes daily exposure              |
| ED <sub>Ingest_HP</sub>    | Exposure Duration – Drinking Water from Hadnot Point (HP) Only     | years                              | 0.5               | Time consuming only HP water        |
| ED <sub>Ingest_TT+HP</sub> | Exposure Duration – Drinking Water from Tarawa Terrace (TT) and HP | years                              | 1.2               | Time consuming both TT and HP water |
| ED <sub>Shower_HP</sub>    | Exposure Duration – Shower Exposures While Living at HP            | years                              | 0.2               | Time living in HP                   |
| ED <sub>Shower_TT</sub>    | Exposure Duration – Shower Exposures While Living at TT            | years                              | 1.2               | Time living in TT                   |
| AT                         | Averaging Time                                                     | days                               | 25,550            | 70-year lifetime × 365 days/year    |
| ELCR                       | Excess Lifetime Cancer Risk                                        | unitless                           | Chemical specific | Calculated                          |
| CSF                        | Cancer Slope Factor                                                | (mg/kg-day) <sup>-1</sup>          | Chemical specific | Section 5 of report                 |
| IUR                        | Inhalation Unit Risk                                               | (µg/m <sup>3</sup> ) <sup>-1</sup> | Chemical specific | Section 5 of report                 |

(b) The margins of exposures (MoEs) are calculated by dividing the POD by the LADD or the LADE.

Table D.2 Summary of Risks By Exposure Pathway for Jacqueline Tukes

| Exposure Scenario               | Exposure Point                                                                                  | Analyte                           | Baseline Exposure Pathways       |      |                                       |      |                          |      |                          |      |                                  |      | Total ELCR |                                  |         |
|---------------------------------|-------------------------------------------------------------------------------------------------|-----------------------------------|----------------------------------|------|---------------------------------------|------|--------------------------|------|--------------------------|------|----------------------------------|------|------------|----------------------------------|---------|
|                                 |                                                                                                 |                                   | Ingestion<br>(Drinking Water HP) |      | Ingestion<br>(Drinking Water HP + TT) |      | Dermal<br>(Shower at HP) |      | Dermal<br>(Shower at TT) |      | Inhalation<br>(Indoor Air at HP) |      |            | Inhalation<br>(Indoor Air at TT) |         |
|                                 |                                                                                                 |                                   | ELCR                             | %    | ELCR                                  | %    | ELCR                     | %    | ELCR                     | %    | ELCR                             | %    |            | ELCR                             | %       |
| Central Tendency Exposure (CTE) |                                                                                                 |                                   |                                  |      |                                       |      |                          |      |                          |      |                                  |      |            |                                  |         |
| CTE                             | Drinking Water:<br>June-November 1985 = 100% HP<br>December 1985-January 1987 = 88% TT + 12% HP | Benzene                           | 1.9E-08                          | 100% | 5.4E-09                               | 3%   | 2.1E-09                  | 100% | NA                       | –    | 8.4E-08                          | 100% | NA         | –                                | 1.1E-07 |
|                                 |                                                                                                 | trans -1,2-Dichloroethylene       | NA                               | –    | NA                                    | –    | NA                       | –    | NA                       | –    | NA                               | –    | NA         | –                                | NA      |
|                                 |                                                                                                 | Tetrachloroethylene               | NA                               | –    | 3.0E-09                               | 2%   | NA                       | –    | 4.6E-09                  | 14%  | NA                               | –    | 3.9E-08    | 22%                              | 4.7E-08 |
|                                 | Dermal and Inhalation from Showering:<br>June-July 1985 = HP<br>December 1985-January 1987 = TT | Trichloroethylene                 | NA                               | –    | 6.7E-10                               | 0.4% | NA                       | –    | 2.5E-10                  | 0.8% | NA                               | –    | 1.1E-08    | 6%                               | 1.2E-08 |
|                                 |                                                                                                 | Vinyl Chloride                    | NA                               | –    | 1.6E-07                               | 95%  | NA                       | –    | 2.8E-08                  | 85%  | NA                               | –    | 1.3E-07    | 72%                              | 3.2E-07 |
|                                 |                                                                                                 | Pathway-Specific Total:           | 2E-08                            |      | 2E-07                                 |      | 2E-09                    |      | 3E-08                    |      | 8E-08                            |      | 2E-07      |                                  | 5E-07   |
|                                 |                                                                                                 | Reasonable Maximum Exposure (RME) |                                  |      |                                       |      |                          |      |                          |      |                                  |      |            |                                  |         |
| RME                             | Drinking Water:<br>June-November 1985 = 100% HP<br>December 1985-January 1987 = 88% TT + 12% HP | Benzene                           | 4.7E-08                          | 100% | 1.3E-08                               | 3%   | 2.1E-09                  | 100% | NA                       | –    | 8.4E-08                          | 100% | NA         | –                                | 1.5E-07 |
|                                 |                                                                                                 | trans -1,2-Dichloroethylene       | NA                               | –    | NA                                    | –    | NA                       | –    | NA                       | –    | NA                               | –    | NA         | –                                | NA      |
|                                 |                                                                                                 | Tetrachloroethylene               | NA                               | –    | 7.4E-09                               | 2%   | NA                       | –    | 4.6E-09                  | 14%  | NA                               | –    | 3.9E-08    | 22%                              | 5.1E-08 |
|                                 | Dermal and Inhalation from Showering:<br>June-July 1985 = HP<br>December 1985-January 1987 = TT | Trichloroethylene                 | NA                               | –    | 1.6E-09                               | 0.4% | NA                       | –    | 2.5E-10                  | 0.8% | NA                               | –    | 1.1E-08    | 6%                               | 1.3E-08 |
|                                 |                                                                                                 | Vinyl Chloride                    | NA                               | –    | 3.8E-07                               | 94%  | NA                       | –    | 2.8E-08                  | 85%  | NA                               | –    | 1.3E-07    | 72%                              | 5.4E-07 |
|                                 |                                                                                                 | Pathway-Specific Total:           | 5E-08                            |      | 4E-07                                 |      | 2E-09                    |      | 3E-08                    |      | 8E-08                            |      | 2E-07      |                                  | 8E-07   |

Notes:

ELCR = Excess Lifetime Cancer Risk; HP = Hadnot Point; NA = Not Applicable; TT = Tarawa Terrace

# Appendix E

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## Point of Departure (POD) Derivations for Trichloroethylene (TCE) and Vinyl Chloride

Because the United States Environmental Protection Agency (US EPA) does not present points of departure (PODs) for trichloroethylene (TCE) or vinyl chloride for several endpoints and exposure pathways for which toxicity criteria are available, as described in this appendix, I have estimated the PODs based on the oral and inhalation toxicity criteria for these chemicals and pathways. These PODs are used in the margin of exposure (MoE) calculations discussed in Section 7.

## E.1 Trichloroethylene (TCE)

PODs can be estimated from cancer toxicity criteria based on the fact that the cancer slope factor (CSF) or inhalation unit risk (IUR) values are expressed in terms of a specific risk per milligrams per kilogram body weight per day (*i.e.*,  $[\text{mg/kg-day}]^{-1}$ ) or per micrograms per cubic meter (*i.e.*,  $[\mu\text{g/m}^3]^{-1}$ ), respectively.

For TCE, the PODs that US EPA provides for some of the CSFs and IURs, and that are used to extrapolate to other cancer toxicity criteria, are based on a cancer risk of 1% (*i.e.*, the lower confidence limit of the exposure dose or concentration at an extra risk level of 1% [ $\text{LED}_{01}$  or  $\text{LEC}_{01}$ ]) (US EPA, 2011a). Assuming that the TCE CSFs and IURs for which PODs were not provided would also be equivalent to a 1% cancer risk, the following equations can be used to calculate PODs from those CSFs and IURs.

To estimate PODs ( $\text{LED}_{01}$  values) from CSFs:

$$\text{POD (mg/kg-day)} = 1\% \div \text{CSF } ([\text{mg/kg-day}]^{-1})$$

To estimate PODs ( $\text{LEC}_{01}$  values) from IURs:

$$\text{POD } (\mu\text{g/m}^3) = 1\% \div \text{IUR } ([\mu\text{g/m}^3]^{-1})$$

Tables E.1 and E.2 summarize the PODs for TCE.

**Table E.1 US EPA TCE Oral Cancer Toxicity Values (Cancer Slope Factors [CSFs]) and Points of Departure (PODs)**

| Chemical | Oral CSF <sup>a</sup><br>( $[\text{mg/kg-day}]^{-1}$ ) | POD <sup>a</sup><br>(mg/kg-day) | Cancer Type                                    | Sources          |
|----------|--------------------------------------------------------|---------------------------------|------------------------------------------------|------------------|
| TCE      | $4.6 \times 10^{-2}$                                   | $\text{LED}_{01} = 0.21$        | Renal cell carcinoma, NHL,<br>and liver cancer | US EPA (2011a,b) |
|          | $9.33 \times 10^{-3}$                                  | $\text{LED}_{01} = 1.07^b$      | Renal cell carcinoma                           |                  |
|          | $2.16 \times 10^{-2}$                                  | $\text{LED}_{01} = 0.46^b$      | NHL                                            |                  |
|          | $1.55 \times 10^{-2}$                                  | $\text{LED}_{01} = 0.65^b$      | Liver cancer                                   |                  |

Notes:

$\text{LED}_{01}$  = Lower Confidence Limit of the Exposure Dose at an Extra Risk Level of 1%; mg/kg-day = Milligrams per Kilogram Body Weight per Day;  $(\text{mg/kg-day})^{-1}$  = Per Milligrams per Kilogram Body Weight per Day; NHL = Non-Hodgkin's Lymphoma; TCE = Trichloroethylene; US EPA = United States Environmental Protection Agency.

(a) US EPA (2011b) calculated the oral CSFs for renal cell carcinoma, NHL, and liver cancer individually and the  $\text{LED}_{01}$  for the three cancers combined as described in Section 5 and Table 5.1.

(b) PODs ( $\text{LED}_{01}$  values) for renal cell carcinoma, NHL, and liver cancer are calculated based on the equation described above. For example, for the renal cell carcinoma  $\text{LED}_{01}$ , the calculation is as follows:  $1\% \div 0.00933 (\text{mg/kg-day})^{-1} = 1.07 \text{ mg/kg-day}$ .

**Table E.2 US EPA TCE Inhalation Cancer Toxicity Values (Inhalation Unit Risks [IURs]) and Points of Departure (PODs)**

| Chemical | IUR <sup>a</sup><br>([ $\mu\text{g}/\text{m}^3$ ] <sup>-1</sup> ; [ppm] <sup>-1</sup> )                       | POD <sup>a</sup><br>( $\mu\text{g}/\text{m}^3$ [ppb]) | Cancer Type                                    | Sources                                                                                          |
|----------|---------------------------------------------------------------------------------------------------------------|-------------------------------------------------------|------------------------------------------------|--------------------------------------------------------------------------------------------------|
| TCE      | $4.1 \times 10^{-6}$ ( $\mu\text{g}/\text{m}^3$ ) <sup>-1</sup> ;<br>$2.2 \times 10^{-2}$ (ppm) <sup>-1</sup> | LEC <sub>01</sub> = 2,445 (455)                       | Renal cell carcinoma,<br>NHL, and liver cancer | Charbotel <i>et al.</i> (2006);<br>Raaschou-Nielsen <i>et al.</i><br>(2003);<br>US EPA (2011a,b) |
|          | $1.0 \times 10^{-6}$ ( $\mu\text{g}/\text{m}^3$ ) <sup>-1</sup> ;<br>$5.5 \times 10^{-3}$ (ppm) <sup>-1</sup> | LEC <sub>01</sub> = 9,781 (1,820)                     | Renal cell carcinoma                           |                                                                                                  |
|          | $2.0 \times 10^{-6}$ ( $\mu\text{g}/\text{m}^3$ ) <sup>-1</sup> ;<br>$1.1 \times 10^{-2}$ (ppm) <sup>-1</sup> | LEC <sub>01</sub> = 4,890 <sup>b</sup> (910)          | NHL                                            |                                                                                                  |
|          | $1.0 \times 10^{-6}$ ( $\mu\text{g}/\text{m}^3$ ) <sup>-1</sup> ;<br>$5.5 \times 10^{-3}$ (ppm) <sup>-1</sup> | LEC <sub>01</sub> = 9,781 <sup>b</sup> (1,820)        | Liver cancer                                   |                                                                                                  |

Notes:

$\mu\text{g}/\text{m}^3$  = Microgram per Cubic Meter; ( $\mu\text{g}/\text{m}^3$ )<sup>-1</sup> = Per Microgram per Cubic Meter; LEC<sub>01</sub> = Lower Confidence Limit of the Exposure Concentration at an Extra Risk Level of 1%; ppb = Parts per Billion; ppm = Parts per Million; (ppm)<sup>-1</sup> = Per Parts per Million; NHL = Non-Hodgkin's Lymphoma; TCE = Trichloroethylene; US EPA = United States Environmental Protection Agency.

(a) US EPA (2011b) calculated the individual IURs and the LEC<sub>01</sub> values for renal cell carcinoma, NHL, and liver cancer combined and renal cell carcinoma individually as described in Section 5 and Table 5.2.

(b) PODs (LEC<sub>01</sub> values) for NHL and liver cancer are calculated based on the equation described above. For example, for the NHL LEC<sub>01</sub>, the calculation is as follows:  $1\% \div 0.000002$  ( $\mu\text{g}/\text{m}^3$ )<sup>-1</sup> = 4,890  $\mu\text{g}/\text{m}^3$ . Note that rounding the IURs changes the PODs slightly.

## E.2 Vinyl Chloride

Similar calculations were conducted for vinyl chloride. As described by US EPA (2003), one set of oral and inhalation cancer toxicity criteria for vinyl chloride (that are essentially identical to the other set of toxicity criteria calculated by the agency) are based on a cancer risk of 10% (*i.e.*, the lower confidence limit of the exposure dose or concentration at an extra risk level of 10% [LED<sub>10</sub> or LEC<sub>10</sub>]). Therefore, the following equations can be used to calculate PODs from these CSFs and IURs.

To estimate PODs (LED<sub>10</sub> values) from CSFs:

$$\text{POD (mg/kg-day)} = 10\% \div \text{CSF } ([\text{mg/kg-day}]^{-1})$$

To estimate PODs (LEC<sub>10</sub> values) from IURs:

$$\text{POD } (\mu\text{g}/\text{m}^3) = 10\% \div \text{IUR } ([\mu\text{g}/\text{m}^3]^{-1})$$

Tables E.3 and E.4 summarize the PODs for vinyl chloride.

**Table E.3 US EPA Vinyl Chloride Oral Cancer Toxicity Values (Cancer Slope Factors [CSFs]) and Points of Departure (PODs)**

| Chemical       | Oral CSF <sup>a</sup><br>([mg/kg-day] <sup>-1</sup> ) | POD <sup>b</sup><br>(mg/kg-day) | Cancer Type<br>(Sex/Species)                                                                       | Sources                                            |
|----------------|-------------------------------------------------------|---------------------------------|----------------------------------------------------------------------------------------------------|----------------------------------------------------|
| Vinyl Chloride | <b>Continuous Lifetime Exposure During Adulthood</b>  |                                 |                                                                                                    |                                                    |
|                | 7.2 × 10 <sup>-1</sup> ;<br>7.5 × 10 <sup>-1</sup>    | LED <sub>10</sub> = 0.133       | Liver angiosarcomas,<br>hepatocellular carcinomas,<br>and neoplastic liver nodules<br>(female rat) | Feron <i>et al.</i> (1981);<br>US EPA (2000, 2003) |
|                | <b>Continuous Lifetime Exposure from Birth</b>        |                                 |                                                                                                    |                                                    |
|                | 1.4;<br>1.5                                           | LED <sub>10</sub> = 0.067       | Liver angiosarcomas,<br>hepatocellular carcinomas,<br>and neoplastic liver nodules<br>(female rat) | Feron <i>et al.</i> (1981);<br>US EPA (2000, 2003) |

Notes:

LED<sub>10</sub> = Lower Confidence Limit of the Exposure Dose at an Extra Risk Level of 10%; mg/kg-day = Milligrams per Kilogram Body Weight per Day; (mg/kg-day)<sup>-1</sup> = Per Milligrams per Kilogram Body Weight per Day; US EPA = United States Environmental Protection Agency.

(a) US EPA (2003) calculated the individual oral CSFs as described in Section 5 and Table 5.10.

(b) PODs (LED<sub>10</sub> values) are calculated based on the equation described above. For example, for the continuous lifetime exposure during adulthood LED<sub>10</sub>, the calculation is as follows: 10% ÷ 0.75 (mg/kg-day)<sup>-1</sup> = 0.133 mg/kg-day.

**Table E.4 US EPA Vinyl Chloride Inhalation Cancer Toxicity Values (Inhalation Unit Risks [IURs]) and Points of Departure (PODs)**

| Chemical       | IUR <sup>a</sup><br>([μg/m <sup>3</sup> ] <sup>-1</sup> ) | POD <sup>b</sup><br>(μg/m <sup>3</sup> [ppb]) | Cancer Type<br>(Sex/Species)                                                                 | Sources                                                                              |
|----------------|-----------------------------------------------------------|-----------------------------------------------|----------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| Vinyl Chloride | <b>Continuous Lifetime Exposure During Adulthood</b>      |                                               |                                                                                              |                                                                                      |
|                | 4.4 × 10 <sup>-6</sup>                                    | LEC <sub>10</sub> =<br>22,727 (8,900)         | Liver angiosarcomas,<br>angiomas, hepatomas, and<br>neoplastic liver nodules<br>(female rat) | Popper <i>et al.</i> (1981);<br>Maltoni <i>et al.</i> (1984);<br>US EPA (2000, 2003) |
|                | <b>Continuous Lifetime Exposure from Birth</b>            |                                               |                                                                                              |                                                                                      |
|                | 8.8 × 10 <sup>-6</sup>                                    | LEC <sub>10</sub> =<br>11,364 (4,445)         | Liver angiosarcomas,<br>angiomas, hepatomas, and<br>neoplastic liver nodules<br>(female rat) | Popper <i>et al.</i> (1981);<br>Maltoni <i>et al.</i> (1984);<br>US EPA (2000, 2003) |

Notes:

μg/m<sup>3</sup> = Micrograms per Cubic Meter; (μg/m<sup>3</sup>)<sup>-1</sup> = Per Microgram per Cubic Meter; LEC<sub>10</sub> = Lower Confidence Limit of the Exposure Concentration at an Extra Risk Level of 10%; ppb = Parts per Billion; US EPA = United States Environmental Protection Agency.

(a) US EPA (2003) calculated the individual IURs as described in Section 5 and Table 5.11.

(b) PODs (LEC<sub>10</sub> values) are calculated based on the equation described above. For example, for the continuous lifetime exposure during adulthood LEC<sub>10</sub>, the calculation is as follows: 10% ÷ 0.0000044 (μg/m<sup>3</sup>)<sup>-1</sup> = 22,727 μg/m<sup>3</sup>.

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