HUMAN HEALTH RISK ASSESSMENT: WILDLAND FIRE-FIGHTING CHEMICALS

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March 17, 2003
(with March 24, 2003 revisions)

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1.0 INTRODUCTION

The U.S.D.A. Forest Service uses a variety of chemicals to aid in the suppression of fire in wildlands, including long-term retardants, foams, and water enhancers. The potential human health impacts of the products in use in 1994 were assessed in a programmatic risk assessment prepared at that time. Since then, new products have been qualified or approved, assumptions regarding exposure required updating, and additional information has become available addressing potential effects as well as areas of concern. Some minor revisions and additions to the 1994 risk assessment were prepared since its publication. However, this report represents an integrated re-assessment and complete update of the potential health impacts of the fire-fighting chemicals on the current Qualified Products List of the U.S.D.A. Forest Service (USDA 2002a), and serves as a single replacement for all of these previous human health risk assessments.

This report is organized into 5 major sections. Section 1.0 provides an introduction, background information, and an overview of the analysis approach. Section 2.0 presents the hazard assessment. Section 3.0 provides the exposure assessment. Section 4.0 presents the risk characterization, and Section 5.0 lists the references cited throughout this report.

1.1 BACKGROUND

The information in the following paragraphs was derived from the Forest Service's Wildland Fire Chemicals Systems information sheet on fire-fighting chemical products (USDA 2002b)

- *Long-term retardants* are the red liquids dropped from aircraft, often viewed in media coverage of wildland fire-fighting activities. These products are supplied as either wet or dry concentrates, and are mixed with water before they are dispersed over the target area. When the water is completely evaporated, the remaining chemical residue (primarily the same types of salts found in fertilizers) serves to retard vegetation or other materials from igniting, until it is removed by rain or erosion.

- *Foams* are supplied as liquid concentrates that are mixed with water. They contain foaming agents, which affect how the product clings to surfaces and how quickly the mix water drains out of the foam; and wetting agents, which increase the ability of the drained water to penetrate fuels.

- Fire suppressant *elastomers*, usually provided as liquid concentrates, improve the ability of water to cling to vertical and smooth surfaces.

- Fire suppressant *gels*, usually provided as dry concentrates, also improve the ability of water to cling to vertical and smooth surfaces.

Foams and water enhancers (elastomers and gels) all increase the inherent ability of water to suppress fire, while long-term fire retardants leave a dried residue after the water evaporates that helps to protect the fuel from burning.

Fire-fighting chemicals may be dropped from fixed-wing airplanes ("airtankers") or helicopters, or applied by ground crews from fire engines or using portable equipment; the application methods approved for each product are listed on the current Qualified Products List (USDA 2002a).

1.2 OVERVIEW OF ANALYSIS

The purpose of this assessment is to estimate the risks to the health of workers and the public as a result of the use of fire-fighting chemicals. The chemicals addressed in this risk assessment are as follows:

Long-Term Fire Retardants
- Fire-Trol FTR
- Fire-Trol GTS-R
- Fire-Trol LCA-R
- Fire-Trol LCG-R
- Phos-Chek 259-R
- Phos-Chek D75-R
- Phos-Chek G75-W
- Phos-Chek HV-R
- Phos-Chek LV-R
- Phos-Chek MV-R

Foams
- 3M Light Water FT-1150
- Angus ForExpan S
- Ansul Silv-Ex
- Fire Choke
- Fire-Trol FireFoam 103
- Fire-Trol FireFoam 103B
- Fire-Trol FireFoam 104
- National Foam KnockDown
- Phos-Chek WD 881
- Pyrocap B-136

Water Enhancers
- FireOut ICE (Chemdal Aqua Shield)
- Stockhausen Firecape FP-47

To assess the risk of human health effects from using fire-fighting chemicals, it was necessary to estimate the human exposures that could occur as a result of their application and associated activities, and to estimate the probability and extent of adverse health effects that could occur as a result of those exposures. This risk assessment employs the three principal analytical elements that the National Research Council (1983) described and EPA (1989, 2000) affirmed as necessary for characterizing the potential adverse health effects of human exposures to existing or introduced hazards in the environment: hazard assessment, exposure assessment, and risk characterization.

1.2.1 HAZARD ASSESSMENT

Hazard assessment requires gathering information to determine the toxic properties of each chemical and its dose-response relationship. Human hazard levels are derived primarily from the results of laboratory studies on animals. The goal of the hazard assessment is to identify acceptable doses for noncarcinogens, and identify the cancer potency of potential carcinogens.

In this risk assessment, the toxicity of each product formulation as a whole was assessed, as well as the toxicity of some individual ingredients in the product formulations, according to criteria described in Section 2.3.2.

1.2.2 EXPOSURE ASSESSMENT

Exposure assessment involves estimating doses to persons potentially exposed to the pesticides or fertilizers. In the exposure assessment, dose estimates were made for typical, maximum, and accidental exposures. These exposures are defined as follows:

- *Typical:* Typical exposure reflects the average dose an individual may receive if all exposure conditions are met. Typical exposure assumptions include the average amount of a chemical to which an individual may be exposed in a day, the average number of days worked throughout their fire-fighting career, the average length of time elapsed until showering or changing clothes, and other similar assumptions.

- *Maximum:* Maximum exposure defines the upper bound of credible doses that an individual may receive if all exposure conditions are met. Maximum exposure assumptions include the estimated upper bounds on the amount of a chemical to which an individual may be exposed in a day, the number of days worked throughout their fire-fighting career, the length of time elapsed until showering or changing clothes, and other similar assumptions.

- *Accidental:* The possibility of error exists with all human activities. Therefore, it is possible that during fire-fighting activities, an individual fire-fighter, other worker, or member of the public could be in the path of an aerial drop, resulting in an accidental drench. This accident scenario was evaluated for potential health effects to all individuals.

It is important to note that these exposure scenarios estimate risks from clearly defined types of exposure. If all the assumptions in an exposure scenario are not met, the dose will differ from that estimated here, or may not occur at all.

1.2.3 RISK CHARACTERIZATION

Risk characterization requires comparing the hazard information with the dose estimates to predict the potential for health effects to individuals under the conditions of exposure. The risk characterization also identifies uncertainties (such as data gaps where scientific studies are unavailable) that may affect the magnitude of the estimated risks.

2.0 HAZARD ASSESSMENT

This section presents the results of the hazard assessment—a review of available toxicological information on the potential human health hazards associated with the fire-fighting chemical formulations and individual ingredients used by the Forest Service. Section 2.1 provides background information to familiarize the reader with the terminology and technical information in this hazard assessment. Section 2.2 describes the hazard assessment methodology. Section 2.3 summarizes the toxicity data and identifies the toxicity values used in this risk assessment. Section 2.4 lists hazard assessment data gaps that affect the ability to quantify risks from these products and their ingredients.

2.1 Background Information

Because of the obvious limitations on testing in humans, information on effects in non-human test systems usually provides the basis for an informed judgment as to whether an adverse impact is correlated with a particular exposure. These animal toxicity test results may be supplemented by information on a chemical's effects on humans, such as the results of dermatologic or exposure testing in humans, and occasional studies of low-level dosing of human volunteers by oral or other routes.

Toxicity tests in laboratory animals are designed to identify specific toxic endpoints (effects of concern), such as lethality or cancer, and the doses associated with such effects. Studies vary according to the test species used, the endpoint, test duration, route of administration, and dose levels. The dosing schedule, number of test groups, and number of animals per group also vary from one test to another, but the tests are generally designed to demonstrate whether a causal relationship exists between administered doses and any observed effects.

2.1.1 Duration of Tests

The duration of toxicity tests ranges from single-dose (acute) or short-term (subacute) tests, through longer subchronic studies, to chronic studies that may last up to the lifetime of an animal. Acute toxicity studies involve administering a chemical to each member of a test group, either in a single dose or in a series of doses over a period less than 24 hours. Subacute, subchronic, and chronic studies are used to determine the effects of multiple doses. Subacute toxicity studies involve repeated exposure to a chemical for one month or less. Subchronic toxicity studies generally last from one to three months, and chronic studies last for more than three months.

Acute studies are used primarily to determine doses that are immediately lethal, which results in limited utility in an assessment of long-term or repeated low-level human exposures. Acute and subacute toxicity studies include dermal irritation tests, dermal sensitization tests, eye irritation tests, and inhalation exposure or daily oral dosing of laboratory animals for up to one month to further define effects from limited exposures.

Longer term studies are designed to characterize the dose-response relationship resulting from repeated exposure to a compound. All other things being equal, the greater the duration of the study, the more reliable will be the resulting value for estimating the effects of subchronic or chronic exposures in humans. Adverse effects in laboratory tests may include overt clinical signs of toxicity, reduced food consumption, abnormal body weight change, abnormal clinical hematology or chemistry, or visible or microscopic abnormalities in the tissue of the test organism. Chronic studies in rats or mice that continue for longer periods of time, usually about two years, may also be used to assess the carcinogenic potential of a chemical.

2.1.2 Routes of Exposure

For assessing hazards from the fire-fighting chemicals, the routes of administration in laboratory tests that reflect the likely types of exposures to humans include dermal (applied to the skin), inhalation (through exposure to vapors or aerosol particles), and oral by dietary (in food or water) or gavage (forced into the stomach through tubing). Selection of the route of administration of a particular test material is based on the probable route of human exposure.

2.1.3 Units

A dose is expressed as milligrams of a chemical per kilogram of body weight of the test animal (mg/kg), in parts per million (ppm) in the animal's diet, in milligrams per liter in the water that it drinks, or mg/L or milligrams per cubic meter (mg/m^3) in the air that the animal breathes. In chronic studies, the test substance is generally administered in the diet at specified amounts in parts per million (mg of chemical per kg of food). The known weight of the animal over the test period and its food intake rate are used to convert parts per million in the diet to milligrams of a chemical per kilogram of body weight per day (mg/kg/day) for extrapolation to humans. In most chronic toxicity studies, at least two dosing levels are used, in addition to a zero-dose, or control group. In general, the control group receives only the vehicle (for example, water or saline) used in administering the test material. In a dietary study, the animal’s feed would serve as the vehicle.

2.1.4 Toxicity Endpoints

In acute toxicity studies, the endpoint of interest is often the median lethal dose (LD_{50}), which is the single dose that is calculated to be lethal to 50 percent of the test animals.

For examination of non-lethal, noncarcinogenic endpoints, toxicity testing can be used to estimate threshold exposure levels. The threshold level is the dose level at which a significant proportion of the test animals first exhibit the toxic effect. The threshold dose will vary among tested species and among individuals within species. Examples of toxic effects include pathologic injury to body tissue; a body dysfunction, such as respiratory failure; or another toxic endpoint, such as developmental defects in an embryo. It is not possible to determine threshold dose levels precisely; however, the no-observed-adverse-effect level (NOAEL) indicates the dose at which there is no statistically or biologically significant increase in the frequency or severity of an adverse effect in individuals in an exposed group, when compared with individuals in an appropriate control group. The next higher dose level in the study is the lowest-observed-adverse-effect level (LOAEL), at which adverse effects are observed. The true threshold dose level for the particular animal species in a study lies between the NOAEL and the LOAEL. If a chemical produces effects at the lowest dose tested in a study, the NOAEL must be at some lower dose. If the chemical produces no effects, even at the highest dose tested, the NOAEL is equal to or greater than the highest dose.

Carcinogenicity studies are used to determine the potential for a compound to cause malignant (cancerous) or benign (noncancerous) tumors when administered over an animal's lifetime. Several dose levels are used, with the highest set at the maximum tolerated dose, as established from preliminary studies. A control group is administered the vehicle (the liquid or food with which the test chemical is given) alone. Because tumors may arise in test animals for reasons unrelated to administration of the test compound, statistical analyses are applied to the tumor incidence results to determine the significance of observed results. Amdur et al. (1991) listed four types of responses that have generally been accepted as evidence of compound-induced tumors:

- The presence of types of tumors not seen in controls.
- An increase in the incidence (compared to controls) of the tumor types that also occur in controls.
- The development of tumors earlier than in controls.
- An increased multiplicity of tumors.

Some chemicals that elicit one or more of these responses may not be primary carcinogens (that is, tumor-inducers on their own), but may be enhancers or promoters. However, a carcinogenicity evaluation remains appropriate, because they may contribute to an increase in cancer incidence.

In a carcinogenicity assay, the dose-specific tumor incidence data are used to calculate a cancer slope factor, which represents the probability that a 1-mg/kg/day chronic dose of the agent will result in formation of a tumor, and is expressed as a probability, in units of "per mg/kg/day" or $(mg/kg/day)^{-1}$.

2.2 Hazard Assessment Methodology

The goal of the hazard analysis is to determine toxicity levels for quantification of risk. There are two types of toxicity endpoints: noncarcinogenic effects and carcinogenic effects.

For noncarcinogenic effects, it is generally assumed that there is a threshold level, and that doses lower than this threshold can be tolerated with little potential for adverse health effects. The U.S. EPA has determined threshold doses for many chemicals, and refers to these as reference doses (RfDs). The RfD is an estimate of the highest possible daily dose of a chemical that will pose no appreciable risk of deleterious effects to a human during his or her lifetime. The uncertainty of the estimate usually spans about one order of magnitude. The RfD is calculated using the lowest NOAEL from the species and study most relevant to humans, or the most sensitive species (the species that exhibited the lowest NOAEL overall). This NOAEL is divided by an uncertainty factor (usually 100) consisting of a factor of 10 to allow for the variation of response within the human population and a factor of 10 to allow for extrapolation to humans. Additional uncertainty factors may be applied to account for extrapolation from a shorter term study, overall inadequacy of data, or failure to determine a no-effect level. RfDs are expressed in units of mg/kg/day. EPA lists RfDs in its Integrated Risk Information System, a chemical risk database (EPA 2002). RfDs can also be calculated using EPA's methodology. RfDs are analagous to the acceptable daily intake levels identified by groups such as the World Health Organization.

For compounds that are known, probable, or possible human carcinogens, cancer slope factors that have been calculated by EPA or other appropriate sources are identified for use in this risk assessment.

2.3 Toxicity Data and Estimation of Reference Doses

2.3.1 Formulations

For many chemicals, including the majority of those found in the fire-fighting products and the formulations themselves, long-term study data for estimating chronic RfDs are not available. Layton et al. (1987) developed a methodology for deriving acceptable daily intake levels for noncarcinogenic compounds for which chronic toxicity data are unavailable. This methodology uses acute toxicity data, specifically, LD_{50}s. Acute and chronic toxicity values for many chemicals were correlated to identify a factor that allowed a reasonable estimate of a chronic NOAEL based on an LD_{50}. The LD_{50} is multiplied by this factor, which ranges from 0.00005 to 0.001, to obtain an estimate of the chronic NOAEL. This is the methodology on which the hazard assessment for the fire-fighting product formulations is based, because only acute toxicity data are available for these mixtures. In addition, Layton et al. (1987) summarized research that identified a factor of 5 that distinguished NOAELs in subchronic studies from NOAELs in chronic studies. Because the exposures evaluated in this risk assessment are predicted to occur at most 120 days per year (airtanker base personnel), this additional factor was also used in estimating the RfDs. The estimated NOAEL was then divided by an uncertainty factor of 100, to account for the uncertainty associated with interspecies extrapolation from laboratory animals to humans, and interindividual variation in sensitivity among humans. The estimated RfD was determined as follows:

$$RfD\ (mg/kg/day) = \frac{LD_{50}\ (mg/kg) \times 0.001 \times 5}{100}$$

This calculation was applied to the acute toxicity data for each of the products assessed, to provide an estimate of an acceptable exposure level. The toxicity values and estimated RfDs are summarized in Table 2-1.

2.3.2 Components

In addition to evaluating the risks to workers and members of the public from the wildland fire-fighting product formulations, several individual ingredients in the formulations were targeted for quantification of the risk that they may present. These ingredients meet one or more of the following criteria:

Table 2-1. Toxicity Values and RfDs for Concentrated Formulations

Product	Oral LD50 (mg/kg)	Estimated RfD (mg/kg)
Long-Term Retardants		
Fire-Trol GTS-R	2850	0.14
Fire-Trol 300-F	4063	0.20
Phos-Chek D75-R	3967	0.20
Phos-Chek D75-F	4722	0.24
Phos-Chek 259-R	5050	0.25
Phos-Chek 259-F	3100	0.16
Phos-Chek G75-W	505	0.025
Phos-Chek G75-F	4200	0.21
Phos-Chek HV-R	5050	0.25
Phos-Chek HV-F	5050	0.25
Phos-Chek MV-R	5050	0.25
Phos-Chek MV-F	5050	0.25
Phos-Chek LV-R	5050	0.25
Fire-Trol LCA-R	5050	0.25
Fire-Trol LCA-F	5000	0.25
Fire-Trol LCG-R	5050	0.25
Fire-Trol LCG-F	5000	0.25
Fire-Trol FTR	5050	0.25
Foams		
Ansul Silv-Ex	5050	0.25
Fire-Trol FireFoam 103	5050	0.25
Fire-Trol FireFoam 103B	5050	0.25
Phos-Chek WD 881	5000	0.25
Fire-Trol FireFoam 104	5050	0.25
Angus ForExpan S	4767	0.24
Pyrocap B-136	5050	0.25
Fire Choke	5050	0.25
National Foam KnockDown	5000	0.25
3M Light Water FT-1150	5050	0.25
Elastomers and Gels		
FireOut ICE	5050	0.25
Stockhausen Firecape FP-47	5000	0.25

Note: Toxicity data source is Stillmeadow Laboratories toxicity test results, with the exceptions of Phos-Chek 259F and Phos-Chek G75-F, for which the data source was the product material safety data sheet.

- It is a suspected or known carcinogen by a relevant route of exposure, and a cancer slope factor is available for that exposure route.
- The oral LD_{50} in laboratory animals is less than 500 mg/kg.

- The chemical is listed on the formulation's material safety data sheet as a toxic chemical reportable under SARA Section 313, or as a hazardous chemical reportable under OSHA's Hazard Communication Standard.

There are 21 chemical ingredients in products on the Qualified Products List that meet one or more of the criteria of carcinogenicity, low LD_{50}s, or reportability to EPA and/or OSHA. Many of these chemicals are contained in more than one formulation.

2.4 Data Gaps

The hazard assessment data gaps are as follows:

- No long-term toxicity tests were available for the products as a whole. RfDs were estimated based on acute toxicity data and the methodology described by Layton et al. (1987).

- Dermal penetration rates were unavailable for most of the chemicals. In the absence of dermal absorption data, a rate of 1% per 8 hours was used for inorganic chemicals, and a rate of 10% per 8 hours was used for organic chemicals.

- No toxicity data were available for several individual ingredients. Therefore, risks from these ingredients were not evaluated.

- Cancer slope factors were unavailable for several chemicals that were identified as potential carcinogens. Therefore, cancer risks from these chemicals could not be quantified.

3.0 EXPOSURE ASSESSMENT

3.1 Introduction

This section describes the human populations potentially exposed to fire-fighting chemicals and the scenarios for which doses were estimated. There are two populations potentially at risk—wildland fire-fighters and members of the public. Fire-fighters include airtanker base personnel, helitack crews, smokejumpers, hotshot crews, type 2 firefighters, engine crews, and overhead workers. The public includes individuals who may be near the scene of an application of fire-fighting chemicals, or who live or work at a house or other structure to which fire-fighting chemicals were applied. In this analysis, it was assumed that an adult male weighs 78.1 kg (172 lb), an adult female weighs 65.4 kg (144 lb), and a six-year old child weighs 22.6 kg (49.8 lb) (EPA 1999).

3.2 Exposure and Dose

Two primary conditions are necessary for a human to receive a chemical dose that may result in a toxic effect. First, the chemical must be present in the person's immediate environment—in the air, on a surface such as vegetation that may contact the skin, or in food or water—so that it is available for intake. The amount of the chemical present in the person's immediate environment is the exposure level. Second, the chemical must enter the person's body by some route. Chemicals on vegetation, on clothing that is in contact with the skin, or on the skin itself, may penetrate the skin. Chemicals in food or water may be ingested. The amount of a chemical that moves into the body by any of those routes constitutes the dose. While two people may be subjected to the same level of exposure (for example, two workers walking through vegetation treated with retardant), one may get a much lower dose than the other by wearing protective clothing or washing as soon as possible. Exposure, then, is the amount of a chemical available for intake into the body; dose is the amount of the substance that actually enters the body.

3.3 Potential Exposures

This subsection describes the populations that may be exposed to the fire-fighting chemicals and lists the representative human health exposure scenarios analyzed in this risk assessment.

3.3.1 Affected Populations and Exposure Scenarios

The human population that could be exposed to fire-fighting chemicals falls into two groups. The first group is the workers directly involved in the use of fire retardants, foams, and gels, including airtanker base personnel, firefighters, and workers who enter areas where the chemicals have been applied. The second group is the public who may be subject to nonoccupational exposure.

Airtanker base personnel, helitack crews, smokejumpers, hotshot crews, type 2 firefighters, engine crews, and overhead workers include both male and female workers. Therefore, risks to each were assessed separately, using appropriate body weight and surface area data.

Members of the public may be exposed as a result of cleaning a structure, and may include both adults and children.

The accidental drench of an individual in the path of an aerial drop of retardant, foam, or gel was also evaluated.

3.3.2 Levels of Exposure

To allow for some of the uncertainty inherent in any quantitative risk assessment, two levels of human exposure were evaluated.

Typical Exposures. Typical exposure assumptions attempt to target the average dose an individual may receive if all exposure conditions are met. These assumptions include the average duration of exposure, typical number of days worked per year, and other similar assumptions.

Maximum Exposures. Maximum exposure assumptions attempt to define the upper bound of credible doses that an individual may receive if all exposure conditions are met. These assumptions include an estimate of the maximum duration of exposure, the maximum number of days worked per year, and other similar assumptions.

3.4 Potential Exposures to Workers

The doses to workers were estimated for each type of worker, using the assumptions described below about their activities and exposures.

3.4.1 Airtanker Base Personnel

Airtanker base personnel include both mixmasters and loaders. They unload retardant concentrate when received from suppliers, prepare mixed retardant by blending dry or wet concentrate with water, pump mixed retardant into airtankers, and wash down spills from ramps and storage areas. Protective clothing includes a dust mask, glasses or goggles, ear protection, cotton overalls, and leather or fabric shoes.

Exposures to mixers were assumed to result from both dermal and inhalation exposure to the powdered retardant. For dermal exposure, 100 g of powdered retardant were assumed to disperse over hands and forearms. Of this amount, 95 percent is dislodged, and 1 percent of the remainder dissolves in perspiration and is available for dermal absorption. There are four (typical) or 50 (maximum) mixing events per day. For inhalation exposure, the retardant concentration of 4.43 mg/m^3 that was measured in a monitoring study at airtanker bases (USDA 1979) was assumed to be present in the air at the mixing station. The mixers were assumed to be exposed to this concentration for either a typical mixing shift of two hours or a maximum shift of 10 hours, at an inhalation rate of 2.5 m^3/hour at 10 percent absorption efficiency of the chemicals by the lungs. The concentration of retardant in inhaled air is estimated to be reduced by 90 percent when the mixers use a dust mask.

The loaders were assumed to be exposed to mixed retardant as a result of spills of 0.25 (typical) and 0.5 (maximum) pint of mixture over the hands and forearms each time a loading hose is disconnected. Of this amount, 90 percent drips off or is otherwise removed, and 1 percent of the remainder is available for dermal absorption. There are four (typical) or 55 (maximum) loading events per day.

Both mixers and loaders are assumed to have a 12-year career, working 37 days per year in the typical case and 120 days per year in the maximum case. It is assumed that two (typical) or 10 (maximum) hours elapse until the chemical is washed off thoroughly by showering and changing clothes.

3.4.2 Helitack Crews

Helitack crews arrive at a fire by helicopter and stay on site for the duration of the fire. Protective clothing includes a helmet (hard hat when on the ground), goggles, ear protection, Nomex® fire shirt and pants, leather boots, leather fire gloves, and a fire shelter.

Helitack crew members were assumed to be exposed to fire-fighting chemicals by walking through an area where vegetation has been treated. This scenario assumes that 75% of the front half of the legs' surface area contacts treated vegetation, with a 90% reduction in exposure due to protective clothing. These individuals are assumed to have a seven-year career, with 25 days per year (typical) or 100 days per year (maximum) when they encounter treated vegetation. Two (typical) or four (maximum) hours elapse until the chemical is washed off thoroughly by showering and changing clothes.

3.4.3 Smokejumpers

Smokejumpers parachute into the area of a fire and stay on site for the duration of the fire or until they are replaced with other firefighters. Protective clothing includes a helmet (hard hat when on the ground), goggles, ear protection, Nomex® fire shirt and pants, leather boots, leather fire gloves, and a fire shelter.

Smokejumpers were assumed to be exposed to fire retardants (more likely) or foams or gels (less likely) by walking through an area where vegetation has been treated. The risk assessment assumes that 75 percent of the front half of the legs' surface area contacts treated vegetation, with a 90% reduction in exposure due to protective clothing. Smokejumpers were assumed to have a 10-year career, with seven days per year (typical) or 20 days per year (maximum) when they encounter treated vegetation, and two (typical) or seven (maximum) hours elapse until the chemical is washed off thoroughly by showering and changing clothes.

3.4.4 Hotshot Crews

Hotshot crews are specialized firefighters, the first reinforcements after initial attack. They are used in suppression of large fires, and build and reinforce fire lines. Protective clothing includes a hard hat, eye and ear protection, Nomex® fire shirt and pants, leather boots, leather fire gloves, and a fire shelter.

Hotshot crew members were assumed to receive exposure to the fire-fighting chemicals by walking through an area where vegetation has been treated. The scenario assumes that 75% of the front half of the legs' surface area contacts treated vegetation, with a 90% reduction in exposure due to protective clothing. These individuals are associated with a seven-year career, with 20 days per year (typical) or 40 days per year (maximum) when they encounter treated vegetation, and three (typical) or seven (maximum) hours elapsing until the chemical is washed off thoroughly by showering and changing clothes.

3.4.5 Type 2 Firefighters

Type 2 firefighters act as reinforcements on large fires. They do mop-up and patrol the control lines. Protective clothing includes a hard hat, eye and ear protection, Nomex® fire shirt and pants, leather boots, leather fire gloves, and a fire shelter.

Type 2 firefighters were assumed to be exposed to fire-fighting chemicals (especially foams) by walking through an area where vegetation has been treated, and by mixing and applying gels to structures. The vegetation contact exposure assumes that 75% of the front half of the legs' surface area contacts treated vegetation, with a 90% reduction in exposure due to protective clothing. For gel mixing and application activities, it was assumed that 0.25 (typical) or 0.5 (maximum) pint of mixture spills over hands and forearms each time a load is mixed and applied, 90% of this amount drips off or is otherwise removed, and 1% of the remainder is available for dermal absorption. They are assumed to have an eight-year career, with two days per year (typical) or six days per year (maximum) when they encounter treated vegetation or mix/apply gels. It was assumed that two (typical) or six (maximum) hours elapse until the chemical is washed off thoroughly by showering and changing clothes.

3.4.6 Engine Crews

Engine crews mix foam concentrates with water, and apply foams in support of fire-fighting activities. Protective clothing includes a hard hat, eye and ear protection, Nomex® fire shirt and pants, leather boots, leather fire gloves, and a fire shelter.

Members of engine crews were assumed to be exposed to foams or gels when walking through an area where vegetation has been treated, and by mixing and applying foam or gel. For mixing/application activities, the assessment assumes that 0.25 (typical) and 0.5 (maximum) pint of mixture spills over the hands and forearms each time a load is mixed and applied, 90% of this amount drips off or is otherwise removed, and 1% of the remainder is available for dermal absorption. The vegetation contact scenario assumes that 75% of the front half of the legs' surface area contacts foam- or gel-treated vegetation, with a 90% reduction in exposure due to protective clothing. These workers are assumed to have a seven-year career, with 28 days per year (typical) or 60 days per year (maximum) when they encounter treated vegetation. It is assumed that four (typical) or seven (maximum) hours elapse until the chemical is washed off thoroughly by showering and changing clothes.

3.4.7 Overhead Workers

Overhead workers oversee an assigned portion of the fire operations. They inspect and supervise from the fire line. Protective clothing includes a hard hat, eye and ear protection, Nomex® fire shirt and pants, leather boots, leather fire gloves, and a fire shelter.

Overhead workers were assumed to be exposed to the fire-fighting chemicals when walking through an area where vegetation has been treated. The risk assessment assumes that 75% of the front half of the legs' surface area contacts treated vegetation, with a 90% reduction in exposure due to protective clothing. Overhead workers are assumed to have a 15-year career, with two days per year (typical) and six days per year (maximum) when they encounter treated vegetation. It is further assumed that two (typical) or six (maximum) hours elapse until the chemical is washed off thoroughly by showering and changing clothes.

3.4.8 Rehabilitation Teams

Members of rehabilitation teams could encounter dried chemical residues as they assess fire damage and plan/implement measures to minimize secondary damage to the environment (such as mud slides). Protective clothing includes a hard hat, eye and ear protection, Nomex® fire shirt and pants, leather boots, and leather fire gloves. These workers have an average 10-year career in this job function, with two (typical) or (six) days per year of exposure at two (typical) or six (maximum) hours of exposure per day. Risks to rehabilitation team members were addressed qualitatively.

3.4.9 Lifetime Doses to Workers

The lifetime doses for workers handling potential carcinogens were estimated assuming that 95 percent of the time the worker is exposed to the typical dose for the typical number of days per year, and five percent of the time the worker is exposed to the maximum dose for the maximum number of days per year. Annual doses were multiplied by the estimated career length to indicate cumulative exposure, which was then averaged over the typical 75-year lifetime, based on EPA (1999).

3.5 Potential Exposures to Members of the Public

The doses to members of the public from exposure to fire-fighting chemicals were estimated for one exposure scenario: cleaning a structure. In this analysis, doses from the dermal route of exposure were estimated. The following section describes the parameters used in calculating these doses. Several additional types of potential exposure to members of the public were evaluated qualitatively.

3.5.1 Quantitative Analysis: Cleaning a Structure

This scenario assumes that, while an adult male or female is cleaning a structure to which a retardant, foam, or gel was applied, 0.5 pint of aqueous rinsate (in a dilution the same as the mixture strength) is dispersed over hands and forearms during pressure washing or observation of cleaning activities, 90% drips off or is otherwise removed, 1% of the remainder stays wet, and 0.5% of that amount dissolves in perspiration and is available for dermal absorption. The same level of exposure was assumed to occur for a child observing this activity as his or her own home is cleaned. The exposure duration is one hour.

3.5.2 Qualitative Analyses

Potential public exposures that were addressed qualitatively in the risk discussion include the following:

- Individuals re-entering areas to which retardant, foam, or gel had been applied; this may include individuals such as hunters and ecologists.
- Individuals harvesting mushrooms, morels, berries from wildlands after vegetative regrowth has occurred.
- Individuals consuming vegetables from home gardens.
- Individuals handling pets who re-entered areas to which retardant, foam, or gel had been applied.
- Salvage logging of burned areas, in which an individual has contact for up to four hours per day twice per year for two years.

3.5.3 Lifetime Doses to Members of the Public

Lifetime doses to members of the public were calculated for the potential carcinogens evaluated in this risk assessment. The lifetime dose was estimated by assuming that an individual participates in cleaning a structure once in his or her lifetime. The estimated dose from this activity was averaged over a 75-year lifetime (EPA 1999).

3.6 Potential Exposure from Accidental Drench

In the event of an accidental drench, workers or members of the public may be exposed to greater amounts of a retardant, foam, or gel than under the previously described routine exposure circumstances.

3.6.1 Workers

The accident scenario in which a worker is drenched by an aerial drop of retardant, foam, or gel was assessed by assuming that the application rate of the chemical is received on 50% of the body surface area, with a 90% reduction in exposure due to protective clothing and 1% of the permeating amount available for dermal absorption and two hours elapses until the individual is able to shower and change clothes. The potential frequency of this accident is assumed to be as follows:

- helitack crews: two per year
- smokejumpers: two per year
- hotshot crews: three per year
- type 2 firefighters: one per year
- engine crews: one per year

3.6.2 Members of the Public

The accident scenario in which an adult or child is drenched by an aerial drop of retardant, foam, or gel was also assessed. In this scenario, the application rate of the chemical is received on 50% of the body surface area, with 1% of this amount available for dermal absorption. This event is assumed to occur no more than once in an individual's lifetime.

4.0 RISK CHARACTERIZATION

4.1 Introduction

This section characterizes the estimated risks to the health of workers and members of the public that may result from any of the long-term retardants, foams, or gels on the Forest Service's Qualified Products List. In the risk characterization, the human doses estimated in the exposure assessment (Section 3.0) are compared with the toxicity characteristics described in the hazard assessment (Section 2.0), to arrive at estimates of risk.

Section 4.2 describes the methods used to evaluate human health risks, including both noncarcinogenic and carcinogenic risks. Section 4.3 contains the results of the quantitative risk characterization for the fire-fighting chemical formulations. Section 4.4 addresses risks from individual ingredients in the products. Section 4.5 discusses several additional exposure scenarios that were addressed qualitatively, and Section 4.6 discusses the uncertainties in this risk assessment.

4.2 Methodology for Assessing Risks

All of the products on the Qualified Products List are mixtures of several ingredients. Risks from these mixtures were evaluated following the recommendations of EPA (2000): *Supplementary Guidance for Conducting Health Risk Assessment of Chemical Mixtures*. Specifically, the following approaches were applied:

- EPA states that "whenever possible, the preferred approach to the health risk evaluation of chemical mixtures is to perform the assessment using health effects and exposure data on the whole mixture." To accomplish this, risks were calculated for the formulated products as a whole, using the RfDs that were estimated for each product in Section 2.3.1 and summarized in Table 2-1.

- EPA also stated that "even if a risk assessment can be made using whole-mixture data, it may be desirable to also conduct a risk assessment based on toxicity data on the components in the mixture . . . When a mixture contains component chemicals whose critical effects are of major concern, e.g., cancer or developmental toxicity, an approach based on the mixture data alone may not be sufficiently protective in all cases." This additional analysis was deemed particularly important in the case of the fire-fighting chemicals because only acute toxicity data were available on the products as a mixture. Therefore, each formulation was reviewed for components that meet the criteria presented in Section 2.3.2; 21 chemicals were identified.

The assessment of risks for the products and for the targeted ingredients was conducted following the standard risk assessment methodology described in NRC (1983) and EPA (1989).

4.2.1 Noncarcinogenic Risk Estimation

In this risk assessment, the potential risks were evaluated by comparing the representative doses (estimated in the exposure assessment) with the RfDs (identified in the hazard assessment). All the RfDs used in this risk analysis take into account the possibility of multiple exposures and represent acceptable dose levels. The comparison of dose to RfD consists of a simple ratio, called the Hazard Quotient:

$$Hazard\ Quotient = \frac{Estimated\ Dose\ (mg / kg / day)}{RfD\ (mg / kg / day)}$$

If the estimated dose does not exceed the RfD, the hazard quotient will be one or less, indicating a negligible risk of noncarcinogenic human health effects. It is important to note two characteristics of the hazard quotient: (1) the greater the value of the hazard above one, the greater the level of concern; but (2) the level of concern does not increase linearly as the hazard quotient increases, because RfDs do not have equal accuracy or precision and are not based on the same severity of toxic effects. Thus, the interpretation of the potential toxic response associated with a particular hazard quotient can range widely depending on the chemical (EPA 1989).

A dose estimate that exceeds the RfD, although not necessarily leading to the conclusion that there will be toxic effects, clearly indicates a potential risk for adverse health effects. Risk is presumed to exist if the hazard quotient is greater than one. However, comparing one-time or once-a-year doses (such as those experienced by the public or in an accident) to RfDs that are designed to represent long-term exposures with repeated daily doses tends to exaggerate the risk from those infrequent events.

For workers and the public, hazard quotients were computed for each product and targeted ingredient for typical, maximum, and accident situations. If the hazard quotient exceeds one, the risk may require mitigation, depending on the circumstances of exposure.

Following the guidance presented in EPA (2000), the additive approach was used to sum the hazard quotients when more than one targeted ingredient was identified in a product. In these cases, a hazard index for the product, representing the sum of the hazard quotients, was calculated. The hazard index is interpreted in the same manner as the hazard quotient; that is, risk is presumed to exist if the product hazard index exceeds one.

4.2.2 Cancer Risk Estimation

As a result of the review of cancer studies presented in the Human Health Hazard Assessment (Section 2.0), a risk analysis for cancer was conducted for one of the ingredients in the gel Stockhausen Firecape FP-47. Although additional ingredients in the formulated products were identified as possible carcinogens, no quantitative cancer slope factors were available on which to base cancer risk estimates.

The mechanism for cancer dose-response can be complex, and EPA is currently developing updated guidance for deriving cancer slope factors that are applicable to human health risk assessment from the results of studies in laboratory animals. In laboratory studies, high doses are used to elicit an observable cancer incidence in a finite group of test animals. Historically, carcinogenic effects were assumed to have no threshold, requiring extrapolation to compare exposures from the much lower doses associated with environmental exposure to chemicals. EPA's current guidance in force, the 1986 *Guidelines for Carcinogen Risk Assessmen*t, provided a basic rationale for linear dose-response assumptions in cancer risk assessment (EPA 1986a). However, new perspectives on methods to assess risks of cancer are gaining wider acceptance, such as consideration of mode of action, thresholds for carcinogenicity, and incorporating other types of biological data. In 1996, EPA proposed revised guidelines for carcinogen risk assessment which address these (and other) issues, but they have not yet been finalized. Estimation of cancer slope factors using updated methods is occurring on a chemical-by-chemical basis, as new laboratory studies are completed and new risk assessments are conducted. For the chemical identified as a probable human carcinogen in this risk assessment, a linear (no-threshold) approach was used in calculating the cancer slope factors, in accordance with the guidance that has been in effect.

Cancer risk from a chemical is expressed as the probability that cancer will occur over the course of a person's lifetime, as a result of the stated exposure. This risk probability is calculated as follows:

$$RISK = DOSE \times CSF \times OCC / LIFE$$

where:

RISK	=	the lifetime probability of cancer as a result of the specified exposure
DOSE	=	estimated dose (mg/kg/day)
CSF	=	cancer slope factor (per mg/kg/day)
OCC	=	number of occurrences of the daily dose during an individual's lifetime
LIFE	=	the number of days in a 75-year lifetime (27,375 days)

The resulting cancer probability is compared to a benchmark value of 1×10^{-6} (or 1 in 1 million), a value commonly accepted in the scientific community as representing a cancer risk that would result in a negligible addition to the background cancer risk of approximately one in four in the United States. In some occupational health risk assessments, cancer risks as high as 1×10^{-4} (1 in 10,000) can be considered acceptable. However, the benchmark of 1 in 1 million is used for both workers and the public in this risk assessment.

4.3 Estimated Risks from the Formulations

Tables 4-1 through 4-8 present the formulated products' estimated risks to workers from routine uses. Table 4-9 presents the estimated risks from the products to members of the public cleaning a structure after an application of a fire-fighting product.

The risk tables in this section use scientific notation, since many of the values are very small. For example, the notation 3.63E-001 represents 3.63×10^{-1}, or 0.363. Similarly, 4.65E-009 represents 4.65×10^{-9}, or 0.00000000465.

Boldface type is used in these tables to indicate the risks for which the hazard quotient, hazard index, or cancer risk exceeds the acceptable value, indicating risk in that scenario; that is, the risk value is in boldface type if the hazard index or hazard quotient is greater than 1, of the cancer risk is greater than 1 in 1 million.

4.3.1 Estimated Risks to Workers from the Formulations

For typical exposures, all products resulted in hazard quotients less than one, indicating negligible risk to fire-fighting personnel from the long-term retardants, foams, and water enhancers under typical conditions of exposure.

In the maximum scenarios, hazard quotients for some products exceeded one for airtanker base personnel, as follows:

- male and female mixmasters' exposure to all powder retardants; and
- male and female airtanker base personnel loading Fire-Trol GTS-R, Fire-Trol 300-F, and Phos-Chek G75-W; and for loaders of Phos-Chek 259-F with the body weight of an average U.S. woman (65.4 kg), as illustrated by the representative female worker in this risk assessment.

4.3.2 Estimated Risks to Members of the Public from the Formulations

No risks were predicted for adult and child members of the public cleaning a structure that had been treated with a long-term retardant, foam, or water enhancer.

4.3.3 Estimated Risks from an Accidental Drench

Risks to workers and members of the public from an accidental drench with a fire-fighting product are presented in Table 4-10. Hazard quotients exceeded one for this accidental scenario for adult and child members of the public for the long-term retardant Phos-Chek G75-W.

4.4 Estimated Risks from Components

4.4.1 Estimated Risks to Workers from Components

In the typical scenarios, no risks to airtanker base personnel or firefighters from individual ingredients were identified.

In the maximum scenarios, the following risks were predicted:

- Mixmasters: risks to both males and females from a retardant salt in Fire-Trol GTS-R, Fire-Trol 300-F, Phos-Chek D75-R, Phos-Chek D75-F, Phos-Chek G75-W, and Phos-Chek G75-F; and risks to females (due to lower average body weight) from a corrosion inhibitor in Phos-Chek 259-F. In each case, the hazard index for the product also exceeded one.

- Loaders: risks to both males and females from a retardant salt in Fire-Trol GTS-R and Fire-Trol 300-F. In both cases, the hazard index for the product as a whole also exceeded one. In addition, the hazard index for the product Phos-Chek G75-F exceeded one, even though the individual component's hazard quotients were all less than one for the targeted ingredients.

4.4.2 Estimated Risks to Members of the Public from Components

No risks from the individual targeted ingredients were predicted for members of the public cleaning a structure to which a fire-fighting product had been applied.

4.4.3 Estimated Risks from the Components in an Accidental Drench

Risks to workers and members of the public from individual ingredients in an accidental drench with a fire-fighting product were also evaluated. Hazard quotients from this accidental scenario were less than one, indicating negligible risk, for all workers and members of the public. In this accident scenario, cancer risks were all less than the generally accepted benchmark value of 1 in 1 million for both workers and the public.

4.5 Qualitative Risk Evaluations

4.5.1 Rehabilitation Team Members

Rehabilitation teams may encounter dried retardant, foam, or gel residue as they carry out their job functions. The estimated daily exposure is comparable to that of overhead workers, although the residues would be dried by the time the rehabilitation team enters the area, resulting in a much lower rate of dermal transfer and absorption. No risks were predicted for overhead workers from the formulations as a mixture or individual ingredients in either the typical or maximum scenarios; therefore, no risks are expected for rehabilitation team members.

4.5.2 Re-Entry to Treated Areas

Individuals such as hunters and ecologists are likely to re-enter areas to which retardant, foam, or water enhancer has been applied. These exposures are expected to similar to and no greater than those of rehabilitation team members. Therefore, no significant risks are predicted for this scenario.

4.5.3 Harvesting Wild Vegetation

Individuals may harvest mushrooms, morels, berries from wildlands after vegetative regrowth has occurred, in areas that were treated with retardants, foams, or water enhancers. The dermal exposure from harvesting these edibles is expected to present negligible risk, similar to the exposure of rehabilitation team members, hunters, ecologists, or others who re-enter treated areas.

4.5.4 Ingesting Vegetables or Wild Vegetation

Individuals are advised against consuming vegetables from home gardens to which retardant, foam, or water enhancerl may have been applied during fire-fighting activities, or from areas in wildlands where residues are apparent. In addition to avoiding consumption of food items with visible residues, the fertilizer component of the long-term retardants may lead to temporary increases in the nitrate content of soils in areas of application. Some vegetables are known to concentrate nitrates, particularly cauliflower, beets, spinach, broccoli, collard greens, carrots, turnips, and other root vegetables. Elevated levels of ingested nitrate could pose a risk upon conversion to nitrite, especially to infants who are more susceptible to methemoglobinemia. Methemoglobinemia results in decreased oxygen transport from the lungs to the body's tissues. Infants are more sensitive to nitrite than adults, because the hemoglobin in an infant's blood is more easily changed into methemoglobin, and an infant's digestive system is less acidic, which enhances the conversion of nitrate to nitrite (AAP 1970, ATSDR 2001).

4.5.5 Handling Pets With Exposure to Treated Vegetation

Handling dogs or other domestic animals whose fur contains residues as a result of exposure to vegetation in treated areas is not expected to pose risks to humans any greater than those that would be associated with direct vegetation contact, as evaluated in Section 4.5.2.

4.5.6 Salvage Logging

Salvage logging may take place in burned areas, in which an individual has contact for up to four hours per day twice per year for two years. This daily exposure exceeds the typical duration predicted for most fire-fighters in the typical scenarios, but is bounded by higher exposures (up to seven hours) for vegetation contact in some maximum scenarios. Therefore, no risks are predicted for salvage loggers from retardants, foams, or water enhancers.

4.6 Discussion and Uncertainties

For those workers identified in the preceding subsections as having estimated hazard quotients greater than one, there may be a risk of adverse health effects if they are exposed to certain fire-fighting products under the exposure assumptions used in this risk assessment. No risks were identified for typical exposures. For maximum exposures, risks were predicted for airtanker base personnel from certain formulations as a mixture, and from some retardants that contain one retardant salt and one corrosion inhibitor.

No risks to members of the public were predicted.

The risks summarized in this assessment are not probabilistic estimates of risk, but are conditional estimates. That is, these risks are likely only if all exposure scenario assumptions that were described are met. The primary areas of uncertainty in this analysis include the predicted RfDs and dermal penetration rates for each formulation and ingredient, and the quantity of a chemical to which an individual may actually be exposed. For individual ingredients with RfDs based on subchronic or chronic studies, more confidence can be placed in the degree to which they represent actual acceptable intake levels. In most cases, no dermal penetration data are available, so reasonable estimates were applied in the assessment. Although monitoring studies could identify some levels of exposure more accurately, the highly variable nature of fire-fighting activities would require application of a large margin of error, limiting their utility in providing greater confidence in the risk conclusions.

Exposure durations for workers were estimated by Forest Service personnel with years of experience in the fire-fighting program. To examine the sensitivity of the analysis to these assumptions, formulation risks from variations in the assumed exposure durations were estimated, as follows:

- For mixers, who are exposed to powdered retardants, hazard quotients could range up to 1.35 in the typical scenario, exceeding the threshold value of 1 (and therefore indicating potential risk) for the product Phos-Chek G75-W, if an exposure duration of 8 hours is assumed. This risk can be mitigated by removing any powder residue from exposed skin by washing with water.

- If the typical scenario exposure duration for mixers is increased to 8 hours, hazard quotients range up to 0.45, remaining below the level of concern.

- For helitack crews, smokejumpers, hotshot crews, type 2 firefighters, engine crews, and overhead workers: if the assumed exposure duration is increased to 8 hours in the typical scenarios and 10 hours in the maximum scenarios, estimated risks remain far below the level of concern.

It is important to note that, during the many years of these chemicals' use in fire-fighting, reports of adverse health effects have been limited to skin and eye irritation, and potential allergic reactions. This use history does not appear to warrant extensive testing, especially given the emergency nature of the use of these products.

Table 4-1. Estimated Product Risks to Airtanker Base Personnel: Mixing

	Typical Hazard Quotient		Maximum Hazard Quotient	
Product	**Male**	**Female**	**Male**	**Female**
Fire-Trol GTS-R	0.06	0.08	**1.85**	**2.21**
Fire-Trol 300-F	0.05	0.05	**1.30**	**1.55**
Phos-Chek D75-R	0.05	0.06	**1.33**	**1.59**
Phos-Chek D75-F	0.04	0.05	**1.12**	**1.34**
Phos-Chek 259-R	0.04	0.04	**1.05**	**1.25**
Phos-Chek 259-F	0.06	0.07	**1.70**	**2.04**
Phos-Chek G75-W	0.37	0.44	**10.47**	**12.50**
Phos-Chek G75-F	0.04	0.05	**1.26**	**1.50**
Phos-Chek HV-R	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek HV-F	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek MV-R	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek MV-F	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek LV-R	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol LCA-R	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol LCA-F	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol LCG-R	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol LCG-F	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol FTR	< 0.01	< 0.01	< 0.01	< 0.01

Table 4-2. Estimated Product Risks to Airtanker Base Personnel: Loading

	Typical Hazard Quotient		Maximum Hazard Quotient	
Product	**Male**	**Female**	**Male**	**Female**
Fire-Trol GTS-R	0.02	0.03	**1.45**	**1.74**
Fire-Trol 300-F	0.02	0.02	**1.09**	**1.30**
Phos-Chek D75-R	0.01	0.01	0.75	0.90
Phos-Chek D75-F	< 0.01	0.01	0.63	0.76
Phos-Chek 259-R	< 0.01	< 0.01	0.56	0.67
Phos-Chek 259-F	0.01	0.02	0.92	**1.10**
Phos-Chek G75-W	0.08	0.10	**5.53**	**6.61**
Phos-Chek G75-F	< 0.01	0.01	0.67	0.79
Phos-Chek HV-R	0.09	0.11	0.64	0.77
Phos-Chek HV-F	0.09	0.11	0.64	0.77
Phos-Chek MV-R	0.09	0.11	0.64	0.77
Phos-Chek MV-F	< 0.01	0.01	0.62	0.74
Phos-Chek LV-R	< 0.01	0.01	0.64	0.77
Fire-Trol LCA-R	< 0.01	< 0.01	0.49	0.58
Fire-Trol LCA-F	< 0.01	< 0.01	0.49	0.59
Fire-Trol LCG-R	< 0.01	< 0.01	0.51	0.61
Fire-Trol LCG-F	< 0.01	< 0.01	0.52	0.62
Fire-Trol FTR	< 0.01	< 0.01	0.51	0.61

Table 4-3. Estimated Product Risks to Helitack Crews

	Typical Hazard Quotient		Maximum Hazard Quotient	
Product	**Male**	**Female**	**Male**	**Female**
Long-Term Retardants				
Fire-Trol GTS-R	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol 300-F	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek D75-R	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek D75-F	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek 259-R	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek 259-F	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek G75-W	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek G75-F	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek HV-R	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek HV-F	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek MV-R	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek MV-F	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek LV-R	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol LCA-R	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol LCA-F	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol LCG-R	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol LCG-F	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol FTR	< 0.01	< 0.01	< 0.01	< 0.01
Foams				
Ansul Silv-Ex	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol FireFoam 103	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol FireFoam 103B	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek WD 881	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol FireFoam 104	< 0.01	< 0.01	< 0.01	< 0.01
Angus ForExpan S	< 0.01	< 0.01	< 0.01	< 0.01
Pyrocap B-136	< 0.01	< 0.01	< 0.01	< 0.01
Fire Choke	< 0.01	< 0.01	< 0.01	< 0.01
National Foam KnockDown	< 0.01	< 0.01	< 0.01	< 0.01
3M Light Water FT-1150	< 0.01	< 0.01	< 0.01	< 0.01
Water Enhancers				
FireOut ICE	< 0.01	< 0.01	< 0.01	< 0.01
Stockhausen Firecape FP-47	< 0.01	< 0.01	< 0.01	< 0.01

Table 4-4. Estimated Product Risks to Smokejumpers

	Typical Hazard Quotient		Maximum Hazard Quotient	
Product	**Male**	**Female**	**Male**	**Female**
Long-Term Retardants				
Fire-Trol GTS-R	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol 300-F	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek D75-R	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek D75-F	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek 259-R	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek 259-F	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek G75-W	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek G75-F	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek HV-R	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek HV-F	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek MV-R	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek MV-F	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek LV-R	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol LCA-R	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol LCA-F	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol LCG-R	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol LCG-F	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol FTR	< 0.01	< 0.01	< 0.01	< 0.01
Foams				
Ansul Silv-Ex	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol FireFoam 103	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol FireFoam 103B	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek WD 881	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol FireFoam 104	< 0.01	< 0.01	< 0.01	< 0.01
Angus ForExpan S	< 0.01	< 0.01	< 0.01	< 0.01
Pyrocap B-136	< 0.01	< 0.01	< 0.01	< 0.01
Fire Choke	< 0.01	< 0.01	< 0.01	< 0.01
National Foam KnockDown	< 0.01	< 0.01	< 0.01	< 0.01
3M Light Water FT-1150	< 0.01	< 0.01	< 0.01	< 0.01
Water Enhancers				
FireOut ICE	< 0.01	< 0.01	< 0.01	< 0.01
Stockhausen Firecape FP-47	< 0.01	< 0.01	< 0.01	< 0.01

Table 4-5. Estimated Product Risks to Hotshot Crews

	Typical Hazard Quotient		Maximum Hazard Quotient	
Product	**Male**	**Female**	**Male**	**Female**
Long-Term Retardants				
Fire-Trol GTS-R	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol 300-F	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek D75-R	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek D75-F	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek 259-R	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek 259-F	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek G75-W	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek G75-F	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek HV-R	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek HV-F	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek MV-R	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek MV-F	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek LV-R	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol LCA-R	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol LCA-F	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol LCG-R	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol LCG-F	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol FTR	< 0.01	< 0.01	< 0.01	< 0.01
Foams				
Ansul Silv-Ex	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol FireFoam 103	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol FireFoam 103B	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek WD 881	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol FireFoam 104	< 0.01	< 0.01	< 0.01	< 0.01
Angus ForExpan S	< 0.01	< 0.01	< 0.01	< 0.01
Pyrocap B-136	< 0.01	< 0.01	< 0.01	< 0.01
Fire Choke	< 0.01	< 0.01	< 0.01	< 0.01
National Foam KnockDown	< 0.01	< 0.01	< 0.01	< 0.01
3M Light Water FT-1150	< 0.01	< 0.01	< 0.01	< 0.01
Water Enhancers				
FireOut ICE	< 0.01	< 0.01	< 0.01	< 0.01
Stockhausen Firecape FP-47	< 0.01	< 0.01	< 0.01	< 0.01

Table 4-6. Estimated Product Risks to Type 2 Firefighters

	Typical Hazard Quotient		Maximum Hazard Quotient	
Product	**Male**	**Female**	**Male**	**Female**
Long-Term Retardants				
Fire-Trol GTS-R	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol 300-F	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek D75-R	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek D75-F	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek 259-R	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek 259-F	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek G75-W	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek G75-F	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek HV-R	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek HV-F	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek MV-R	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek MV-F	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek LV-R	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol LCA-R	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol LCA-F	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol LCG-R	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol LCG-F	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol FTR	< 0.01	< 0.01	< 0.01	< 0.01
Foams				
Ansul Silv-Ex	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol FireFoam 103	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol FireFoam 103B	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek WD 881	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol FireFoam 104	< 0.01	< 0.01	< 0.01	< 0.01
Angus ForExpan S	< 0.01	< 0.01	< 0.01	< 0.01
Pyrocap B-136	< 0.01	< 0.01	< 0.01	< 0.01
Fire Choke	< 0.01	< 0.01	< 0.01	< 0.01
National Foam KnockDown	< 0.01	< 0.01	< 0.01	< 0.01
3M Light Water FT-1150	< 0.01	< 0.01	< 0.01	< 0.01
Water Enhancers				
FireOut ICE	< 0.01	< 0.01	< 0.01	< 0.01
Stockhausen Firecape FP-47	< 0.01	< 0.01	< 0.01	< 0.01

Table 4-7. Estimated Product Risks to Engine Crews

	Typical Hazard Quotient		Maximum Hazard Quotient	
Product	**Male**	**Female**	**Male**	**Female**
Foams				
Ansul Silv-Ex	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol FireFoam 103	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol FireFoam 103B	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek WD 881	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol FireFoam 104	< 0.01	< 0.01	< 0.01	< 0.01
Angus ForExpan S	< 0.01	< 0.01	< 0.01	< 0.01
Pyrocap B-136	< 0.01	< 0.01	< 0.01	< 0.01
Fire Choke	< 0.01	< 0.01	< 0.01	< 0.01
National Foam KnockDown	< 0.01	< 0.01	< 0.01	< 0.01
3M Light Water FT-1150	< 0.01	< 0.01	< 0.01	< 0.01
Water Enhancers				
FireOut ICE	< 0.01	< 0.01	< 0.01	< 0.01
Stockhausen Firecape FP-47	< 0.01	< 0.01	< 0.01	< 0.01

Table 4-8. Estimated Product Risks to Overhead Workers

	Typical Hazard Quotient		Maximum Hazard Quotient	
Product	**Male**	**Female**	**Male**	**Female**
Long-Term Retardants				
Fire-Trol GTS-R	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol 300-F	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek D75-R	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek D75-F	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek 259-R	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek 259-F	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek G75-W	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek G75-F	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek HV-R	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek HV-F	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek MV-R	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek MV-F	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek LV-R	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol LCA-R	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol LCA-F	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol LCG-R	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol LCG-F	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol FTR	< 0.01	< 0.01	< 0.01	< 0.01
Foams				
Ansul Silv-Ex	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol FireFoam 103	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol FireFoam 103B	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek WD 881	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol FireFoam 104	< 0.01	< 0.01	< 0.01	< 0.01
Angus ForExpan S	< 0.01	< 0.01	< 0.01	< 0.01
Pyrocap B-136	< 0.01	< 0.01	< 0.01	< 0.01
Fire Choke	< 0.01	< 0.01	< 0.01	< 0.01
National Foam KnockDown	< 0.01	< 0.01	< 0.01	< 0.01
3M Light Water FT-1150	< 0.01	< 0.01	< 0.01	< 0.01
Water Enhancers				
FireOut ICE	< 0.01	< 0.01	< 0.01	< 0.01
Stockhausen Firecape FP-47	< 0.01	< 0.01	< 0.01	< 0.01

Table 4-9. Estimated Product Risks to the Public From Cleaning a Structure

	Hazard Quotient	
Product	**Adult**	**Child**
Long-Term Retardants		
Fire-Trol GTS-R	< 0.01	< 0.01
Fire-Trol 300-F	< 0.01	< 0.01
Phos-Chek D75-R	< 0.01	< 0.01
Phos-Chek D75-F	< 0.01	< 0.01
Phos-Chek 259-R	< 0.01	< 0.01
Phos-Chek 259-F	< 0.01	< 0.01
Phos-Chek G75-W	< 0.01	0.01
Phos-Chek G75-F	< 0.01	< 0.01
Phos-Chek HV-R	< 0.01	< 0.01
Phos-Chek HV-F	< 0.01	< 0.01
Phos-Chek MV-R	< 0.01	< 0.01
Phos-Chek MV-F	< 0.01	< 0.01
Phos-Chek LV-R	< 0.01	< 0.01
Fire-Trol LCA-R	< 0.01	< 0.01
Fire-Trol LCA-F	< 0.01	< 0.01
Fire-Trol LCG-R	< 0.01	< 0.01
Fire-Trol LCG-F	< 0.01	< 0.01
Fire-Trol FTR	< 0.01	< 0.01
Foams		
Ansul Silv-Ex	< 0.01	< 0.01
Fire-Trol FireFoam 103	< 0.01	< 0.01
Fire-Trol FireFoam 103B	< 0.01	< 0.01
Phos-Chek WD 881	< 0.01	< 0.01
Fire-Trol FireFoam 104	< 0.01	< 0.01
Angus ForExpan S	< 0.01	< 0.01
Pyrocap B-136	< 0.01	< 0.01
Fire Choke	< 0.01	< 0.01
National Foam KnockDown	< 0.01	< 0.01
3M Light Water FT-1150	< 0.01	< 0.01
Water Enhancers		
FireOut ICE	< 0.01	< 0.01
Stockhausen Firecape FP-47	< 0.01	< 0.01

Table 4-10. Estimated Product Risks From Accidental Drench

	Hazard Quotient			
	Workers		Public	
Product	**Male**	**Female**	**Adult**	**Child**
Long-Term Retardants				
Fire-Trol GTS-R	0.11	0.11	0.54	0.81
Fire-Trol 300-F	0.08	0.08	0.40	0.60
Phos-Chek D75-R	0.06	0.06	0.28	0.42
Phos-Chek D75-F	0.05	0.05	0.24	0.35
Phos-Chek 259-R	0.04	0.04	0.21	0.31
Phos-Chek 259-F	0.07	0.07	0.34	0.51
Phos-Chek G75-W	0.40	0.42	**2.05**	**3.07**
Phos-Chek G75-F	0.05	0.05	0.25	0.37
Phos-Chek HV-R	0.05	0.05	0.24	0.36
Phos-Chek HV-F	0.05	0.05	0.24	0.36
Phos-Chek MV-R	0.05	0.05	0.24	0.36
Phos-Chek MV-F	0.05	0.05	0.23	0.34
Phos-Chek LV-R	0.05	0.05	0.24	0.36
Fire-Trol LCA-R	0.04	0.04	0.18	0.27
Fire-Trol LCA-F	0.04	0.04	0.18	0.27
Fire-Trol LCG-R	0.04	0.04	0.19	0.28
Fire-Trol LCG-F	0.04	0.04	0.19	0.29
Fire-Trol FTR	0.04	0.04	0.19	0.28
Foams				
Ansul Silv-Ex	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol FireFoam 103	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol FireFoam 103B	< 0.01	< 0.01	< 0.01	< 0.01
Phos-Chek WD 881	< 0.01	< 0.01	< 0.01	< 0.01
Fire-Trol FireFoam 104	< 0.01	< 0.01	< 0.01	< 0.01
Angus ForExpan S	< 0.01	< 0.01	< 0.01	< 0.01
Pyrocap B-136	< 0.01	< 0.01	< 0.01	< 0.01
Fire Choke	< 0.01	< 0.01	< 0.01	< 0.01
National Foam KnockDown	< 0.01	< 0.01	< 0.01	< 0.01
3M Light Water FT-1150	< 0.01	< 0.01	< 0.01	< 0.01
Water Enhancers				
FireOut ICE	< 0.01	< 0.01	0.05	0.07
Stockhausen Firecape FP-47	< 0.01	< 0.01	0.04	0.06

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