Risks of Methyl Bromide Use to Federally Threatened California Tiger Salamander (*Ambystoma californiense)* (Central California Distinct Population Segment) and Federally Endangered Sonoma County and Santa Barbara County Distinct Population Segments of California Tiger Salamander

Pesticide Effects Determinations

PC Codes: 053201(Methyl Bromide) CAS Numbers: 74-83-9

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List of Commonly Used Abbreviations and Nomenclature

µg/kg	Symbol for "micrograms per kilogram"
µg/L	Symbol for "micrograms per liter"
ºC	Symbol for "degrees Celsius"
AAPCO	Association of American Pesticide Control Officials
a.i. or ai	Active Ingredient
AIMS	Avian Monitoring Information System
Acc#	Accession Number
amu	Atomic Mass Unit
BCB	Bay Checkerspot Butterfly
BCF	Bioconcentration Factor
BEAD	Biological and Economic Analysis Division
bw	Body Weight
CAM	Chemical Application Method
CARB	California Air Resources Board
CAW	California Alameda Whipsnake
CBD	Center for Biological Diversity
CCR	California Clapper Rail
CDPR	California Department of Pesticide Regulation
CDPR-PUR	California Department of Pesticide Regulation Pesticide Use Reporting Database
CFWS	California Freshwater Shrimp
CI	Confidence Interval
CL	Confidence Limit
CTS	California Tiger Salamander
CTS-CC	California Tiger Salamander Central California Distinct Population Segment
CTS-SB	California Tiger Salamander Santa Barbara County Distinct Population Segment
CTS-SC	California Tiger Salamander Sonoma County Distinct Population Segment
DS	Delta Smelt
EC	Emulsifiable Concentrate
EC_{05}	5% Effect Concentration
EC_{25}	25% Effect Concentration
EC_{50}	50% (or Median) Effect Concentration

ECOTOX	EPA managed database of Ecotoxicology data
EEC	Estimated Environmental Concentration
EFED	Environmental Fate and Effects Division
e.g.	Latin *exempli gratia* ("for example")
EIM	Environmental Information Management System
EPI	Estimation Programs Interface
ESU	Evolutionarily significant unit
et al.	Latin *et alii* ("and others")
etc.	Latin *et cetera* ("and the rest" or "and so forth")
EXAMS	Exposure Analysis Modeling System
FIFRA	Federal Insecticide Fungicide and Rodenticide Act
FQPA	Food Quality Protection Act
ft	Feet
GENEEC	Generic Estimated Exposure Concentration model
HPLC	High Pressure Liquid Chromatography
IC_{05}	5% Inhibition Concentration
IC_{50}	50% (or median) Inhibition Concentration
i.e.	Latin for *id est* ("that is")
IECV1.1	Individual Effect Chance Model Version 1.1
KABAM	K_{OW} (based) Aquatic BioAccumulation Model
kg	Kilogram(s)
kJ/mole	Kilojoules per mole
km	Kilometer(s)
K_{AW}	Air-water Partition Coefficient
Kd	Solid-water Distribution Coefficient
KF	Freundlich Solid-Water Distribution Coefficient
K_{OA}	Octanol-air Partition Coefficient
K_{OC}	Organic-carbon Partition Coefficient
K_{OW}	Octanol–water Partition Coefficient
LAA	Likely to Adversely Affect
lb a.i./A	Pound(s) of active ingredient per acre
LC_{50}	50% (or Median) Lethal Concentration
LD_{50}	50% (or Median) Lethal Dose
LOAEC	Lowest Observable Adverse Effect Concentration
LOAEL	Lowest Observable Adverse Effect Level
LOC	Level of Concern

LOD	Level of Detection
LOEC	Lowest Observable Effect Concentration
LOQ	Level of Quantitation
m	Meter(s)
MA	May Affect
MATC	Maximum Acceptable Toxicant Concentration
m^2/day	Square Meters per Days
ME	Microencapsulated
mg	Milligram(s)
mg/kg	Milligrams per kilogram (equivalent to ppm)
mg/L	Milligrams per liter (equivalent to ppm)
mi	Mile(s)
mmHg	Millimeter of mercury
MRID	Master Record Identification Number
MW	Molecular Weight
n/a	Not applicable
NASS	National Agricultural Statistics Service
NAWQA	National Water Quality Assessment
NCOD	National Contaminant Occurrence Database
NE	No Effect
NLAA	Not Likely to Adversely Affect
NLCD	National Land Cover Dataset
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOAEC	No Observable Adverse Effect Concentration
NOAEL	No Observable Adverse Effect Level
NOEC	No Observable Effect Concentration
NRCS	Natural Resources Conservation Service
OCSPP	Office of Chemical Safety and Pollution Prevention
OPP	Office of Pesticide Programs
OPPTS	Office of Prevention, Pesticides and Toxic Substances
ORD	Office of Research and Development
PCE	Primary Constituent Element
pH	Symbol for the negative logarithm of the hydrogen ion activity in an aqueous solution, dimensionless

pKa	Symbol for the negative logarithm of the acid dissociation constant, dimensionless
ppb	Parts per Billion (equivalent to µg/L or µg/kg)
ppm	Parts per Million (equivalent to mg/L or mg/kg)
PRD	Pesticide Re-Evaluation Division
PRZM	Pesticide Root Zone Model
ROW	Right of Way
RQ	Risk Quotient
SFGS	San Francisco Garter Snake
SJKF	San Joaquin Kit Fox
SLN	Special Local Need
SMHM	Salt Marsh Harvest Mouse
TG	Tidewater Goby
T-HERPS	Terrestrial Herpetofaunal Exposure Residue Program Simulation
T-REX	Terrestrial Residue Exposure Model
UCL	Upper Confidence Limit
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VELB	Valley Elderberry Longhorn Beetle
WP	Wettable Powder
wt	Weight

1. Executive Summary

1.1. **Purpose of Assessment**

The purpose of this assessment is to evaluate potential direct and indirect effects from methyl bromide applications (PC code: 053201) on the California Tiger Salamander (*Ambystoma californiense* - referred to hereafter as CTS) in its terrestrial and aquatic habitats arising from FIFRA regulatory actions regarding use of methyl bromide on agricultural and non-agricultural sites. In addition, this assessment evaluates whether these actions can be expected to result in modification of designated critical habitat for CTS. Methyl bromide is considered the primary stressor of concern in this risk assessment for both the aquatic and terrestrial phase CTS. See **Sections 1.2.2 and 2.1.1** for further details. This assessment was completed in accordance with the U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) *Endangered Species Consultation Handbook* (USFWS/NMFS, 1998), procedures outlined in the Agency's Overview Document (USEPA, 2004b), and consistent with a stipulated injunction ordered by the Federal District Court for the Northern District of California in the case *Center for Biological Diversity (CBD) vs. EPA et al*. (Case No. 07-2794-JCS).

There are currently three CTS Distinct Population Segments (DPSs): the Sonoma County (SC) DPS, the Santa Barbara (SB) DPS, and the Central California (CC) DPS. Each DPS is considered separately in the risk assessment as they occupy different geographic areas. This assessment will include a spatial analysis of potential risk to the different habitat locations. The CTS-SB and CTS-SC were downlisted from endangered to threatened in 2004 by the USFWS. However, the downlisting was vacated by the U.S. District Court. Therefore, the SC and SB DPSs are currently listed as endangered. The CC-DPS is currently listed as threatened. Critical habitat for the CTS was designated in December 2005 (70 FR 74137). The CTS utilizes vernal pools, semi-permanent ponds, and permanent ponds, and the terrestrial environment in California. The aquatic environment is essential for breeding and reproduction and mammal burrows are also important habitat for aestivation.

1.1. Scope of Assessment

1.1.1. Uses Assessed

Currently, methyl bromide is used throughout the United States, mainly as a broad-spectrum soil fumigant to control soil-borne pests such as weeds, diseases, and nematodes applied before planting a wide variety of crops. Methyl bromide is also used for multiple purpose pest control inside buildings and structures such as food and commodity fumigation inside grain mills and fumigation chambers within cargo holds as well as indoor space fumigation, inside food processing plants, greenhouses, warehouses, and residential sites. Since the most recent assessment supporting the reregistration of methyl bromide was submitted on June 6, 2005, changes have been applied to all product labels collectively associated with the amended Reregistration Eligibility Decision (RED) for the soil fumigant and non-food structural uses in May 2009. The RED also considered uses allowed under the Montreal Protocol, which mandates the phase-out of methyl bromide given its contribution to stratospheric ozone depletion. As of 2008, new stocks of imported or manufactured methyl bromide are not allowed to be used under the Montreal Protocol. However, critical use exemptions (hereafter identified as CUEs) allowing for new stock of methyl bromide are allowed for various pre-plant soil fumigant crop uses including orchard replant, peppers, eggplant, cucurbits, forestry nursery, nursery and ornamentals, strawberries, sweet potatoes, and tomatoes. Other uses of methyl bromide on berries (including but not limited to raspberries and blueberries), golf courses, and athletic fields have only been permitted for leftover methyl bromide stockpiles. In addition to the CUEs, there is a quarantine and pre-shipment (hereafter identified as QPS) exemption for methyl bromide which applies to food and commodities stored in buildings or cargo holds that are eventually distributed domestically or imported. Available stockpiles are only allowed for space fumigation inside of buildings. Methyl bromide uses for stockpiles are expected to decline as available stockpiles decline. Methyl bromide CUE and QPS uses will eventually be phased-out. However, it is anticipated that these uses will not decline as rapidly as other uses. The CUE and QPS exemptions are re-evaluated on a case-by-case basis each year by the EPA Office of Air and Radiation.

Both soil fumigant uses and structural uses of methyl bromide are expected to contribute to potential outdoor exposure to the CTS and its designated critical habitat. Soil fumigant application methods include bedded tarped shank injection, broadcast tarped shank injection, deep untarped shank injection, and hot gas tarped chemigation. For each application method, methyl bromide is expected to off-gas and diffuse into the atmosphere even given tarp applications. In addition, methyl bromide aeration of fumigated structures is expected to be the source of outdoor exposure to terrestrial wildlife and plants. Furthermore, both soil fumigant and structural fumigant uses are major uses in California, and there are CUE and QPS exemptions from the Montreal Protocol which apply to both of these use patterns. Please refer to **Section 2.4** for further details on the specifics of fumigant application methods and management practices for the treated field.

A memo from the Pesticide Re-evaluation Division (PRD) at the Agency's Office of Pesticide Programs (OPP) dated December 14, 2011 (**Appendix A**) along with a cursory review of the labels verified aspects of current methyl bromide uses. The memo provides a listing of specific crops eligible for soil fumigant use, application methods for each crop use, and the requirement of certain field management practices or, "Good Agricultural Practices," in conjunction with fumigant use. In addition, the Label Use Information System (LUIS) report, received from the OPP's Biological and Economic Analysis Division (BEAD) dated September 19, 2011, lists the following use groups for methyl bromide: terrestrial-greenhouse food, greenhouse, non-food, terrestrial non-food, terrestrial feed, forestry, agricultural soils, nonagricultural soils, greenhouse non-food, indoor food, indoor non-food, and indoor residential.

1.1.2. Evaluation of Stressors of Concern

In this risk assessment, methyl bromide is considered to be the stressor of concern. Environmental exposure for this chemical is closely related to its high volatility from soil and water (off gassing). It has been proposed that the toxic effects of methyl bromide in animal species are due to direct cytotoxic actions of methyl bromide or a methyl bromide metabolite, possibly through alkylation of proteins (WHO 1995). In terrestrial mammals, central nervous system toxicity appears related to the incorporation of methyl bromide or the methyl moiety into tissues (WHO 1995). There is no proven mechanism for the phytotoxic effects of methyl bromide, although it has been proposed that excessive accumulation of the bromide ion by plants produces toxic effects (WHO 1995). However, it is also possible that some of the phytotoxic effects of methyl bromide are due to indirect actions, such as the elimination of beneficial microorganisms from soil.

Several environmental fate laboratory studies such as hydrolysis as well as aerobic and anaerobic soil metabolism studies show the formation of methanol and the bromide ion which form in a S_N2 nucleophilic substitution reaction. Degradation products are not considered as part of the stressor of concern for two main reasons. First, major amounts of methyl bromide will evaporate to the air from soil or be released from buildings without forming a substantial amount of degradates. This is due to its rapid volatilization rate from soil and high persistence in the atmosphere. Therefore, major degradates of methyl bromide are not expected in the air resulting from soil fumigant or structural methyl bromide applications. Second, methyl bromide degradates are not expected to be of toxicological concern as compared to methyl bromide. Further justification is provided in **Section 2.1.1** and in **Appendix B.**

1.1.3. Environmental Fate Properties of Methyl Bromide

Methyl bromide is not expected to be retained in soil or water bodies for a long period of time due to its high volatility. Its volatilization dissipation half life from water has been measured less than two hours in a few studies. The degree of methyl bromide gas release from soil, following fumigation, depends on field management practices such as application of tarps and incorporation depths. Further information is provided in **Section 2.4** and **Appendix F**.

After releases from treated and aerated structures, methyl bromide is expected to remain as a gas in the atmosphere due to its high vapor pressure and high Henry's Law Constant values. Further information is provided in **Section 2.3**.

1.2. Assessment Procedures

A description of routine procedures for evaluating risk to the San Francisco Bay Species are provided in **Attachment 1**.

1.2.1. Exposure Assessment

1.2.1.a. Aquatic Exposures

Aquatic concentrations and exposure are not expected to be significant from methyl bromide use as a soil fumigant or from structural applications. Observational evidence of this includes its volatility noted in several aquatic laboratory studies from the open literature. In addition, no known quantifiable detections of methyl bromide have been detected in target surface water monitoring studies with the United States. Furthermore, concentrations observed in targeted ground water monitoring studies are less than 0.5 ppb with very infrequent detections (0.07 percent out of 26,149 total ground water samples). Further description is provided in **Section**

2.9.2, and a quantitative analysis supporting this conclusion using the PRZM/EXAMS model and calculated water body concentrations is provided in **Appendix D.**

1.2.1.b. Terrestrial Exposures

The dominate route of exposure for the CTS from soil and structural treatment is air exposure (i.e., inhalation exposure) as suggested from methyl bromide's high vapor pressure and Henry's Law Constant. This exposure occurs as methyl bromide off-gases from the soil and accumulates downwind towards CTS populations inhabiting areas nearby the edge of the field above the ground. Therefore, acute inhalation exposure is estimated for the two main types of applications:

1. Methyl bromide acute inhalation exposure is estimated from soil fumigant applications to terrestrial species. In this case, the SCREEN3 (screening-level) air exposure model is used in conjunction with peak volatile soil flux values representative of numerous application methods to calculate peak (one-hour) estimated exposure concentrations (EECs) in air. These flux values were composited from numerous field volatility studies cited by CALDPR (California Department of Pesticide Regulation) for bedded tarped shank injection, deep untarped shank injection, and hot gas tarped chemigation applications (see **Appendix F**), as well as from a field volatility conducted, by the registrant, at Wasco, CA for a broadcast tarped application (MRID 48006001). Peak (1-hour) methyl bromide EECs in air ranged from between 36,560 $\mu g/m^3$ – 200,342 $\mu g/m^3$ (9.42 – 51.59 ppm, converted from the ideal gas law). To address direct and indirect effects risk determinations to the CTS for all bedded tarped shank injection, broadcast tarped shank injection, and hot gas tarped chemigation applications, the refined model PERFUM was run with a distribution of flux rates using the CALDPR composited temporal flux profiles developed for the hot gas tarped chemigation method. The PERFUM 90th percentile upper-bound peak (hourly) EECs in air did not exceed 16,706 $\mu g/m^3$ (4.30 ppm, converted from the ideal gas law) for all treatments where the refined approach was applied.

2. Methyl bromide acute inhalation exposure is also estimated for releases associated with structural uses of methyl bromide. In this case, only a refined approach utilizing the PERFUM model with different release scenarios is used (please refer to **Section 3.1** for details). PERFUM upper 90th percentile peak (one-hour) EECs in air ranged between 1,554 – 230,769 $\mu g/m^3$ (0.4 – 59.43 ppm, converted from the ideal gas law). A wide range of release scenarios are considered for structural fumigations due to the lack of label specifications for this use. **In comparison, labels for soil fumigants include detailed specifications related to field management practices including tarp applications and injection depths which likely results in lower exposure than for structural treatments depicted in this risk assessment.** Therefore, direct and indirect adverse effects to the CTS are likely only for structural uses due to the higher air exposure expected for these uses (please refer to **Section 7**) for details.

Many air monitoring studies have been conducted in California to determine the concentrations of methyl bromide in air adjacent to the methyl bromide application sites associated with specific application methods. In addition, methyl bromide has been monitored in ambient air in air sheds targeted spatially and temporally concurrent with methyl bromide applications. For non-targeted ambient air, the highest measured concentration methyl bromide most representative of background levels was 560 ppt. The highest methyl bromide measured concentration was 27 ppm (104,842μg/m^3) in conjunction with structural applications and 3.35 ppm (13,008 μg/m^3) for soil applications. In general, the departures between modeled and application monitoring data for both soil and structural methyl bromide applications were small (within an order of magnitude). Factors most contributing towards the discrepancies between modeled and monitored values include the variability of monitored averaging periods (greater than one-hour in many cases) and the one-hour EEC calculated by the model, as well as the consideration of a distribution of meteorological conditions in the modeling. In addition, there are uncertainties in the representativeness of the soil application air monitoring data to the current field management practices required with the use of methyl bromide. Furthermore, comparisons between structural application monitoring and modeled values were difficult due to various uncertainties related to release parameters from treated facilities. Please refer to **Section 3.1.2** and **Section 5.2.1** for additional information regarding air monitoring data including a discussion on their appropriate comparisons to modeling EEC in air results calculated in this risk assessment.

Chronic exposure(s) of the CTS to airborne methyl bromide gas could conceivably occur due to repeated exposures from multiple treated fields where methyl bromide is used in large quantities and multiple treatments in structures due to commodity and food treatments. However, chronic exposure from single soil applications of methyl bromide is not expected due to the highly transient nature of methyl bromide concentrations in the atmosphere and restrictive application practices that involve tarps and deep shank injections. For structural fumigation treatments, chronic exposure may be a concern given that label requirements do not restrict the amount of methyl bromide treatments and subsequent releases for buildings. Upper-bound and lower-bound chronic exposure estimates are investigated quantitatively by examining lower-bound and upper-bound RQs developed from maximum ambient air monitoring concentrations and PERFUM upper 90th percentile peak (hourly) EECs in air, respectively. These chronic exposure estimates are then compared to available rat reproduction methyl bromide inhalation toxicological data. Low values of methyl bromide have been measured in targeted ambient air throughout California (air concentrations $\leq$30.8 ppb). In addition, the majority of methyl bromide use is seasonal for post-harvested food and commodities treatments. Therefore, the risk of chronic exposure from treated structures may be discounted considering these two pieces of information. Please refer to Indirect Effects section in the Summary of Conclusions in this executive summary below for further details. In addition, this analysis is presented in **Section 5.2.2.**

Soil-borne exposure via inhalation and dermal routes of exposure can be an important exposure pathway of concern for populations of burrowing CTS given methyl bromide's direct applications to soil. Although the dermal route of exposure is also possible in soil treated with methyl bromide, this route of exposure is not assessed at this time due to a lack of a tool available to extrapolate a gas-phase concentration to a dermal exposure concentration and because of a lack of dermal representative toxicity data available for methyl bromide. EECs are calculated in soil within treated fields and qualitatively compared to the available acute avian inhalation study. Calculated peak EECs from soil fumigation applications are in the range of

49,031,066 – 882,559,185 μg/m^3 (calculated based on a homogeneous concentration of methyl bromide gas residing within the depths of incorporation specified on labels for various application methods). Although peak EECs in soil indicate very high levels of exposure , the probability of CTS inhabiting a bare soil field during methyl bromide applications is very low. Necessary cultivations required by field management practices based on the label likely disturb the landscape where CTS thrive. In addition, broadcast tarps reduce the probability that CTS species congregate in such areas. CTS can inhabit deep burrows between 2 to 4 feet below the soil. In addition, CTS populations off the treated field may be exposed to laterally diffusing methyl bromide gas. However, for each of these scenarios, exposure is not expected to be significant as the predominate movement of methyl bromide is expected to be mainly directed vertically towards the cultivated soil region and soil surface. The calculation of soil EECs are shown in **Section 3.1.3** and soil exposure is discussed qualitatively in **Section 5.2.1.**

Dietary exposure is not anticipated for the CTS because methyl bromide is expected to be in the gas-phase with little or no residues expected on CTS food items and prey. Methyl bromide also has a low propensity to bioaccumulate in fatty tissues as indicated by its low K_{ow}. In addition, exposure via residues on treated crops is not expected given the typical plant-back interval of 10 days for methyl bromide applications. The T-REX and T-HERPS models that are routinely used by EFED to estimate residues on food items for birds, mammals, and reptiles, were not used because dietary exposure is not anticipated from the use of methyl bromide. The TerrPlant model estimates the effect on plants from residue exposure via runoff and spray drift. However, TerrPlant was not used because the dominant exposure pathway is expected to be in the form of air exposure from volatilized methyl bromide applications. It is also noted that plant toxicity data were not available to estimate the effects from air concentrations of methyl bromide.

Since retention times of methyl bromide in water are small, the probability of imbibition exposure via water borne residues in puddles, dew, and ground drinking water sources due to leaching is low.

1.2.1.c. Changes from the Methyl Bromide Re-registration Eligibility Decision (RED) Assessment

In this assessment, there are many changes from the exposure analysis presented in the, "Environmental Fate and Ecological Risk Assessment for the Re-registration of Methyl Bromide", dated June 6, 2005. The exposure analysis in this assessment reflects the new labels implemented with the RED issued by the Agency for methyl bromide along with the enactment of exemptions from the Montreal Protocol. Such changes include:

1. Structural uses are addressed in this assessment because of the QPS exemption specifically addressing these uses. The PERFUM model and accompanying temporal emissions and flux profiles were utilized to estimate exposure due to methyl bromide releases during and after treatments. This methodology is discussed in **Section 3.1.1**.

2. SCREEN3 was chosen as the basis for the screening level terrestrial air exposure assessment for soil fumigant applications. SCREEN3 is equivalent to the screening version of the ISCST3 model used in the Reregistration assessment. In addition, the

refined tool PERFUM was chosen to evaluate those uses exceeding the LOC for surrogate endangered species birds and mammals by the SCREEN3 model.

3. The additional field volatility study conducted for broadcast tarped shank injection applications of methyl bromide at Wasco, CA (MRID No. 48006001) was considered in calculating EECs in air.

1.2.2. Toxicity Assessment

Consistent with the process described in the Overview Document (US EPA 2004b), this risk assessment uses a surrogate species approach in its evaluation for methyl bromide. Toxicological data generated from surrogate test species, which are intended to be representative of broad taxonomic groups, are used to extrapolate the potential effects on a variety of species (receptors) included under these taxonomic groupings. Given the absence of inhalation toxicological data for amphibians, birds were selected as surrogates for terrestrial-phase amphibians. However, it is important to note there are several physiological differences between amphibians and birds that lead to uncertainty in the assessment. There is uncertainty due to the lower inhalation rate for amphibians versus birds. Differences in lung physiology also increase the uncertainty. Amphibian lungs are tidal systems as opposed to bird lungs which are unidirectional. The skin of the terrestrial-phase CTS also acts as an inhalation membrane. The available avian inhalation toxicity data does not account for simple diffusion across the skin.

The acute and chronic assessment endpoints include direct toxic effects on survival, reproduction, and growth of individuals, as well as indirect effects, such as reduction of the food source and/or modification of habitat. Federally-designated critical habitat has been established for the CTS. Primary constituent elements (PCEs) were used to evaluate whether methyl bromide applications have the potential to modify designated critical habitat.

The Agency evaluated registrant-submitted studies and data from the open literature to characterize methyl bromide toxicity. The most sensitive acute and chronic inhalation toxicity values available from acceptable or supplemental studies for each taxon relevant for estimating potential risks to the assessed species and/or their designated critical habitat were used. **Section 4** summarizes the terrestrial ecotoxicity data available on methyl bromide. All ecotoxicity data for methyl bromide is provided in **Appendix G**.

The primary terrestrial exposure route is anticipated to be inhalation. However, acute inhalation data for amphibians are not available. Therefore, toxicity data for birds were used as a surrogate for the terrestrial phase CTS. A 4-hour avian acute inhalation LC_{50} of 561 ppm (MRID 481156-01) was used to evaluate direct effects to the CTS and indirect effects via its amphibian prey (frogs). In addition to the avian inhalation study, a 6-hour inhalation study evaluating the effect on survival from exposure to methyl bromide on mice (MRID 42504101)-was used to estimate the indirect effects to mammals that serve as prey items for the CTS.

As suggested by the herbicidal mode of action for methyl bromide, plants are expected to be sensitive to methyl bromide. However, terrestrial plant studies are not available for methyl bromide. A waiver request for the terrestrial plant seedling emergence study was reviewed and supported by the Agency based on presumed lack of exposure of seeds to methyl bromide given its highly volatile fate characteristics, application methods and plant back interval. However, a waiver request for the terrestrial plant vegetative vigor study was rejected because exposure of terrestrial plants to gas phase methyl bromide could not be precluded and the known phytotoxic properties of methyl bromide. Modifications to the current terrestrial plant vegetative vigor protocol will be necessary to provide information on exposure from methyl bromide gas.

1.2.3. Measures of Risk

Acute risk quotients (RQs) are compared to the Agency's Levels of Concern (LOCs) to identify instances where methyl bromide use has the potential to adversely affect the assessed species or modify their designated critical habitat. When RQs for a particular type of effect are below LOCs, the pesticide is considered to have "no effect" on the species and its designated critical habitat. When RQs exceed LOCs, a potential to cause adverse effects or habitat modification is identified, leading to a conclusion of "may affect". If methyl bromide use "may affect" the assessed species, and/or may cause effects to designated critical habitat, the best available additional information is considered to refine the potential for exposure and effects, and distinguish actions that are Not Likely to Adversely Affect (NLAA) from those that are Likely to Adversely Affect (LAA).

1.3. Summary of Conclusions

Based on the best available information, the Agency makes a May Affect, and Likely to Adversely Affect determination for CTS (all 3 DPSs) from the use of methyl bromide. Additionally, the Agency has determined that there is the potential for modification of designated critical habitat for CTS (all 3 DPSs) from the use methyl bromide.

Direct and indirect effects were evaluated using lines of evidence, including use, potential exposure and toxicity endpoints. **Direct, indirect effects, and habitat modification determinations for the aquatic-phase CTS were evaluated using lines of evidence based on fate and transport properties resulting in a "No Effect" determination. No RQs for the aquatic-phase CTS were calculated.**

Direct Effects

Direct acute effects to the terrestrial-phase CTS due to inhalation were evaluated using the bird as a surrogate. **An "LAA" determination resulted from LOC exceedance for structural tile, timber and space applications of methyl bromide. RQs exceed the endangered species LOCs for horizontal and vertical mechanical release scenarios only at the application rate of 15 lbs./1,000 ft.^{3} corresponding to tile, timber, and space structural fumigant treatments.** Labeled uses at this application rate include tile, timber, and space fumigation which is a QPS-exempted use and space fumigation where only stockpiles are allowed. The highest **RQ of 0.11** exceeds the endangered species LOC of 0.1. **The refined approach using the PERFUM model indicates that an upper-bound downwind distance for concentrations to fall below the LOC is 70 meters (230 feet) from the treated building.** This risk determination was further refined using the probit analysis to estimate the chance of an individual effect. Based on this analysis, the chance of an individual effect at the RQ is ~ 1 in 6.75. Although RQs for structural fumigants suggest that endangered species LOC excedances are marginal, there are several considerations which suggest that this risk concern is not discountable. First, estimates of exposure are developed using PERFUM upper 90th percentile peak (hourly) EECs in air. Therefore, it is possible that there may be cases where air concentrations may actually exceed these levels, although this scenario is not anticipated to occur frequently. Such a scenario may include temperature inversion conditions which are often associated with air stagnation events. In addition, application air monitoring data suggests that maximum air concentrations are within an order of magnitude of the acute EEC in air for the release scenario modeled resulting in the highest EECs in PERFUM. Therefore, this low magnitude departure of modeled values from monitoring values suggests that PERFUM EEC likely depicts some realism. Furthermore, it is entirely possible that there would be horizontal releases close to the ground as depicted from the scenario modeled which result in the maximum upper-bound PERFUM air EEC. In addition, for releases from the tops of buildings, phenomena such as building downwash and convective downdrafts in the wake of buildings may contribute to ground-level exposures of methyl bromide. Similar RQ magnitudes of 0.11 were calculated in PERFUM from a scenario depicting a mechanical release from a 10 foot stack from the top of a 10,000,000 ft.^{3} building corresponding to the 15 lb./1,000 ft.^{3} application rate. However, it is important to note that the bird is used as a surrogate species for the CTS in the absence of an inhalation endpoint value available for the CTS. **There is a "NLAA" determination for food and commodity structural applications (maximum application rate = 9 lbs./1,000 ft.^{3}) of methyl bromide**. The acute RQs using EECs from the refined approach using PERFUM ranged from <0.01 to 0.03.

A "NLAA" determination was also made for pre-plant soil fumigant broadcast applications including broadcast, bedded, and hot gas chemigation tarped applications for peppers, forestry nursery, nursery and ornamentals, sweet potatoes and golf courses and athletic fields. Based on EECs from the refined approach using the PERFUM model, no LOCs were exceeded. The soil fumigant uses resulted in RQs ranging from between 0.02 – 0.09 based on SCREEN3 peak EECs. Although no exceedances occurred at the endangered species LOC using the SCREEN3 model, the PERFUM model was used to further refine this analysis since the upper range of the RQs approached the endangered species LOC, and to address indirect effects risk concerns (see below) for all pre-plant broadcast tarped shank injection, bedded tarped shank injection, and hot gas tarped chemigation applications. RQs developed using the peak upper 90th percentile peak (hourly) EECs from the PERFUM model equaled < 0.01 for all of the evaluated soil fumigation uses.

The "No Effect" determination for pre-plant deep shank untarped applications for orchard replant crops resulted from lack of LOC exceedance based on SCREEN3 peak EECs. The resulting RQ of 0.02 does not indicate a risk of concern directly to the CTS for these applications.

There are also uncertainties with both the exposure and effects aspects of the risk determinations associated with soil fumigant applications. These include the incorporation of field volatility flux profiles from a limited amount of study sites and using the bird as a surrogate for the CTS in the absence of an inhalation endpoint value available for the CTS. However, RQs are much less than the endangered species LOC. Therefore, this wide margin suggests that uncertainties would not preclude the NE or NLAA determinations for direct risks of concern to the CTS related to soil fumigant applications.

Chronic inhalation exposure is not expected to occur with methyl bromide soil fumigation given the one seasonal application occurring on treated fields. For methyl bromide structural fumigation treatments, chronic exposure may occur due to a potentially high frequency of releases which may occur from treated structures. . Upper-bound chronic RQs are presented for indirect effect to mammalian prey based on the comparison of the upper 90th percentile peak (hourly) PERFUM air EECs to the same toxicological endpoint. Lower-bound chronic RQs calculated for indirect effects to mammalian prey based on the comparison of the maximum value from ambient air monitoring concentrations in California to a reproductive mammalian chronic toxicological study indicates that long-term air concentrations are far below the LOC concentration by two orders of magnitude. Although RQs exceed the LOC by a wide margin, the significant departure of the ambient air monitoring value below the LOC concentration suggests that the upper bound RQ based on peak air EECs is discountable. Please refer to the indirect effects section below for further details. It should be noted that the discussion below is relevant for indirect effects to mammalian prey. There is a degree of uncertainty that exists between the extrapolation of this information and its relevance to the direct effects on CTS populations. However, in the absence of other chronic toxicological data, the mammalian data are being used in this characterization discounting direct effects due to chronic exposure to the CTS resulting from structural fumigant applications.

Indirect Effects

Indirect acute effects for the terrestrial-phase CTS are indicated by the potential for reduction in mammal, amphibian, and terrestrial invertebrate prey as well as loss of habitat associated with reduction of mammal burrows. **A LAA determination is made for reduction in prey of mammals using the mouse as a surrogate based on tile, timber, and space structural methyl bromide applications.** The acute inhalation RQ was estimated using the PERFUM model for tile, timber and space applications at the application rate of 15 lb/1000ft^3. The resulting **RQ of 0.32** exceeds the endangered species LOC of 0.1 from timber, tile, and space structural treatments. **The PERFUM model indicates that an upper-bound downwind distance for concentrations to fall below the LOC is also 70 meters (230 feet) from the treated building for indirect effects occurring due to reduction in mammalian prey and loss of habitat from timber, tile, and space treatments (maximum application rate = 15 lbs./1,000 ft.^{3}). For food and commodity uses, an LAA determination is also made** using PERFUM EECs. The resulting **RQ of 0.19** exceeds the endangered species LOC of 0.1 from food and commodity structural uses. **The PERFUM model indicates that an upper-bound downwind distance for concentrations to fall below the LOC is 50 meters from the treated building for indirect effects occurring due to the reduction in mammalian prey and loss of habitat from food and commodity uses (maximum application rate of 9 lbs./1,000 ft.^{3}).**

A "NLAA" determination was made for pre-plant soil fumigant broadcast applications including bedded, broadcast, and hot gas tarped chemigation applications for peppers, forestry nursery, nursery and ornamentals, sweet potatoes and golf courses and athletic fields. No LOC exceedances resulted from the refined approach using PERFUM modeled air EECs. The soil fumigant uses resulted in acute RQs ranging from between 0.05 – 0.27 based on SCREEN3 peak EECs. Since there were some exceedances which occurred at the endangered species LOC using the SCREEN3 model, the PERFUM model was used to further refine this analysis since the upper range of the RQs approached the endangered species LOC. RQs developed using the upper 90^{th} percentile peak (hourly) EECs from the PERFUM model ranged between < 0.01 – 0.02 for all of these uses.

The "No Effect" determination for deep shank untarped pre-plant application for orchard replant crops resulted from lack of LOC exceedance based on SCREEN3 peak EECs. The resulting acute RQ of 0.05 does not indicate a risk of concern directly to the CTS for these applications.

The diet of the terrestrial-phase CTS also includes other amphibians. Therefore, indirect acute effects for the terrestrial CTS are indicated by the potential for reduction in amphibian, and terrestrial invertebrate prey. A LAA determination is made for reduction in prey of frogs using the bird as a surrogate based on tile, timber, and space structural methyl bromide applications. The acute inhalation RQ was estimated using the PERFUM model for tile, timber and space applications at the application rate of 15 lb/1000ft^3. The resulting **RQ of 0.11** exceeds the endangered species LOC of 0.1.

Chronic inhalation exposure is not expected to occur with methyl bromide soil fumigation given the one seasonal application occurring on treated fields. For methyl bromide structural fumigation treatments, chronic exposure may occur due to a potentially high amount of releases which may occur from treated structures. Upper-bound chronic RQs are presented for indirect effect to mammalian prey based on the comparison of the upper 90^{th} percentile peak (hourly) PERFUM air EECs to a reproductive mammalian chronic toxicological study (MRID 00160477). Lower-bound chronic RQs calculated for indirect effects to mammalian prey based on the comparison of the maximum value from ambient air monitoring concentrations in California to the same toxicological endpoint as calculated from upper-bound RQs. Upper-bound chronic RQs are very high ranging between 0.13 – 20.40, and the lower-bound chronic RQs is 0.01. This analysis is shown in **Section 5.1.1.c.** Indirect Effects to CTS (Mammalian Prey) Although the upper-bound RQs exceed the LOC by a wide margin, the significant departure of the ambient air monitoring value two orders of magnitude below the LOC concentration suggests that the upper bound RQs based on peak air EECs are discountable. The calculation of the upper-bound RQ reflects very high conservatism as it is based on a one-hour estimated concentration. The ambient air monitoring data at a 24-hour average concentration for monitoring data in a targeted air shed reflects a more relevant if not conservative chronic exposure concentration in air. Furthermore, the reproductive rat study may represent a conservative endpoint value considering the repetitive 6-hour exposure duration over 11 weeks in the study. It is not anticipated that the CTS mammalian prey would be exposed to this level of continuous exposure considering that structural methyl bromide treatments mainly encompass post-harvesting seasons. Therefore, chronic exposure from releases occurring after structural treatments is discounted considering the high level of conservativeness inherent in the upper-bound RQs, and more realistic but still conservative lower-bound RQs.

Risk is also evaluated for terrestrial invertebrates from both soil and structural applications of methyl bromide. Acceptable toxicity data for terrestrial invertebrates were not available to estimate RQs for terrestrial invertebrate prey of the CTS. Labeled uses of methyl bromide include terrestrial invertebrates as target pests and efficacy data support the presumed toxicity of methyl bromide to soil invertebrates. Therefore, based on these lines of evidence, risk to terrestrial invertebrates is presumed. An analysis utilizing methyl bromide insect pest efficacy data and maximum upper 90th percentile PERFUM peak (hourly) concentrations confirms this presumption, and is shown in **Section 5.2.2.**

In addition to indirect reduction in prey risk determinations, the results from the mammal assessment are also used to evaluate changes in availability of mammal burrows for shelter for the CTS. Based on LOC exceedances for structural uses, adverse effects on the availability of mammal burrows are expected. However, no adverse effects are expected resulting from soil uses as there are no LOC exceedances noted.

Indirect effects to the terrestrial CTS also include effects to terrestrial plants that may contribute to the alteration of habitat. There is the potential for indirect effects based on the uncertainty due to absence of data. Methyl bromide also has a phytotoxic mode of actions leading to a presumption of risk for terrestrial plants for uses of methyl bromide applied as soil and structural fumigants.

Effects to Endpoints used to Assess Critical Habitat

The CTS has designated critical habitat and the results from the indirect effects assessment are used to evaluate the effect of methyl bromide on critical habitat. A “Habitat Modification” determination is made for reduction in prey as well as alteration of the habitat as described above for the indirect effects determination.

A summary of all risk conclusions and effects determinations contributing to the LAA determination is presented in **Table 1-1 and Table 1-2**. Use-specific determinations are provided in **Table 1-3**. Further information on the results of the effects determination is included as part of the Risk Description in **Section 5.2**. Given the LAA determination for the CTS (all 3 DPSs) and potential modification of designated critical habitat for CTS (all 3 DPSs), a description of the baseline status and cumulative effects for CTS is provided in **Attachment 2**.

Table 1-1. Effects determination summary for effects of methyl bromide on the CTS (all 3 DPSs).

Species	Overall Effects Determination	Basis for Determination
California Tiger Salamander (*Ambystoma californiense*)	**May Affect and Likely to Adversely Affect (LAA)**	**Potential for Direct Effects** *Terrestrial phase:* Using birds as a surrogate for the terrestrial-phase CTS, the potential for direct effects to the CTS is expected from labeled methyl bromide uses. Specifically, the avian acute inhalation RQ for structural tile, timber, and space fumigant applications (**0.11) marginally exceed the acute listed species** LOC of 0.1. A probit

Table 1-1. Effects determination summary for effects of methyl bromide on the CTS (all 3 DPSs).		
Species	**Overall Effects Determination**	**Basis for Determination**
		analysis at this RQ resulted in an estimated chance of individual effect of ~1 in 6.75. A spatial analysis indicates overlap between potential methyl bromide application sites and CTS occurrence locations.
		Potential for Indirect Effects
		Terrestrial prey items, riparian habitat The diet of the terrestrial CTS includes frogs, small mammals, and terrestrial invertebrates. As described under direct effects to the CTS, the RQ of 0.11 calculated for birds (used as a surrogate for terrestrial phase CTS) exceeded the acute listed species LOC of 0.1 for structural tile, timber, and space fumigant applications. A probit analysis at this RQ resulted in an estimated chance of an individual effect of ~1 in 6.75. Risk to the terrestrial-phase CTS based on reduction in prey resulted in RQs exceeding the LOC of 0.1 for structural food and commodity uses, as well as tile, timber and space uses. RQs for food and commodity uses based on refined PERFUM modeling ranged from <0.01 to 0.19. RQs for structural tile, timber and space uses based on refined PERFUM modeling ranged from <0.01 to 0.32. The evaluation of mammal risk is also used to evaluate risk from reduction in mammal burrows used for shelter. There is a potential indirect effect from alteration in the environment as reduction in shelter based on the refined PERFUM modeling indicating LOC exceedance. Risk to terrestrial invertebrates from soil and structural applications could not be determined quantitatively using RQs because acute toxicity endpoints were not available for terrestrial invertebrates. Given that methyl bromide is used as a nematicide, it is reasonable to presume risk to terrestrial invertebrate species residing in or near application sites. Risks to terrestrial plants from soil and structural applications of methyl bromide could not be determined quantitatively using RQs because toxicity endpoints for terrestrial plants were not available. However, based on the known herbicidal properties of methyl bromide and one reported incident involving plants, risk to terrestrial plants is presumed. A spatial analysis indicates overlap between potential methyl bromide application sites and the occurrence of CTS prey species.

Table 1-2. Effects determination summary for the Critical Habitat impact analysis.		
Designated Critical Habitat for:	**Effects Determination**	**Basis for Determination**
CTS (all 3 DPSs)	Habitat Modification	Habitat modification mediated by reduction in prey is described under indirect effects for amphibians and terrestrial invertebrates. Habitat modification is indicated based on potential reduction in prey species for the CTS (amphibians and terrestrial invertebrates). The potential for alteration in upland habitat is indicated due to presumed impacts on terrestrial plants and the mammal burrows. Based on the absence of data and mode of action, methyl bromide may indirectly affect the CTS (all 3 DPSs) and/or affect their designated critical habitat by changing the composition of the terrestrial plant community.

Table 1-3. Use specific summary of the potential for adverse effects to terrestrial taxa.						
Potential for Effects to Identified Taxa Found in the Terrestrial Environment						
Uses and Montreal Protocol Designation	**Application Method**	**Small Mammals[2]**	**Small Birds**	**Invertebrates[3]**	**Dicots[4]**	**Monocots[4]**
Orchard Replant (CUE)	Deep Shank	No	No	Yes	Yes	Yes

Table 1-3. Use specific summary of the potential for adverse effects to terrestrial taxa.						
Potential for Effects to Identified Taxa Found in the Terrestrial Environment						
Uses and Montreal Protocol Designation	**Application Method**	**Small Mammals[2]**	**Small Birds**	**Invertebrates[3]**	**Dicots[4]**	**Monocots[4]**
Cucurbits (CUE) Forestry Nursery (CUE) Nursery and Ornamentals (CUE) Strawberries (CUE) Berries (SP) Sweet Potatoes (CUE) Tomatoes (CUE) Golf Courses and Athletic Fields (SP)	Shallow Shank (Broadcast and Bedded) and Hot Gas Tarped Chemigation	No	No	Yes	Yes	Yes
Post Harvest Indoor Food Fumigation (QPS) Commodity Indoor Fumigation (QPS)	Structural	Yes	No	Yes	Yes	Yes
Timber and Tile Indoor Fumigation (CUE) Space Fumigation (SP)	Structural	Yes	Yes	Yes	Yes	Yes

[1]Montreal Protocol Designation Codes: CUE – Critical Use Exemption; QPS – Quarantine and Pre-Shipment Exemption; SP – Stockpile

[2,]A yes in this column indicates a potential for direct and indirect effects to CTS-CC, CTS-SC, and CTS-SB
[3]A yes in this column indicates a potential for indirect effects to CTS-CC, CTS-SC, and CTS-SB
[4]A yes in this column indicates a potential for indirect effects to CTS-CC, CTS-SC, CTS-SB. Risk is evaluated based on the absence of data for and known phytotoxic properties

Based on the conclusions of this assessment, a formal consultation with the U. S. Fish and Wildlife Service under Section 7 of the Endangered Species Act should be initiated.

When evaluating the significance of this risk assessment's direct/indirect and adverse habitat modification effects determinations, it is important to note that pesticide exposures and predicted risks to the listed species and its resources (*i.e.*, food and habitat) are not expected to be uniform across the action area. In fact, given the assumptions of downstream transport (*i.e.*, attenuation with distance), pesticide exposure and associated risks to the species and its resources are expected to decrease with increasing distance away from the treated field or site of application. Evaluation of the implication of this non-uniform distribution of risk to the species would require information and assessment techniques that are not currently available. Examples of such information and methodology required for this type of analysis would include the following:

- Enhanced information on the density and distribution of CTS life stages within the action area and/or applicable designated critical habitat. This information would allow for quantitative extrapolation of the present risk assessment's predictions of individual effects to the proportion of the population extant within geographical areas where those effects are predicted. Furthermore, such population information would allow for a more comprehensive evaluation of the significance of potential resource impairment to individuals of the assessed species.

- Quantitative information on prey base requirements for the assessed species. While existing information provides a preliminary picture of the types of food sources utilized by the assessed species, it does not establish minimal requirements to sustain healthy individuals at varying life stages. Such information could be used to establish biologically relevant thresholds of effects on the prey base, and ultimately establish geographical limits to those effects. This information could be used together with the density data discussed above to characterize the likelihood of adverse effects to individuals.

- Information on population responses of prey base organisms to the pesticide. Currently, methodologies are limited to predicting exposures and likely levels of direct mortality, growth or reproductive impairment immediately following exposure to the pesticide. The degree to which repeated exposure events and the inherent demographic characteristics of the prey population play into the extent to which prey resources may recover is not predictable. An enhanced understanding of long-term prey responses to pesticide exposure would allow for a more refined determination of the magnitude and duration of resource impairment, and together with the information described above, a more complete prediction of effects to individual species and potential modification to critical habitat.

2. Problem Formulation

The purpose of this endangered species assessment is to evaluate potential direct and indirect effects on individuals of the federally Threatened CTS (Central California Distinct Population Segment) and federally Endangered Sonoma County and Santa Barbara County Distinct Population Segments of CTS on agricultural and non-agricultural sites (structural applications) arising from FIFRA regulatory actions regarding registered uses of methyl bromide. Such uses include its application as a pre-plant soil fumigant for replanted orchard trees, peppers, eggplant, cucurbits, forestry nursery, nursery and ornamentals, strawberries, berries, sweet potatoes, tomatoes, golf courses, and athletic fields and for structural applications including related uses on post-harvest commodities and food products as well as multiple purpose space fumigation.

The Santa Barbara and Sonoma County Distinct Population Segments (DPS) of the CTS are listed as endangered and the central population of the CTS is listed as threatened. The Santa Barbara County DPS of the CTS was listed as endangered on September 21, 2000 (65 FR 57241). The Sonoma County DPS of the CTS was listed as endangered on March 19, 2003 (68 FR 13497). On August 4, 2004, the CTS was listed as threatened throughout its range thereby downlisting the Sonoma and Santa Barbara County DPS of the CTS from endangered to threatened (69 FR 47212). Also on this date, the U.S. Fish and Wildlife Service (USFWS) finalized the 4(d) rule, which exempts existing routine ranching activities, for this species throughout its range. On August 19, 2005, the special rule exemption for existing routine ranching activities was upheld, but the downgrading of the Santa Barbara and Sonoma County DPS was vacated. As a result, the endangered species status for the Santa Barbara and Sonoma County DPS of the CTS was reinstated. The CTS is restricted to vernal pools and seasonal ponds in grassland and oak savannah plant communities in central California. However, the downlisting was vacated by the U.S. District Court.

In this assessment, direct and indirect effects to the CTS and potential modification to designated critical habitat for the CTS are evaluated in accordance with the methods described in the Agency's Overview Document (USEPA, 2004b). In accordance with the Overview Document, provisions of the ESA, and the Services' *Endangered Species Consultation Handbook*, the assessment of effects associated with registrations of methyl bromide is based on an action area. The action area is the area directly or indirectly affected by the federal action, as indicated by the exceedance of the Agency's Levels of Concern (LOCs). It is acknowledged that the action area for a national-level FIFRA regulatory decision associated with a use of methyl bromide may potentially involve numerous areas throughout the United States and its Territories. However, for the purposes of this assessment, attention will be focused on relevant sections of the action area including those geographic areas associated with locations of the CTS and their designated critical habitat within the state of California. As part of the "effects determination," one of the following three conclusions will be reached separately for each of the assessed species regarding the potential use of methyl bromide in accordance with current labels:

- "No effect";
- "May affect, but not likely to adversely affect"; or
- "May affect and likely to adversely affect".

Additionally, for habitat and PCEs, a "No Effect" or a "Habitat Modification" determination is made.

A description of routine procedures for evaluating risk to the San Francisco Bay Species is provided in **Attachment 1**.

2.1. Scope

The end result of the EPA pesticide registration process (*i.e.*, the FIFRA regulatory action) is an approved product label. The label is a legal document that stipulates how and where a given pesticide may be used. Product labels (also known as end-use labels) describe the formulation type (*e.g.*, liquid or granular), acceptable methods of application, approved use sites, and any restrictions on how applications may be conducted. Thus, the use or potential use of methyl bromide, in accordance with the approved product labels for California is "the action" relevant to this ecological risk assessment. Only registered uses of the active ingredient methyl bromide will be assessed.

Methyl bromide is a fumigant used on agricultural and nonagricultural sites to control fungi**,** nematodes, weeds and rodents. Methyl bromide is used as a pre-plant soil fumigant for a wide variety of crops including replanted fruit and nut orchard trees, peppers, eggplant, cucurbits, forestry nursery, nursery and ornamentals, strawberries, berries, sweet potatoes, tomatoes, golf courses and athletic fields. Methyl bromide is also used for indoor structural uses on stored post-harvested food and commodity products as well as multiple purpose space fumigation. The end use products of methyl bromide are formulated as solutions and emulsifiable concentrates and rapidly convert to a gas at room temperature and within soil. In addition, pressurized gas formulations of methyl bromide are also used in soil and treated structures.

The Use Verification Memo (**Appendix A**) from Pesticide Re-evaluation Division (PRD) dated December 14, 2011 and the Label Use Information System (LUIS) report received from the OPP's Biological and Economic Assessment Division (BEAD) dated September 19, 2011 (**Appendix L**) list the following use groups for methyl bromide: terrestrial food, terrestrial feed, terrestrial non-food, aquatic non-food, industrial, agricultural soils, nonagricultural soils, greenhouse non-food, and outdoor residential. There are approximately 46 different products containing methyl bromide in concentrations ranging from 33-100% active ingredient.

Terrestrial (outdoor) non-food uses and indoor food and non-food uses have the highest potential for risk of concern to CTS in their habitats given the exposure scenario inherent with outdoor soil fumigant applications and the resulting exposure from outdoor releases associated with aeration of fumigated buildings. **Section 2.4** provides additional details regarding all of the active uses of methyl bromide.

Although current registrations of methyl bromide allow for use nationwide, this ecological risk assessment and effects determination addresses currently registered uses of methyl bromide in portions of the action area that are reasonably assumed to be biologically relevant to the CTS and their designated critical habitat. Further discussion of the action area for the CTS and their critical habitat is provided in **Section 2.5**.

2.1.1. Evaluation of Degradates

Methyl bromide degrades primarily by hydrolysis and biotic soil degradation to form the bromide ion and methanol. Refer to **Section 2.3** for a complete characterization on the formation and decline of these degradates. However, these degradates are not expected to be of toxicological concern since methyl bromide is unlikely to be available in large quantities over a long enough duration for these degradates to form in the soil. Furthermore, methyl bromide possesses acute and chronic toxicity endpoints that are between 1,393 – 20,000 times more toxic than the bromide ion to aquatic species. For mammal species, the bromide ion is not expected to be of toxicological concern (memo from D. Ritter, Health Effects Division, to Jeff Kempster, Registration Division, dated 4/19/89). In addition, acute and chronic toxicity endpoints for methanol are between 20 and 13,575 times less toxic than methyl bromide for aquatic organisms and 82 times less toxic for acute terrestrial organisms (inhalation). Therefore, methyl bromide is considered the stressor of concern in this risk assessment. Please refer to **Appendix B** for additional clarification and justification of this conclusion.

2.1.2. Evaluation of Mixtures

The Agency does not routinely include, in its risk assessments, an evaluation of mixtures of active ingredients, either those mixtures of multiple active ingredients in product formulations or those in the applicator's tank. In the case of the product formulations of active ingredients (that is, a registered product containing more than one active ingredient), each active ingredient is subject to an individual risk assessment for regulatory decision regarding the active ingredient on a particular use site. If effects data are available for a formulated product containing more than one active ingredient, they may be used qualitatively or quantitatively in accordance with the Agency's Overview Document and the Services' Evaluation Memorandum (U.S., EPA 2004b; USFWS/NMFS 2004). **Table 2-1** shows currently available labeled multiple active ingredients for methyl bromide.

As discussed in U.S. EPA (2000), a quantitative component-based evaluation of mixture toxicity requires data of appropriate quality for each component of a mixture. In this mixture evaluation, an LD_{50} with associated 95% CI is needed for the formulated product. The same quality of data is also required for each component of the mixture. Given that the formulated products with multiple active ingredients for methyl bromide do not have toxicity data available, it is not possible to undertake a quantitative or qualitative analysis for potential interactive effects.

Table 2-1. Products containing multiple active ingredients.

FORMULATED PRODUCT INFORMATION			PRODUCT TOXICITY		TOXICITY ADJUSTED FOR ACTIVE INGREDIENT	
PRODUCT/TRADE NAME	EPA Reg.No.	% Methyl Bromide	LC 50 (mg/kg)	CI (mg/kg)	LC50 (mg/kg)	CI (mg/kg)
DOWFUME MC-33 FUMIGANT	00337700017	67	Not Available		-	-
M-B-R 75	00337700030	75			-	-
TERR-O-GAS 70 PREPLANT SOIL	00578500019	70			-	-

Table 2-1. Products containing multiple active ingredients.						
FORMULATED PRODUCT INFORMATION			PRODUCT TOXICITY		TOXICITY ADJUSTED FOR ACTIVE INGREDIENT	
PRODUCT/TRADE NAME	EPA Reg.No.	% Methyl Bromide	LC 50 (mg/kg)	CI (mg/kg)	LC50 (mg/kg)	CI (mg/kg)
FUMIGANT			Not Available			
TERR-O-GAS 98	00578500022	98			-	-
TERR-O-GAS 45	00578500023	45			-	-
TERR-O-GAS 67	00578500024	67			-	-
TERR-O-GAS 33 PREPLANT SOIL FUMIGANT	00578500025	33			-	-
TERR-O-GAS 57 PREPLANT SOIL FUMIGANT	00578500028	57			-	-
GLC TERR-O-GAS 75 PREPLANT SOIL FUMIGANT	00578500040	75			-	-
TERR-O-GAS 80	00578500047	80			-	-
TERR-O-GAS 50	00578500048	50			-	-
67-33	00578500052	67			-	-
PIC-BROM 33	00853600005	67			-	-
PIC-BROM 55	00853600006	45			-	-
PIC-BROM 43	00853600007	56.6			-	-
PIC-BROM 50	00853600009	50			-	-
PIC BROM 25	00853600011	75			-	-
PIC-BROM 67	00853600020	33			-	-
67-33 PREPLANT SOIL FUMIGANT	00862200013	67			-	-
75-25 PREPLANT SOIL FUMIGANT	00862200015	75			-	-
50-50 PREPLANT SOIL FUMIGANT	00862200039	50			-	-
57-43 PREPLANT SOIL FUMIGANT	00862200040	57			-	-
80-20 PREPLANT SOIL FUMIGANT	00862200044	80			-	-
MBC-33 SOIL FUMIGANT	00885300003	67			-	-
TRI-CON 57/43 PREPLANT SOIL FUMIGANT	01122000004	57			-	-
TRI-CON 67/33	01122000007	67			-	-
TRI-CON 75/25	01122000008	75			-	-
TRI-CON 50/50	01122000010	50			-	-
TRI-CON 45/55	01122000011	45			-	-
REDDICK BRO-MEAN C-2R	03773300005	98			-	-

Table 2-1. Products containing multiple active ingredients.						
FORMULATED PRODUCT INFORMATION			PRODUCT TOXICITY		TOXICITY ADJUSTED FOR ACTIVE INGREDIENT	
PRODUCT/TRADE NAME	EPA Reg.No.	% Methyl Bromide	LC 50 (mg/kg)	CI (mg/kg)	LC50 (mg/kg)	CI (mg/kg)
REDDICK BRO-MEAN C-33	03773300006	67	Not Available		-	-
TRI-CON 80/20	05826600001	80			-	-
DOWFUME MC-33 FUMIGANT	00337700017	67			-	-
M-B-R 75	00337700030	75			-	-

* Mammal inhalation toxicity data shown in table.

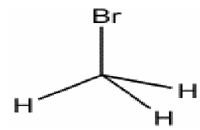
2.2. Previous Assessments

The most recent risk assessment was completed in June 2005 in support of the Agency's reregistration program (USEPA, 2004c). The 2005 risk assessment indicated no concern via the inhalation route of exposure for birds or mammals. However, to complete the risk assessment, an inhalation toxicity study for birds was requested and has since been submitted to the Agency. This study has been reviewed and will be considered in this assessment.

Based on the 2005 risk assessment, the Agency has released a Reregistration Eligibility Decision (RED) for methyl bromide in 2009. The RED has incorporated many changes in the use pattern of methyl bromide including establishing several mitigation requirements during application and reducing the uses for only a few crops. These mitigation measures were implemented mainly due to human worker and bystander risk issues related to methyl bromide soil fumigation applications. In addition, the Agency has taken into account the various provisions in the Montreal Protocol, mandating the phase out of ozone depleting substances such as methyl bromide, to determine uses that were eligible for reregistration. The Montreal Protocol designated Critical Use Exemptions (CUEs) and Quarantine and Pre-Shipment Exemptions (QPS) from the phase-out for certain methyl bromide uses for soil fumigant treatments and structural fumigation treatments. Therefore, conclusions from the previous risk assessment may change in this risk assessment based upon the uses deemed eligible for reregistration in the 2009 RED. Refer to **Section 2.4** on the details of the phase-out and current uses of methyl bromide.

2.3. Environmental Fate Properties

Methyl bromide is colorless gas at room temperature and standard atmospheric pressure with a boiling point of 4.5°C. It is highly soluble and has high vapor pressure. Based on the Henry's Law Constant and dissipation half-life in water of 72 minutes, volatilization of methyl bromide from soil and water surfaces is expected to be significant fate processes. Once it is volatilized, methyl bromide degrades in the upper troposphere and stratosphere through its reaction with the hydroxyl radical. Methyl bromide is relatively persistent in air with and lifetime of 303 days. The pertinent physical, chemical, and environmental fate properties relating to methyl bromide are illustrated in **Table 2-2**.

Table 2-2. Physical and chemical properties of methyl bromide.		
Property	**Value and units**	**MRID or Source**
Structure		EPISUITE
Chemical Formula	CH_3Br	Tomlin, 1994
Molecular Weight	94.94 g/mol	Tomlin, 1994
Vapor pressure (25°C)	1,620.13 torr	Tomlin, 1994
Henry's Law Constant	7.34×10^{-3} atm·m^3/mol	Yates and Gan, 1998
Water Solubility (25°C)	15,200 mg/L	Horvath, 1982
Octanol – water partition coefficient (log K_{OW})	1.18	EPISUITE
Half-life in air (troposphere) (days)	210	Atkinson, 1989

Laboratory studies indicate that methyl bromide is affected by hydrolysis (half-lives of between 11 and 15 days) as well as aerobic and anaerobic soil metabolism (half-lives of between 6 to 59 days). These processes are expected to be important in degradation of methyl bromide left in the soil following its major loss by volatilization. In soils, the rate of degradation is highly variable but appears to be correlated to the amount of organic matter contained in the soil. Soils rich in organic matter have shown greater rates of degradation than soils low in organic matter. Field management practices also significantly affect the relative amounts of methyl bromide volatilization following fumigation. Covering a field with a tarp immediately following fumigation has been shown to be an effective technique at increasing degradation and attenuating the amount of methyl bromide which is volatilized to the atmosphere. Please refer to **Section 2.4** on the details of the required field management practices required for methyl bromide. The most recent estimates for the total lifetime of atmospheric methyl bromide is approximately 0.7 years outlasting methyl bromide retention times in soil and water by a very wide margin. In the troposphere, the rate of degradation is highly dependent upon the concentration of photochemically produced hydroxyl radicals which varies spatially and temporally. Degradation of methyl bromide in the stratosphere is more dependent on direct photolysis (*hv* processes).

According to the FAO classification, methyl bromide is expected to be highly mobile ($K_{oc} \leq 32.01$ ml/g) and could ultimately leach into ground water. However, the expected rapid soil loss of the chemical by volatilization and degradation will reduce the potential for leaching. The reported limited detection of methyl bromide in ground water strongly suggest that although methyl bromide is very mobile in soils, it is either volatilized or degraded before migrating to lower soil horizons and contaminating groundwater. Furthermore, methyl bromide applied to a field has the potential to move into nearby surface water by runoff in dissolved form. However, this potential is expected to be low for the same reasons stated earlier for ground water. In conclusion, it appears that the most important dissipation pathway for methyl bromide is partitioning into the atmosphere by volatilization. Quantities of methyl bromide left in the soil are expected to be insignificant compared to that released into the atmosphere. Therefore, methyl bromide exposure, in this assessment, is considered to be mainly associated with volatilization.

Table 2-3 lists the environmental fate properties of methyl bromide. The open literature has been used to fulfill many outstanding data gaps related to the environmental fate. Details describing evidence for the behavior of methyl bromide in the environment is described below.

Table 2-3. Summary of methyl bromide environmental fate properties.

Study	Value and unit	Major Degradates[4,6]	MRID # or Citation	Study Classification, Comment
Abiotic Hydrolysis	MRID 42720201 $t_{½}$ = 11 days (pH 5, 25°C) $t_{½}$ = 11 days (pH 7, 25°C) $t_{½}$ = 15 days (pH 9, 25°C) Papiernik et al., 2000 $t_{½}$ = 20 days (pH 7, 25°C) Gentile et al., 1989 $t_{½}$ = 29 days (pH 3, 18°C) $t_{½}$ = 19 days (pH 5, 18°C) $t_{½}$ = 12 days (pH 7, 18°C) $t_{½}$ = 9 days (pH 8, 18°C) $t_{½}$ =28 days (pH 3, 30°C) $t_{½}$ = 18 days (pH 5, 30°C) $t_{½}$ = 10 days (pH 7, 30°C)	Bromide ion (pH 5, 7, and 9) and Methanol (pH 5, 7, and 9)	42720201 Papiernik et al., 2000 Gentile et al., 1989	Acceptable
Aqueous Photolysis	$t_{½}$ = 9 days	Bromide Ion and Methanol	Atkinson, 1989	-
Soil Photolysis	No Data	-	NA	NA
Atmospheric Degradation	Atkinson, 1989 $t_{1/2}$ = 210 days or 0.58 years (troposphere) Butler and Rodriguez, 1996 Lifetime = 35 years (stratosphere) WMO, 2002 Lifetime = 255.68 days or 0.7 years (total atmosphere)	Bromide Ion	Atkinson, 1989 Butler and Rodriguez, 1996 WMO, 2002	NA
Aerobic Soil Metabolism	MRID 40863301 Bi-phasic Half Lives 1rst $t_{1/2}$ = 1.5 days (SL) 2nd $t_{1/2}$ = 20 days (SL) 1rst $t_{1/2}$ = 0.15 days (CL) 2nd $t_{1/2}$ = 19 days (CL)	Bromide Ion and Methanol	40863301	Supplemental

Table 2-3. Summary of methyl bromide environmental fate properties.				
Study	**Value and unit**	**Major Degradates[4,6]**	**MRID # or Citation**	**Study Classification, Comment**
Aerobic Soil Metabolism (continued)	Papiernik et al., 2000 $t_{1/2}$ = 39 days (SL, 0.92% OM) $t_{1/2}$ = 4 days (CL, 2.51% OM) Gan and Yates, 1996 $t_{1/2}$ = 22 days (SL, 0.92 % OM) $t_{1/2}$ = 6 days (LS, 2.51% OM) $t_{1/2}$ = 6 days (CL, 2.99% OM) $t_{1/2}$ = 6 days (NPM, 9.6%, OM) Gan et al., 1994 $t_{1/2}$ = 27 days (SL – moist, 0.92% OM) $t_{1/2}$ = 34 days (SL – moist, 0.65 % OM) $t_{1/2}$ = 57 days (LS – moist, 0.22% OM) $t_{1/2}$ = 11 days (CL – moist, 2.99 % OM) $t_{1/2}$ = 13 days (SL – air dry, 0.92% OM) $t_{1/2}$ = 24 days (SL – air dry, 0.65% OM) $t_{1/2}$ = 39 days (LS – air dry, 0.22% OM) $t_{1/2}$ = 6 days (CL – air dry, 2.99% OM) $t_{1/2}$ = 36 days (SL – oven dry, 0.92% OM) $t_{1/2}$ = 59 days (SL – oven dry, 0.65% OM) $t_{1/2}$ = 27 days (LS – oven dry, 0.22% OM) $t_{1/2}$ = 47 days (CL – oven dry, 2.99% OM)		Papiernik et al., 2000 Gan and Yates, 1996 Gan et al., 1994	
Anaerobic Soil Metabolism	MRID 40863301 Bi-phasic Half Lives 1[rst] $t_{1/2}$ = 6 days (SL) 2[nd] $t_{1/2}$ = 24 days (SL) 1[rst] $t_{1/2}$ = 2 days (CL) 2[nd] $t_{1/2}$ = 20 days (CL)	Bromide Ion and Methanol	40863301	Supplemental
Aerobic Aquatic Metabolism	5 days (freshwater) 36 days (estuary water) 82 days (coastal seawater) 298 days (hypersaline water)	-	Goodwin et al., 1998	NA
Anaerobic Aquatic Metabolism	No Data	-	NA	NA

Table 2-3. Summary of methyl bromide environmental fate properties.				
Study	**Value and unit**	**Major Degradates[4,6]**	**MRID # or Citation**	**Study Classification, Comment**
Mobility, unaged leaching, adsorption/ desorption and aged leaching soil column	K_{oc} = 7.07 mL/g (LS) K_{oc} = 32.01 mL/g (LS) K_{oc} = 17.40 mL/g (L) K_{oc} = 16.38 mL/g (PC)	-	Daelmans and Siebering, 1977	NA
Volatility from Soil (Laboratory)	No Data	-	NA	NA
Volatility from Soil (Field)	See **Table 2-4** for field volatility study descriptions and volatile flux measurements	-	NA	NA
Volatility from Water (Laboratory)	$t_{1/2}$ = 72 minutes	-	Nelly, W.B., 1976	NA
Terrestrial Field Dissipation	St. Helene, CA (MRID No. 00013032) $t_{½}$ = 4 - 6 days (broadcast tarp at 300 lbs. a.i./A removed after 6 days) $t_{½}$ = 11 – 38 days (broadcast tarp at 800 lbs. a.i./A removed after 6 days) Arvin, CA (MRID No. 00013173) $t_{½}$ = 7.98 days (broadcast tarp at 161.71 lbs. a.i./A removed after 11 days) Lodi, CA (MRID No. 0013173) $t_{½}$ = 7.98 days – 9.75 days (broadcast tarp between 121.28 - 161.71 lbs. a.i./A removed after 11 days)	-	00013032 00013173	Supplemental Supplemental
Bio-concentration Factor (BCF) - Species Name	No Data [2]	-	NA	NA

[1] Legend for Soil Types:
- SL = Sandy Loam
- LS = Loamy Sand
- L = Loam
- PC = Peaty Clay
- NPM= Nursery Potting Mix
- CL = Clay Loam

[2] Methyl bromide's Log Kow < 3. Therefore, no data are necessary.

[3] All studies used methyl bromide as the test substance.

[4] Dashes mean no constituents found or measured.

[5] NA means not applicable.
[6] Degradate levels not quantified in studies.

Volatility from Soil and Water

In its previous risk assessment, EFED considered field volatility studies used in supporting the California Department of Pesticide Regulation's risk assessment. It is noted that these studies were used to establish fumigant permitting procedures for methyl bromide applicators statewide. The CALDPR endorsed methyl bromide field volatility study dataset consists of four studies for deep shank untarped applications, two studies for broadcast tarped applications, five studies for bedded tarped applications, and three studies for hot gas tarped chemigation applications. CALDPR used these individual field volatility studies to develop hourly temporal flux profiles composited by application method normalized to a 430 lbs. a.i./A application rate. Please refer to **Appendix F** on the details of the compositing method employed by CALDPR to develop these flux rates, and refer to **Section 2.4** in this chapter on the application methods for methyl bromide. Considering these profiles, the hot gas tarped chemigation method results in the highest hourly flux rate, followed by bedded tarped, deep shank untarped, and finally broadcast tarped applications. Peak hourly fluxes ranged from between 11.93% for hot gas tarped chemigation applications to 1.37% mass loss for broadcast tarped applications. Cumulative fluxes over a 48-hour period ranged from nearly 100% mass loss for hot gas tarped chemigation to 44.5% mass loss for broadcast tarped applications. The reduction in cumulative flux for broadcast tarped applications as compared to hot gas tarped chemigation applications is expected to be directly related to tarp coverage as well as incorporation depths of the application.

Since the previous risk assessment, there has also been another field volatility study submitted by the registrant conducted in Wasco, California (MRID No. 48006001). In this study, Tri-Con 50/50, an even mixture of methyl bromide and chloropicrin, was applied to five one-acre fields. The mixture containing an equivalent rate of 180 lbs. a.i./A of methyl bromide was applied to bare soil of the five fields as follows:

- Field 1 - shallow broadcast shank injection (at 12 inches below the surface) application immediately followed by a low density polyethylene (LDPE) tarp covering to the field
- Field 2 - shallow broadcast shank injection (at 12 inches below the surface) application immediately followed by a high density polyethylene (HDPE) tarp covering to the field
- Field 3 – same as Field 2 except co-applied with potassium thiosulfate
- Field 4 – deep bedded shank injection (at 18 inches below the surface) application immediately followed by HDPE tarp covering to the beds
- Field 5 – deep broadcast shank injection (at 18 inches below the surface) application immediately followed by HDPE tarp covering to the field

Given the application methods allowed on the labels, only Fields 1 and 2 are considered in this risk assessment, since the remaining studies are not representative of the label requirements and specified application methods for labeled methyl bromide soil fumigant use. In this study, peak fluxes ranged from between 23.45% mass loss for Field 1 to 11.93% mass loss for Field 2, and cumulative fluxes ranged from 93.76% for Field 1 to 23.45% mass loss for Field 2 through 396 hours post-application. This field volatility study demonstrates the wide variability that exists with different tarp permeabilities. The tarp applied in Field 2 is most likely the most impermeable given its higher density material as compared to Field 1 and most likely was a key factor in attenuating the methyl bromide emissions from the soil.

The summary of the measured flux from the Wasco, CA field volatility study and the developed CALDPR composited flux profiles for each application method is shown in **Table 2-4** along with the other studies stated above.

Table 2-4. Data obtained from methyl bromide field volatility studies including varied flux measurements for volatility.

Field Volatility Study (Application Rate)	Time Applied	MRID or Study Citation	Study Classification	Maximum Conc. ($\mu g/m^3$)	Peak Flux Rate ($\mu g/m^2 s$)	Cumulative Mass Loss (lbs. /A)
Wasco, CA Sandy Loam Field 1 – Broadcast LDPE Tarped Shank Injection (180 lbs. a.i./A)	June 2 8:26 am	48006001	Supplemental	467.48	224.06 [1] (23.45 % mass loss)	168.77 through 310 hours post-application (93.76 % mass loss)
Wasco, CA Sandy Loam Field 2 – Broadcast HDPE Tarped Shank Injection (180 lbs. a.i./A)	June 2 8:28 am	48006001	Supplemental	177.08	76.00 [1] (11.93 % mass loss)	109.37 through 310 hours post-application (60.76% mass loss)
CALDPR Composite Flux Profile for Broadcast Tarped Studies (430 lbs. a.i./A)	NA	Johnson, 1999	NA	NA	183.68 [2] (1.37 % mass loss)	191.35 through 48 hours post-application (44.50% mass loss)
CALDPR Composite Flux Profile for Bedded Tarped Studies (430 lbs. a.i./A)	NA	Johnson, 1999	NA	NA	889.64 [2] (6.65 % mass loss)	226.57 through 48 hours post-application (52.69% mass loss)
CALDPR Composite Flux Profile for Deep Shank Untarped Studies (430 lbs. a.i./A)	NA	Johnson and Segawa, 2000	NA	NA	222.42 [2] (1.66 % mass loss)	244.41 through 48 hours post-application (56.84% mass loss)

Table 2-4. Data obtained from methyl bromide field volatility studies including varied flux measurements for volatility.						
Field Volatility Study (Application Rate)	**Time Applied**	**MRID or Study Citation**	**Study Classification**	**Maximum Conc. ($\mu g/m^3$)**	**Peak Flux Rate ($\mu g/m^2 s$)**	**Cumulative Mass Loss (lbs. /A)**
CALDPR Composite Flux Profile for Hot Gas Tarped Chemigation Application (430 lbs. a.i./A)	NA	Johnson and Segawa, 2004	NA	NA	1,481.21 [2] (11.06 % mass loss)	429.91 through 48 hours post-application (99.98% mass loss)

1. Peak flux rate refers to the average over ~ 4 hours as per the sampling periods in the field volatility studies.
2. Peak flux rate refers to hourly flux rates as developed in the CALDPR composited temporal flux profiles developed for each methyl bromide soil fumigation application method.
3. NA means not applicable.

The impact of application management practices such as tarp covers, consideration of injection depths, and soil amendments have been investigated in numerous field volatility studies for methyl bromide which are available in the open literature and are summarized below:

(1) Gan et al., 1998: In a Greenfield sandy loam soil from California (0.92% organic carbon), the cumulative volatilization loss of methyl bromide injected at a depth of 60 cm was 75%, 68%, and 45% for an uncovered soil column, a soil column covered with HDPE, and a soil column covered with a high barrier plastic film (Gan et al. 1997). The addition of soil amendments rich in organic matter were also shown to be an effective method of reducing volatilization losses of methyl bromide by enhancing the rate of degradation (Gan et al. 1998). Applying 5% composted manure to soil columns containing methyl bromide reduced volatilization approximately 12 percent as compared to unamended soil columns

(2) Majewski, 1995: Field experiments conducted in Monterey County, California have also demonstrated the effectiveness of covering the treated area following the application of methyl bromide in order to attenuate volatilization. A fumigant composed of methyl bromide/chrloropricrin was injected at a depth of 25 – 30 cm in liquid form at an application rate of 392 kg/ha to fields located approximately 6 km away from each other. One field was immediately covered with a high barrier plastic tarp while the other field was left uncovered. Both fields were a silty clay loam with similar soil texture, moisture content, and organic matter composition. The cumulative volatilization of methyl bromide from the tarpaulin covered field was 22% at five days post-application and about 32% at nine days post application. In contrast, the cumulative volatilization loss of methyl bromide from the uncovered field was about four times greater and occurred earlier in the experiment.

(3) Wang et al., 1997: Methyl bromide was injected at concentrations of about 600 – 700 grams per plot into and Arlington fine sandy loam (64% sand, 29% silt, 7% clay) near Riverside, CA. At an injection depth of 25 cm, the total volatilization losses ranged from between 87%, <42%, and 59% for uncovered plots, watered HDPE tarped plots, and unwatered HDPE tarped plots, respectively. However, at an injection depth of 60 cm, the total volatilization losses were lower at 60 percent, 15 percent, and <15 percent for the same plots respectively.

The volatilization kinetics of methyl bromide in water has also been studied under controlled laboratory conditions. Methyl bromide solution concentrations of 50, 150, and 300 μM were placed in a beaker containing 400 ml of distilled water and gently stirred at ~20°C. In all cases, volatilization occurred rapidly, with volatilization half lives occurring over time periods of less than 2 hours (Gentile et al., 1989). In addition, a peer-reviewed experiment quantified a volatilization half life of 72 minutes with 100 ppm of methyl bromide placed into a cylinder filled with 39.4 cm of water with air bubbled through it for 4 hours at a temperature of 25°C. A mass transfer coefficient of 22.56 cm/hr for methyl bromide dissipation was measured. The 72 minute half-life was determined assuming a first-order rate constant of 0.57 hr^{-1} derived from the measured mass transfer coefficient and initial depth of the water column (Nelly W.B., 1976).

Degradation in Air

Methyl bromide is expected to degrade in the troposphere through its reaction with photochemically produced hydroxyl radicals. Direct photolysis, hydrolysis in water droplets, and degradation by other atmospheric oxidants (i.e., nitrate radicals and ozone) are not expected to be significant degradation pathways for methyl bromide in the troposphere (Butler and Rodriguez 1996). The gas phase hydroxyl radical rate constant of methyl bromide has been measures as 3.81×10^{-14} cm^3/molecule-sec at 25°C (Atkinson, 1989), which corresponds to an atmospheric half-life of about 210 days in the troposphere. However, in the stratosphere, degradation of methyl bromide primarily occurs via photoionization by UV light. Since adsorption of radiation in the actinic region for methyl bromide is weak, the atmospheric lifetime in the stratosphere is very long as it was estimated to be 35 years (Butler and Rodriguez 1996). The WMO has calculated the total global lifetime of atmospheric methyl bromide of 0.7 years. (WMO 2002). The WMO cautions that some uncertainty exists in the magnitudes of the various sources and sinks of methyl bromide in the atmosphere (WMO 2002). Therefore, this lifetime can only be considered a best estimate for the global lifetime of atmospheric methyl bromide.

Field Dissipation

Several terrestrial field dissipation studies were conducted for methyl bromide (MRID Nos. 00013032, 00013173, 00013175, 00161982). All studies involved methyl bromide soil applications followed by immediate tarp coverage of the entire field. For this application method, the current labels for methyl bromide require tarps to be in place for a minimum of five days after the application. Therefore, only a certain set of these studies are applicable for this risk assessment including the four plots studied in St. Helene, CA where tarps were removed six days after the application (MRID 00013032), one plot in Arvin, CA where tarps were removed 11 days after the application (MRID 00013173), and one plot in Lodi, CA where tarps were also removed 11 days after the application (MRID 00013173). Field dissipation half-lives were determined to be in the range between 4 and 11 days and appeared to vary based on the application rate but may have also varied due to weather conditions. No field dissipation studies were conducted for deep shank injection/untarped applications, bedded tarped application, and hot gas applications (see **Section 2.4** on the use characterization). It is noted that the observed field dissipation half-lives of 4 and 10 days is probably a reflection of volatility (which was not measured) rather than degradation.

Degradation in Water

The known degradation of methyl bromide in water occurs through hydrolysis. Hydrolysis of methyl bromide occurs through a S_N2 nucleophilic substitution reaction, resulting in the formation of methanol and the bromide anion as shown in the net reaction below:

$$CH_3Br + H_2O \longrightarrow CH_3OH + Br^- + H^+$$

In this study, methyl bromide degraded rapidly by hydrolysis with half lives ranging from 9 to 29 days in alkaline and acidic environments over a temperature range of 18°C – 30°C. Methanol and the bromide ion were detected at major levels (> 10 percent of the overall material balance) at the end of each study (Gentile et al., 1989).

Direct photolysis in water is not expected to be significant for methyl bromide. Dark controls verify similar degradation rates to hydrolysis studies in the absence of light.

Degradation in Soil

It has been suggested that methyl bromide reacts with nucleophilic sites in soil organic matter resulting in the methylation of the organic matter and the release of the bromide anion (Papiernik et al. 2000). This reaction is abiotic in nature as was demonstrated by the degradation kinetics of methyl bromide in an Arlington sandy loam (74.6% sand, 18.0% silt, 7.4% clay, 9.2 g/kg organic carbon, pH = 6.73) and a Linne clay loam (36.7 % sand, 32.0% silt, 31.3% clay, 25.1 g/kg organic carbon, pH = 6.80) under sterile and non sterile conditions (Papiernik et al., 2000). The observed half-life of methyl bromide in the Arlington sandy loam was approximately 39 and 46 days in non-autoclaved and autoclaved samples, respectively. The half-lives were about four days in both non autoclaved and autoclaved Linne clay loam samples. Therefore, abiotic processes were apparently largely responsible for the observed degradation since the degradation rates were not significantly different in the autoclaved versus the non-autoclaved soil experiments.

The greater content of organic matter in the Linne c1ay loam resulted in much greater degradation rates than in the lower organic containing Arlington sandy loam. This observation is supported by data reported by Gan and Yates (1996) which showed a similar correlation between the degradation rate of methyl bromide and soil organic matter content. In four soils containing 0.92%, 2.51 %, 2.99%, and 9.60% organic matter, the half lives of methyl bromide were reported to be 22, 6, 6, and 6 days, respectively with no statistically significant difference in degradation rates in sterilized versus non-sterilized soils (Gan and Yates 1996). Similar results were observed in studies using Kimberlina sandy loam (63.1 % sand, 13 % silt, and 11.9% clay) and Panoche clay loam (43.1 % sand, 17% silt, and 39.9% clay) under aerobic and anaerobic conditions (MRID 40863301).

Under aerobic conditions, methyl bromide degradation was observed to be bi-phasic with initial half-lives of 35 hours and 47 hours in non sterilized and sterilized sandy loams, respectively. The second half-lives were reported to be 20 and 18 days in non sterilized and sterilized sandy loams, respectively. It is noted that the average initial half-life of methyl bromide in the clay was 3.8 hours and 2.5 hours in non-sterilized and sterilized clay loams, respectively. The second half-lives were 19 and 11 days in non-sterilized and sterilized clays, respectively.

Under anaerobic conditions the initial methyl bromide half-life was 39 and 34 hours for the unsterilized and sterilized clays, respectively. The second half-lives were reported as 20 days for the unsterilized clay loam and 18 days for the sterilized clay loam (MRID 40863301).
The average initial half-life was 144 hours for the non sterilized sandy loam and 80 hours for the sterilized loam. The second half-lives were reported to be 24 days for the unsterilized sandy loam and 21 days for the sterilized loam. Correlation analysis between the degradation rate constant and the properties of the soil indicated that the degradation of methyl bromide is highly correlated with the amount of organic matter contained in moist and air dried soils, but not oven dried soils (Gan et al., 1996). The regression derived equations provided by the study authors were:

$k_{air\text{-}dried} = 0.0090 + 0.0174 * \%OM$ ($r^2 = 0.999$)
$k_{moist} = 0{:}0116 + 0.0364 * \%OM$ ($r^2 = 0.989$)

where each k represents the first-order degradation rate constant in terms of $days^{-1}$ and *%OM* reflects the percentage of organic matter contained in the soil. Half lives of approximately 11 to 33 days and 6 to 39 days were calculated for the 4 soils under moist and air dried conditions while half-lives of roughly 27 to 59 days were estimated in the oven-dried soil experiments.

The microbial degradation of methyl bromide was shown to be enhanced significantly under aerobic conditions in methanotrophic soils (soils containing bacteria that readily oxidize methane) (Ou 1998). Using methantrophic soils and an application rate of 11,000 μg/g, methyl bromide degraded completely within 40-90 hours under aerobic conditions. At a lower application rate of 10 μg/g, methyl bromide degraded completely in five hours under aerobic conditions, but degraded very slowly under anaerobic conditions (Ou 1998). The primary degradation products of methyl bromide from methanotrophic microbes have been reported as formaldehyde and the bromide anion (Ou 1998). While pointing out these results, the authors also noted that the majority of agricultural soils in the U.S are not methanotropic and have low methane oxidizing capabilities. Very low levels of methyl bromide were shown to degrade rapidly in agricultural (corn field) and highly organic forest soils obtained from southern New Hampshire under aerobic conditions (Hines et al. 1998). In these experiments, low concentrations of methyl bromide (10 ppb) degraded completely within minutes in the forest soil and within hours in the agricultural soil. Almost no degradation occurred in autoc1aved soils or soils that had previously been sterilized by the addition of antibiotics twelve hours earlier confirming that the source of degradation was biological. The authors reported that experiments using high levels of methyl bromide (10 to 10,000 ppm) resulted in toxicity to the microbes and slowed degradation rates. Experiments conducted under a nitrogen rich environment showed little degradation of methyl bromide for any of the soils tested, suggesting that biodegradation is very slow under anaerobic conditions. Although biodegradation under anaerobic conditions is considered to occur slowly in the environment, Oremland et al. (1994) demonstrated that methyl bromide may react with free sulfide commonly found in anaerobic sediments and salt marshes resulting in the production of methylated sulfur reaction products, which in turn degrade by sulfate reducing bacteria.

Mobility in Soil

USDA reports K_{oc} values of methyl bromide in the range of 9 - 22 mL/g, but no experimental details were provided (USDA 2004). Daelemans and Siebering (1977) measured soil adsorption isotherms of methyl bromide in loam and peaty clay soils at different moisture contents. The K_{om} (soil adsorption coefficient normalized with organic matter) ranged from 4.10 -18.37 mL/g in the loamy sand and was between 10.09 and 9.50 mL/g in the loam and peaty clay, respectively. Using the relationship $K_{oc} \sim 1.724 \times K_{om}$ (Lyman et al. 1990), these K_{om} values correspond to K_{oc} values in the range of approximately 7 -32 mL/g.

Adsorption and desorption of methyl bromide was studied in four different soil types at several different methyl bromide concentrations (MRID 00157128). The amount of methyl bromide adsorbed to the soils increased with increasing methyl bromide concentration and the adsorption was reversible. It was observed that 89-97% desorption of methyl bromide bound to the surface of soils was achieved with a single washing.

The relatively low K_{oc} for methyl bromide suggests that this compound will not adsorb strongly to soils, possesses high mobility, and could ultimately leach into groundwater. However, the rapid volatilization and degradation rates of methyl bromide in soil will along with its tendency to volatilize will reduce the potential of this chemical to leach. The lack of detection of methyl bromide in ground water (refer to **Section 3.2.2**) strongly suggests that although methyl bromide is very mobile in soils, it is either volatilized or degraded before migrating to lower soil horizons and contaminating groundwater.

Bioconcentration

Bioaccumulation of methyl bromide is not expected in fish or aquatic organisms due to its low Log K_{ow} value of 1.18 (K_{ow}= 15.1).

2.3.1. Atmospheric Environmental Issues

Given methyl bromide's relatively high persistence in the atmosphere and its halogenated structure (bromine and methyl group), it has the potential to contribute two phenomena: ozone depletion and global warming. Ozone depletion is expected to increase the penetration of harmful ultraviolet radiation to the Earth's surface while global warming is expected to cause many undesired consequences resulting from the increase in the earth temperature. Ozone depletion can lead to CTS populations being exposed to elevated levels of ultraviolet radiation, and studies have shown that amphibians are especially sensitive (see **Section 5.2.2** for further details). Global warming can have adverse impacts on the CTS and obligate species beyond the toxicological impacts resulting from methyl bromide applications. Given methyl bromide's high persistence in the atmosphere, it is not expected to contribute to reactions with atmospheric nitrogen oxides (N_{ox}) resulting in the production ground-level ozone.

2.3.2. Environmental Transport Mechanisms

The main transport mechanism for methyl bromide is its partition into air and movement as gas from treated field or structures leading to deposition onto nearby or more distant ecosystems. Since methyl bromide is persistent with an atmospheric half-life much greater than two days, long range transport of methyl bromide in the atmosphere is likely. Given methyl bromide's high Henry's Law Constant value, methyl bromide is expected to mainly remain, as gas, in the air once lost from the soil after fumigation. In addition, methyl bromide has been detected in very frequently in air monitors nearby methyl bromide applications, in ambient air sheds with high volume methyl bromide use, and global-scale methyl bromide air monitoring sites. Please refer to **Section 3.1.2** for air monitoring data in air sheds within California where methyl bromide applications occur as well as global air monitoring methyl bromide data for evidence of regional and long range atmospheric transport of methyl bromide. Also, please refer to **Section 5.2.1** on the characterization related to the long range transport potential and overall persistence of methyl bromide in the environment.

Transport from processes such as pesticide surface water runoff and leaching in soils are not expected to be dominant given the non significant quantities of methyl bromide that are expected to be available for runoff or leaching in the soil system. The reasons for the presence of insignificant quantities of methyl bromide following treatment to soil and structures are the chemical's tendency to rapidly volatilize from soil and water (high vapor pressure and Henry's low constant) resulting in small retention times in these compartments of the environmental soil and water. Please refer to **Section 2.9** on the full justification for the limited aquatic exposure expected associated with methyl bromide applications.

2.3.3. Mechanism of Action

The mechanism of toxicity of methyl bromide has not been definitively established. It has been proposed that the toxic effects of methyl bromide in animal species are due to direct cytotoxic actions of methyl bromide or a methyl bromide metabolite, possibly through alkylation of proteins (WHO 1995). In terrestrial mammals, central nervous system toxicity appears related to the incorporation of methyl bromide or the methyl moiety into tissues (WHO 1995). In fish, methyl bromide exposure results in dose-related degenerative effects to the epithelia of gills and the oral mucosa (Webster et al. 1998, Webster and Vos 1994), which ultimately lead to death due to suffocation (Segers et al. 1984). Although the mechanism of toxicity in fish had not been proven, morphololgical damage to gills and mucosal membranes are indicative of alkylation of cell membranes (Segers et al. 1984). No mechanism of toxicity for methyl bromide has been established or proposed for other aquatic species. There is no proven mechanism for the phytotoxic effects of methyl bromide, although it has been proposed that excessive accumulation of the bromide ion by plants produces toxic effects (WHO 1995). In carnation plants exposed to methyl bromide by soil fumigation, plant survival and flower yield were inversely proportional to inorganic bromide concentration in the soil (Kempton and Maw 1974). However, it is also possible that some of the phytotoxic effects of methyl bromide are due to indirect actions, such as the elimination of beneficial microorganisms from soil (MRID 00118842, Lambert et al. 1979).

2.4. Use Characterization

Analysis of labeled use information is the critical first step in evaluating the federal action. The current labels for methyl bromide represent the FIFRA regulatory action; therefore, labeled use and application rates specified on the label form the basis of this assessment. The assessment of use information is critical to the development of the action area and selection of appropriate modeling scenarios and inputs.

Methyl bromide is a broad spectrum fumigant on agricultural and non-agricultural sites to control nematodes, soil-borne diseases, insects and weeds. In addition, methyl bromide is used indoors to treat structures and stored food products and commodities for multiple purpose pest control targeting spiders, mites, fungi, plants, insects, nematodes, rodents, and snakes. There are approximately 48 different products containing methyl bromide in concentrations ranging from 33 - 100% active ingredient. As mentioned in **Section 2.3**, methyl bromide uses have been by in-large phased out due to the Montreal Protocol of 1987 which mandated the phase-out of all ozone depleting substances by January 1, 2005. The phase-out effectively bans the manufacturing and importing of methyl bromide in the United States. However, the Montreal Protocol allowed for certain exemptions from the manufacturing and importation restrictions for certain uses of methyl bromide, and these were enacted on January 1, 2005. The first exemption is known as a critical use exemption (CUE) which applies for pre-plant soil fumigation uses and applies specifically for orchard replant, peppers, eggplant, cucurbits, forestry nursery, nursery and ornamentals, strawberries, sweet potatoes, and tomato pre-plant soil uses. In addition, methyl bromide is registered for uses on berries (including but not limited to raspberries and blueberries), golf courses and athletic fields. However, leftover methyl bromide stockpiles are only permitted for these uses. The second exemption allowed under the Montreal Protocol where recently manufactured and imported methyl bromide can be used is known as a quarantine and pre-shipment (QPS) exemption for methyl bromide. In general, this exemption applies for the use of methyl bromide on food and commodities stored in buildings or cargo holds that are eventually distributed domestically or imported. As with the soil uses, other indoor uses of methyl bromide such as space fumigation inside of buildings are only allowed with available stockpiles. The uses that only allowed with methyl bromide stockpiles will decline over time as supply declines. In addition, the CUE and QPS exemptions are re-evaluated by the EPA Office of Air and Radiation every year. Over time, it is anticipated that these exemptions will be phased-out gradually. Further information on the phase-out of methyl bromide may be found at http://www.epa.gov/ozone/mbr/.

The Label Use Information System (LUIS) report, received from the OPP's Biolgical and Economic Analysis Division dated September 19, 2011 and a memo from the Pesticide Re-evaluation Division at the Office of Pesticide Programs dated December 14, 2011 list the following use groups for methyl bromide: terrestrial-greenhouse food, greenhouse, non-food, terrestrial non-food, terrestrial feed, forestry, agricultural soils, nonagricultural soils, greenhouse non-food, indoor food, indoor non-food, and indoor residential. There are approximately 46 different active products containing methyl bromide in concentrations ranging from 33 - 100% active ingredient. **Table 2-5** and **Table 2-6** present the current uses and corresponding application rates, methods of application, as well derived from labels for methyl bromide relevant to this risk assessment for soil fumigant and structural uses, respectively. Eleven cropped uses and four general indoor use patterns have been identified as the current active labeled uses of methyl bromide. The tables also provide the Montreal Protocol exemptions and other uses where only stockpiled methyl bromide products are allowed.

Table 2-5. Methyl bromide soil fumigant use information based on labels.

Uses and Montreal Protocol Designation[1]	Formulation[2]	Application Methods	Methyl Bromide Maximum Single Application Rate (lb a.i./A)[4]	Maximum Number of Applications per Year (#)	Maximum Seasonal Application Rate (lb ai/A)	Application Interval[3] (days)
Orchard Replant (CUE)	EC, CG	• Deep Shank Injection Untarped (EC and CG)	400	1	400	NA
Peppers (CUE)	EC, CG, HG	• Broadcast Shank Injection Tarped (EC and CG) • Bedded Shank Injection Tarped (EC and CG) • Hot Gas Tarped Chemigation (HG only)	396		396	NA
Eggplant (CUE)	EC, CG, HG		240		240	
Cucurbits (CUE)	EC, CG, HG		240		240	NA
Forestry Nursery (CUE)	EC, CG, HG		400		400	NA
Nursery and Ornamentals (CUE)	EC, CG, HG		400		400	NA
Strawberries (CUE)	EC, CG, HG		282		282	NA
Berries (SP)	EC, CG, HG		240		240	NA
Sweet Potatoes (CUE)	EC, CG, HG		400		400	NA
Tomatoes (CUE)	EC, CG, HG		264		264	NA

Table 2-5. Methyl bromide soil fumigant use information based on labels.						
Uses and Montreal Protocol Designation[1]	**Formulation[2]**	**Application Methods**	**Methyl Bromide Maximum Single Application Rate (lb a.i./A)[4]**	**Maximum Number of Applications per Year (#)**	**Maximum Seasonal Application Rate (lb ai/A)**	**Application Interval[3] (days)**
Golf Courses and Athletic Fields (SP)	EC, CG, HG	• Broadcast Shank Injection Tarped (EC and CG) • Hot Gas Tarped Chemigation (HG only)	400		400	NA

[1]Montreal Protocol Designation Codes: CUE – Critical Use Exemption; QPS – Quarantine and Pre-Shipment Exemption; SP – Stockpile
[2]Formulation codes: EC - Emulsifiable Concentrate; G - Granular; RTU – Ready to use; HG – Hot Gas; CG – Compressed Gas
[3]NA – Not Applicable
[4]Values represent maximum application rates on the labels. These rates are not adjusted for the area treated for application methods such as bedded tarped shank injection.

Table 2-6. Methyl bromide indoor structural use information based on labels.					
Uses and Montreal Protocol Designation[1]	**Formulation[2]**	**Methyl Bromide Maximum Single Application Rate (lb a.i./ 1,000 ft.³)**	**Maximum Number of Applications per Year (#)**	**Maximum Seasonal Application Rate**	**Application Interval (days)**
Post-Harvest Indoor Food Fumigation (QPS)[4]	CG	9	NS	Unknown	NS
Commodity Indoor Fumigation (QPS)[4]	CG	9			
Timber and Tile Indoor Fumigation (QPS)	CG	15			

Table 2-6. Methyl bromide indoor structural use information based on labels.					
Uses and Montreal Protocol Designation[1]	**Formulation[2]**	**Methyl Bromide Maximum Single Application Rate (lb a.i./ 1,000 ft.[3])**	**Maximum Number of Applications per Year (#)**	**Maximum Seasonal Application Rate**	**Application Interval (days)**
Space Indoor Fumigation (SP)	CG	15	NS	Unknown	NS

[1]Montreal Protocol Designation Codes: CUE – Critical Use Exemption; QPS – Quarantine and Pre-Shipment Exemption; SP – Stockpile
[2]Formulation codes: EC - Emulsifiable Concentrate; G - Granular; RTU – Ready to use; HG – Hot Gas; CG – Compressed Gas
[3]NS - Not specified on label
[4]There are a few food and commodity uses listed in the LUIS Report (Appendix L) at an application rate of 12 lbs./1,000 ft.[3] for grain mills. However, these uses are very limited at most in California as per the Health Effects Division Risk Assessment (Appendix K).

The Agency's Biological and Economic Analysis Division (BEAD) provided an analysis from the California's Department of Pesticide Regulation Pesticide Use Reporting (CDPR PUR) database[1] . CDPR PUR is considered a more comprehensive source of usage data than US Department of Agriculture's National Agricultural Statistics Service (USDA-NASS) or EPA proprietary databases, and thus the usage data reported for methyl bromide by county in this California-specific assessment were generated using CDPR PUR data. Sixteen years (1994-2009) of usage data were provided. Data from CDPR PUR were obtained for every pesticide application made on every use site at the section level (approximately one square mile) of the public land survey system. BEAD summarized these data to the county level by site, pesticide, and unit treated. Calculating county-level usage involved summarizing across all applications made within a section and then across all sections within a county for each use site and for each pesticide. The county level usage data that were calculated include: average annual pounds applied, average annual area treated, and average and maximum application rate across all eight years. The units of area treated are also provided where available. Finalized usage data for 2010 in California is not available at this time.

[1] The CDPR's Pesticide Use Reporting database provides a census of pesticide applications in the state. See http://www.cdpr.ca.gov/docs/pur/purmain.htm.

Despite the restrictions of methyl bromide use as mandated by the Montreal Protocol, methyl bromide continues to be used in California. Figure 2-1 shows that methyl bromide use in California has decreased by roughly 50 percent since 1994 by 2001. However, despite methyl bromide applications being restricted to stockpile, QPS, and CUE uses starting in 2005, the amount of total methyl bromide applied per year in California has not changed appreciably since 2001 as 5.5 million pounds of methyl bromide was still used statewide in 2009.

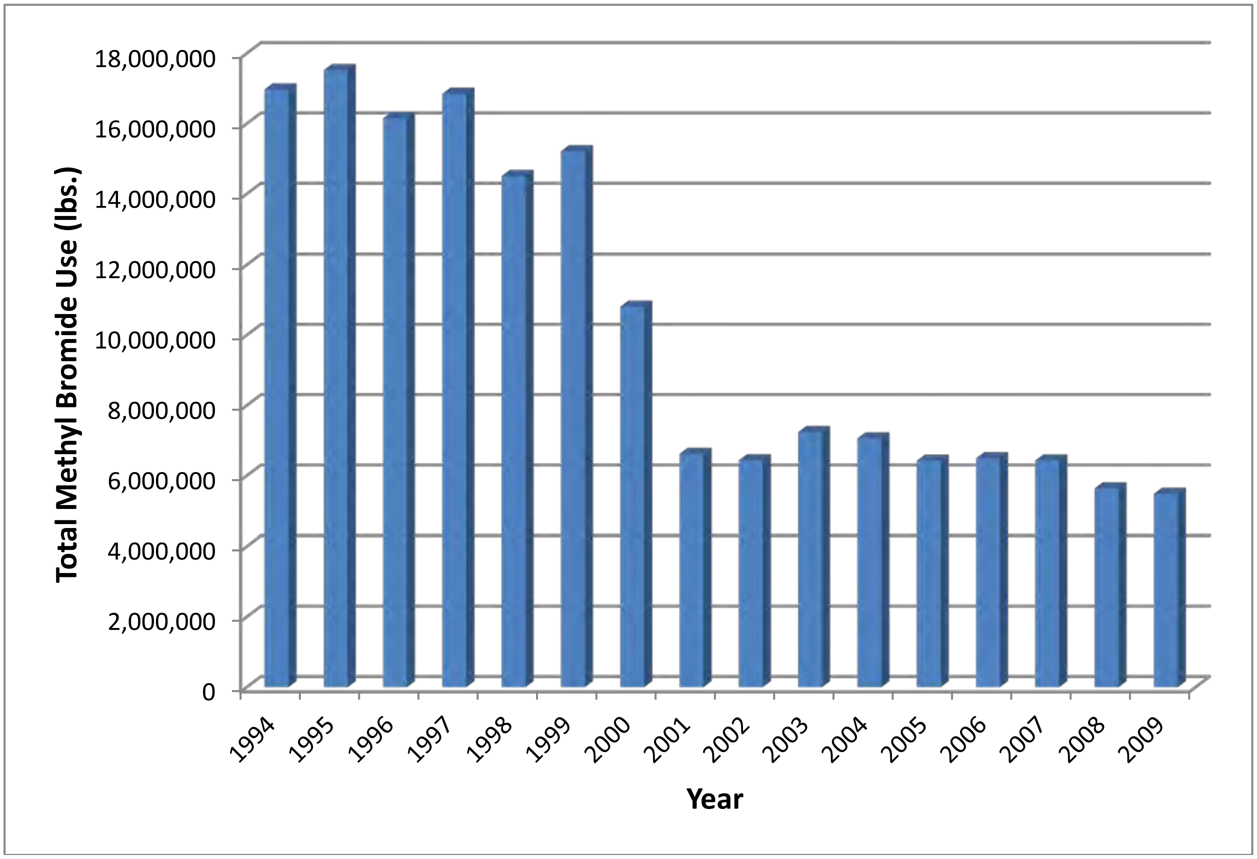


Figure 2-1. Total methyl bromide use in California by year between 1994 – 2009.

Figure 2-2 shows the average annual usage in various counties in California between 2005 – 2009 when Montreal Protocol restrictions were fully implemented. Highest usage (>1 million lbs. of methyl bromide) was reported in Monterrey County, and above 500,000 lbs. of methyl bromide was reported in Ventura and Santa Cruz counties.

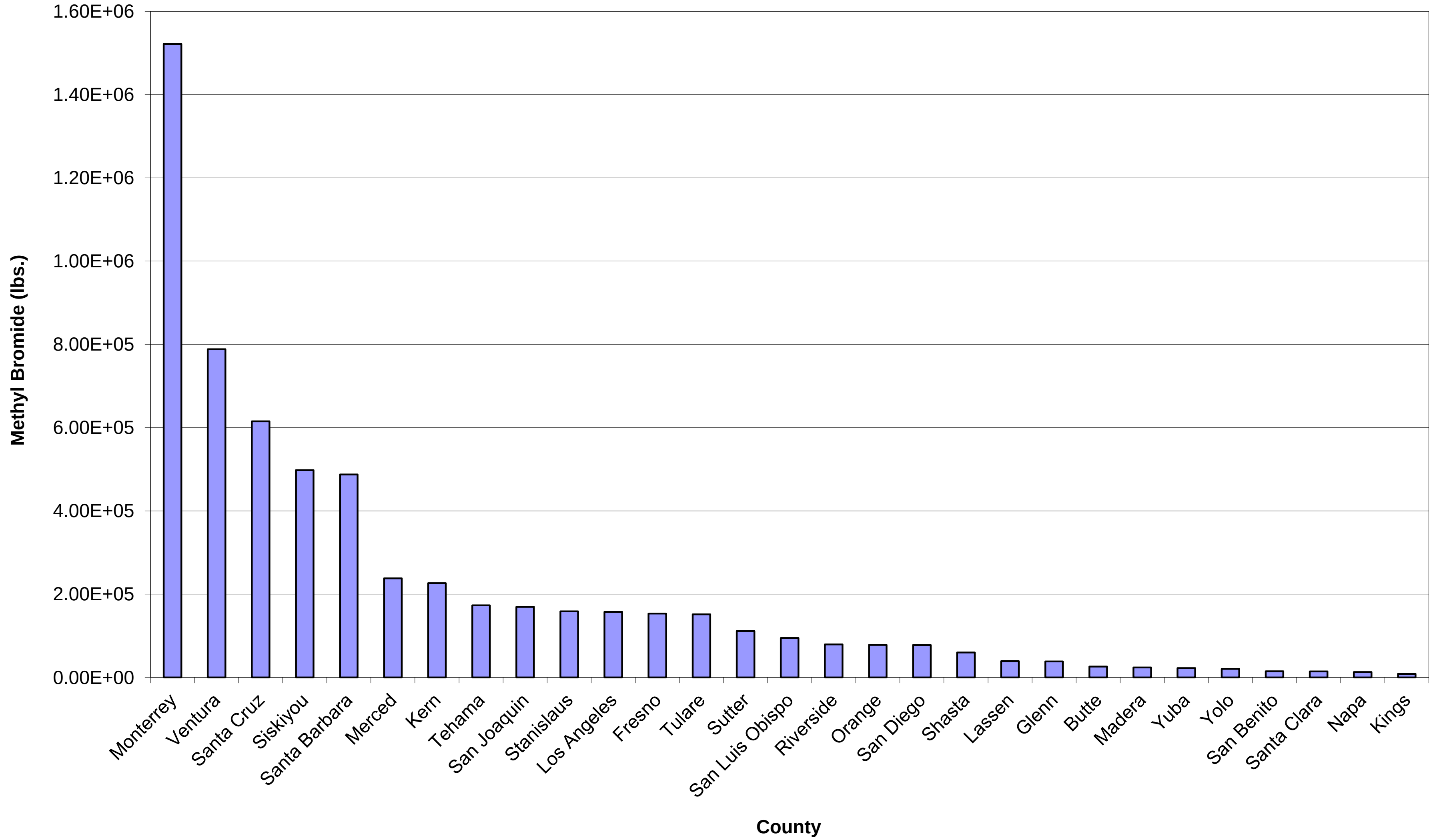


Figure 2-2. Estimated agricultural use of methyl bromide in California by County (average use between 2005 – 2009).

*Counties shown represent 99.5 percent of methyl bromide average use in California between 2005 – 2009.

Table 2-3 shows the distribution of average methyl bromide applications between 2005 - 2009 by use site in California. Pre-plant soil fumigant treatments for strawberries (45%), nursery plants (14%), nut orchards (4%), raspberries (3 %), and unspecified pre-plant soil fumigation (18%) accounts for the major usage of methyl bromide in California. In addition, methyl bromide indoor uses on commodities account for 2% the overall use in California. It is anticipated that use on grapes, turf and sod, and raspberries will decline as stockpiles of methyl bromide are depleted over time.

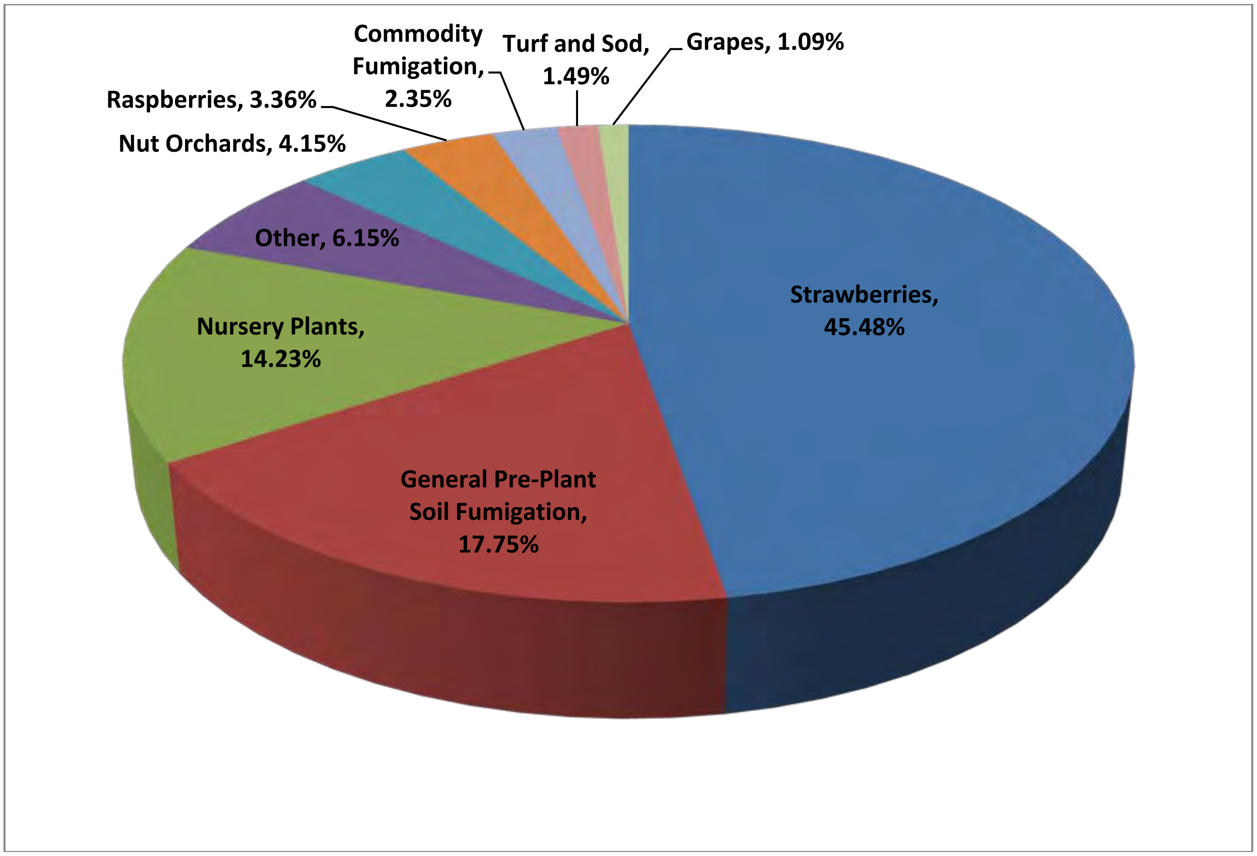


Figure 2-3. Estimated agricultural use of methyl bromide in California by crop (average use between 2005 – 2009).

Methyl Bromide Soil Fumigant Application Methods and Field Management Practices

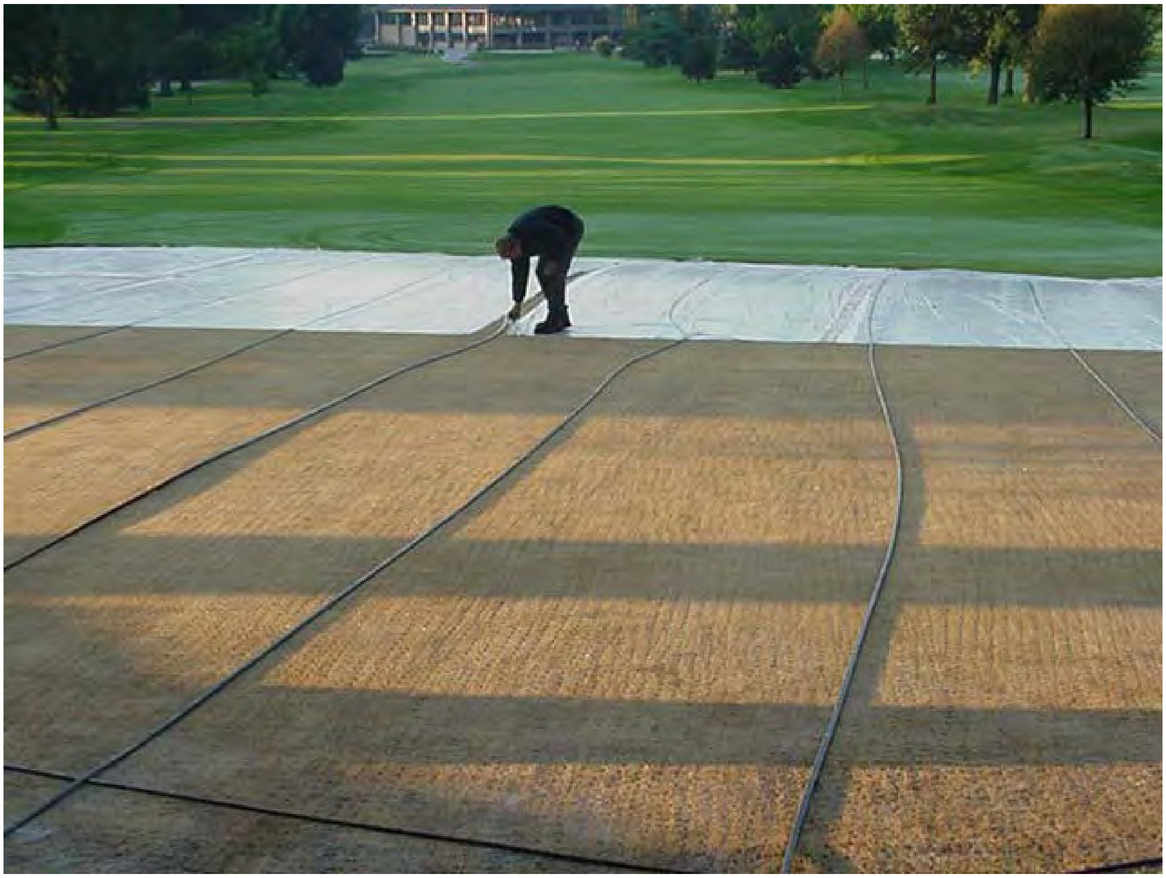
Table 2-5 specifies certain application methods by pre-plant treatment for crops. These application methods, illustrated in **Figure 2-4, Figure 2-5, and Figure 2-6**, show a shank injection broadcast (flat fume) application, a shank injection bedded tarped application, and a hot gas tarped chemigation application, respectively.

Credit: http://www.goodfruit.com

Figure 2-4. Photograph showing flat fume or broadcast shank injection application followed by tarp covering.

Credit: EPA, 2005b

Figure 2-5. Photograph showing shank injection application to raised beds followed by tarp covering.



Credit: http://hendrixanddail.com/

Figure 2-6. Photograph showing hot gas tarped chemigation application.

Soil fumigant labels for methyl bromide contain specific restrictions related to field management practices such as minimum shank injection depths and tarping practices with each application method specified for all of the uses shown in **Table 2-5**. These include the following:

Deep Shank Injection Untarped Application:

- Minimum shank injection depth = 18 cm below the ground
- Maximum field size = 40 acres

Broadcast Shank Injection Tarped Application:

- Minimum shank injection depth = 8 cm below the ground
- Minimum days to remove tarp from field = 5 days after application
- Maximum field size = 100 acres

Bedded Shank Injection Tarped Application:

- Maximum shank injection depth = No deeper than deepest point of the tuck of the tarp on both sides of the bed (~1 inch below the adjacent furrow surface)
- Tarps remain over top of beds and holes in tarp are cut where planting occurs
- Maximum field size = 100 acres

Hot Gas Tarped Chemigation Application:

- Surface tube chemigation with tarped application
- Minimum days to remove tarp from field = 5 days after application
- Maximum field size = 10 acres

There are a variety of tarps used to reduce emissions from the fumigated field. Low density polyethylene (LDPE) and high density polyethylene (HDPE) are most commonly used for tarping methods. Recently, high barrier impermeable films [e.g., virtually impermeable film (VIF) and totally impermeable film (TIF)] are becoming more widely available on the market to reduce emissions from the fumigated field.

Methyl Bromide Indoor Structural Fumigant Applications

For indoor uses, methyl bromide is typically applied as a gas under pressurized cylinders or pumped into buildings or cargo holds/fumigation chambers at application rates up to the maximum indoor air concentration specified on the t label. Typically, the dose concentration is distributed homogeneously inside the building and is maintained at a constant dose level for up to 24 hours. Leakage from the building often requires continuing input of additional fumigant mass into the building. After 24 hours, buildings must be aerated using either mechanical (active) methods whereby methyl bromide gas flow streams are directed through vents or stacks to the outdoors and/or passive methods whereby windows and doors are opened allowing for air to naturally flush out the structure. Sufficient aeration time is needed for people to re-enter the buildings as they are vacant during treatment for safety concerns. Only indoor concentrations and dosing times are specified on indoor fumigant labels. There are no gas stream flow rates for mechanical ventilation specified on the label. Typically, labels and the State of California (CALEPA, 2004) require aeration times or release periods of six hours occur for smaller buildings ($\leq$ 250,000 ft.^{3}) or between 12 – 24 hours for larger buildings (up to 10,000,000 ft.^{3}).

2.5. Assessed Species

Table 2-7 provides a summary of the current distribution, habitat requirements, and life history parameters for the listed species being assessed (CTS). More detailed life-history and distribution information can be found in **Attachment 3**. The distribution of CTS within California is presented in **Figure 2-7**.

There are currently three CTS Distinct Population Segments (DPSs): the Sonoma County (SC) DPS, the Santa Barbara (SB) DPS, and the Central California (CC) DPS. Each DPS is considered separately in the risk assessment as they occupy different geographic areas and therefore, the main difference in this assessment will be in the spatial analysis. The CTS-SB and CTS-SC were downlisted from endangered to threatened in 2004 by the USFWS, however, the downlisting was vacated by the U.S. District Court. Therefore, the Sonoma and Santa Barbara DPSs are currently listed as endangered while the CTS-CC is listed as threatened. CTS utilize vernal pools, semi-permanent ponds, and permanent ponds, and the terrestrial environment in California. The aquatic environment is essential for breeding and reproduction and mammal burrows are also important habitat for aestivation.

Table 2-7. Summary of current distribution, habitat requirements, and life history information for the CTS.						
Assessed Species	**Size**	**Current Range**	**Habitat Type**	**Designated Critical Habitat?**	**Reproductive Cycle**	**Diet**
California Tiger Salamander (CTS) (*Ambystoma californiense*)	50 g	CTS-SC are primarily found on the Santa Rosa Plain in Sonoma County. CTS-CC occupies the Bay Area (central and southern Alameda, Santa Clara, western Stanislaus, western Merced, and the majority of San Benito Counties), Central Valley (Yolo, Sacramento, Solano, eastern Contra Costa, northeast Alameda, San Joaquin, Stanislaus, Merced, and northwestern Madera Counties), southern San Joaquin Valley (portions of Madera, central Fresno, and northern Tulare and Kings Counties), and the Central Coast Range (southern Santa Cruz, Monterey, northern San Luis Obispo, and portions of western San Benito, Fresno, and Kern Counties). CTS-SB are found in Santa Barbara County	Freshwater pools or ponds (natural or man-made, vernal pools, ranch stock ponds, other fishless ponds); Grassland or oak savannah communities, in low foothill regions; Small mammal burrows	Yes	Emerge from burrows and breed: fall and winter rains Eggs: laid in pond Dec. – Feb., hatch: after 10 to 14 days Larval stage: 3-6 months, until the ponds dry out, metamorphose late spring or early summer, migrate to small mammal burrows	Aquatic Phase: algae, snails, zooplankton, small crustaceans, and aquatic larvae and invertebrates, smaller tadpoles of Pacific tree frogs, CRLF, toads; Terrestrial Phase: terrestrial invertebrates(insects and worms), small mammal pups and frogs

[1]For more detailed information on the distribution, habitat requirements, and life history information of the assessed listed species, see **Attachment 2.**

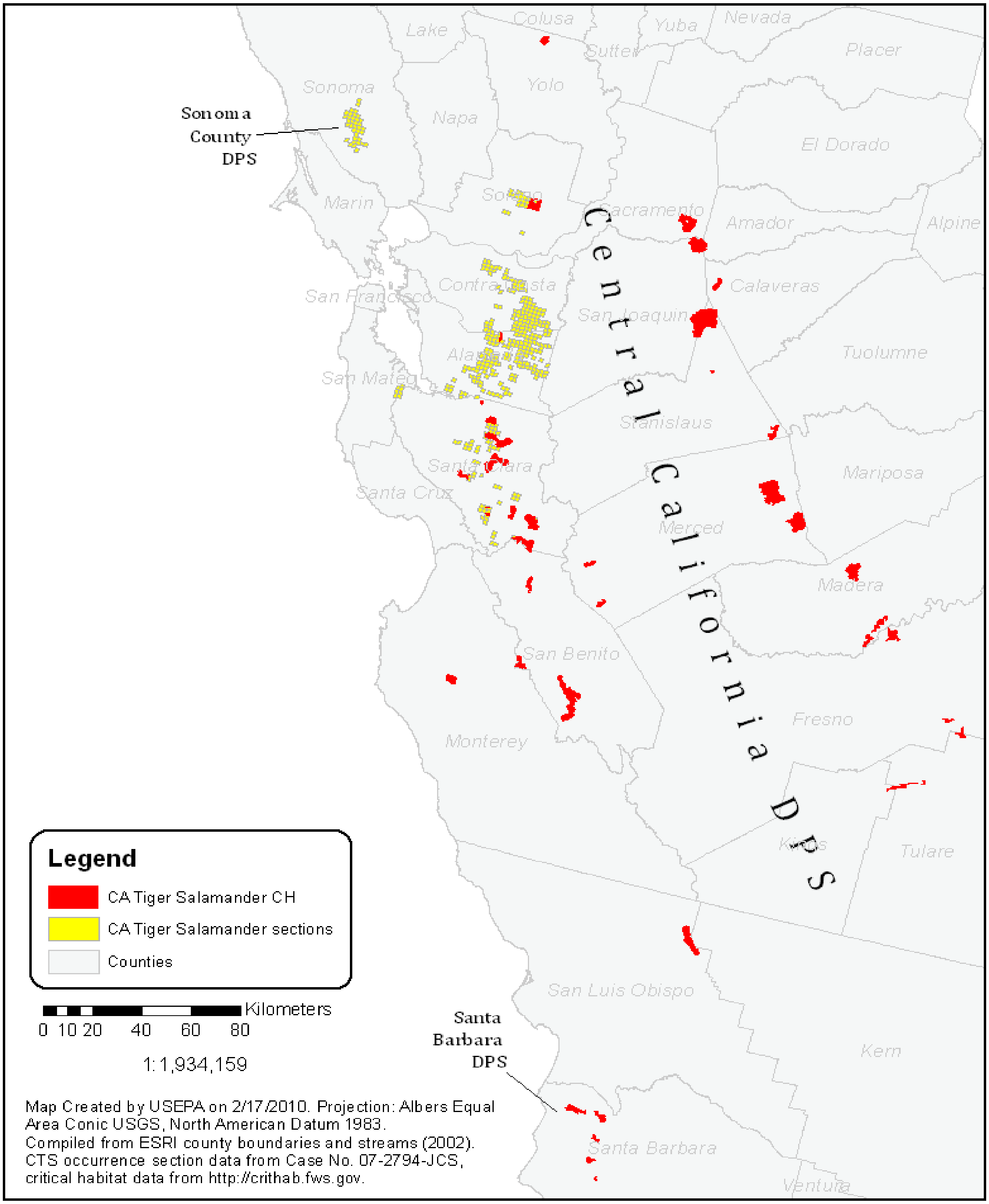


Figure 2-7. California tiger salamander critical habitat and occurrence sections identified in Case No. 07-2794-JCS

2.6. Designated Critical Habitat

Critical habitat has been designated for the CTS. Risk to critical habitat is evaluated separately from risk to effects on the species. 'Critical habitat' is defined in the ESA as the geographic area occupied by the species at the time of the listing where the physical and biological features necessary for the conservation of the species exist, and there is a need for special management to protect the listed species. It may also include areas outside the occupied area at the time of listing if such areas are essential to the conservation of the species. Critical habitat designations identify, to the extent known using the best scientific and commercial data available, habitat areas that provide essential life cycle needs of the species or areas that contain certain primary constituent elements (PCEs) (as defined in 50 CFR 414.12(b). **Table 2-8** describes the PCEs for the critical habitats designated for the CTS.

Table 2-8. Designated critical habitat PCEs for the CTS.

Species	PCEs	Reference
California tiger salamander	PCE 1. Standing bodies of fresh water, including natural and man-made (*e.g.*, stock) ponds, vernal pools, and dune ponds, and other ephemeral or permanent water bodies that typically become inundated during winter rains and hold water for a sufficient length of time (*i.e.*, 12 weeks) necessary for the species to complete the aquatic (egg and larval) portion of its life cycle[2]	FR Vol. 69 No. 226 CTS, 68584, 2004
	PCE 2. Barrier-free uplands adjacent to breeding ponds that contain small mammal burrows. Small mammals are essential in creating the underground habitat that juvenile and adult California tiger salamanders depend upon for food, shelter, and protection from the elements and predation	
	PCE 3. Upland areas between breeding locations (PCE 1) and areas with small mammal burrows (PCE 2) that allow for dispersal among such sites	

[1]These PCEs are in addition to more general requirements for habitat areas that provide essential life cycle needs of the species such as, space for individual and population growth and for normal behavior; food, water, air, light, minerals, or other nutritional or physiological requirements; cover or shelter; sites for breeding, reproduction, rearing (or development) of offspring; and habitats that are protected from disturbance or are representative of the historic geographical and ecological distributions of a species.
[2]PCEs that are abiotic, including, physical-chemical water quality parameters such as salinity, pH, and hardness are not evaluated because these processes are not biologically mediated and, therefore, are not relevant to the endpoints included in this assessment.

More detail on the designated critical habitat applicable to this assessment can be found in **Attachment 2.** Activities that may destroy or adversely modify critical habitat are those that alter the PCEs and jeopardize the continued existence of the species. Evaluation of actions related to use of methyl bromide that may alter the PCEs of the designated critical habitat for the CTS form the basis of the critical habitat impact analysis.

As previously noted in **Section 2.1**, the Agency believes that the analysis of direct and indirect effects to listed species provides the basis for an analysis of potential effects on the designated critical habitat. Because methyl bromide is expected to directly impact living organisms within the action area, critical habitat analysis for methyl bromide use is limited in a practical sense to those PCEs of critical habitat that are biological or that can be reasonably linked to biologically mediated processes.

2.7. Action Area and LAA Effects Determination Area

2.7.1. Action Area

The action area is used to identify areas that could be affected by the Federal action. The Federal action is the authorization or registration of pesticide use or uses as described on the label(s) of pesticide products containing a particular active ingredient. The action area is defined by the Endangered Species Act as, "all areas to be affected directly or indirectly by the Federal action and not merely the immediate are involved in the action" (50 CFR §402.2). Based on an analysis of the Federal action, the action area is defined by the actual and potential use of the pesticide and areas where that use could result in effects. Specific measures of ecological effect for the assessed species that define the action area include any direct and indirect toxic effect to the assessed species and any potential modification of its critical habitat, including reduction in survival, growth, and fecundity as well as the full suite of sublethal effects available in the effects literature. It is recognized that the overall action area for the national registration of methyl bromide is likely to encompass considerable portions of the United States based on the large array of agricultural and non-agricultural uses. However, the scope of this assessment limits consideration of the overall action area to those portions that may be applicable to the protection of the CTS and their designated critical habitat within the state of California. For this assessment, the entire state of California is considered the action area. The purpose of defining the action area as the entire state of California is to ensure that the initial area of consideration encompasses all areas where the pesticide may be used now and in the future, including the potential for off-site transport via spray drift and downstream dilution that could influence the San Francisco Bay Species. Additionally, the concept of a state-wide action area takes into account the potential for direct and indirect effects and any potential modification to critical habitat based on ecological effect measures associated with reduction in survival, growth, and reproduction, as well as the full suite of sublethal effects available in the effects literature.

It is important to note that the state-wide action area does not imply that direct and/or indirect effects and/or critical habitat modification are expected to or are likely to occur over the full extent of the action area, but rather to identify all areas that may potentially be affected by the action. The Agency uses more rigorous analysis including consideration of available land cover data, toxicity data, and exposure information to determine areas where CTS and designated critical habitat may be affected or modified via endpoints associated with reduced survival, growth, or reproduction.

2.7.2. LAA Effects Determination Area

A stepwise approach is used to define the Likely to Adversely Affect (LAA) Effects Determination Area. An LAA effects determination applies to those areas where it is expected that the pesticide's use will directly or indirectly affect the species and/or modify its designated critical habitat using EFED's standard assessment procedures (see **Attachment 1**) and effects endpoints related to survival, growth, and reproduction. This is the area where the "Potential

Area of LAA Effects" (initial area of concern + drift distance or downstream dilution distance) overlaps with the range and/or designated critical habitat for the species being assessed. If there is no overlap between the potential area of LAA effects and the habitat or occurrence areas, a no effect determination is made. The first step in defining the LAA Effects Determination Area is to understand the federal action. The federal action is defined by the currently labeled uses for methyl bromide. An analysis of labeled uses and review of available product labels was completed. A distinction has been made between food use crops and those that are non-food/non-agricultural uses. For those uses relevant to the assessed species, the analysis indicates that, for methyl bromide, the following agricultural uses are considered as part of the federal action evaluated in this assessment:

- Orchard Replant
- Peppers
- Eggplant
- Cucurbits
- Forestry Nursery
- Nursery and Ornamentals
- Strawberries
- Berries (e.g., raspberries and blueberries)
- Sweet Potatoes
- Tomato

In addition, the following non-food and non-agricultural uses are considered:

- Golf Courses and Athletic Fields as Turf
- Post-Harvest Indoor Food Fumigation
- Commodity Indoor Fumigation
- Timber and Tile Indoor Fumigation
- Space Indoor Fumigation

Following a determination of the assessed uses, an evaluation of the potential "footprint" of methyl bromide use patterns (*i.e.*, the area where pesticide application may occur) is determined. This "footprint" represents the initial area of concern, based on an analysis of available land cover data for the state of California. The initial area of concern is defined as all land cover types and the stream reaches within the land cover areas that represent the labeled uses described above. For methyl bromide, these land cover types include cultivated crops (e.g., peppers, eggplant, cucurbits, forestry nursery, nursery and ornamentals strawberries, berries, sweet potatoes, and tomatoes), orchard/vineyard (orchard replant for pre-plant treatments), developed open space (golf course and athletic field applications), low/medium/high developed (e.g., turf). A map representing all the land cover types that make up the initial area of concern for methyl bromide outdoor uses is presented in **Figure 2-8**. It is worthy of note that the forestry layer in the initial area of concern for outdoor uses is very broad and is a likely over-representation of the actual area treated with methyl bromide. The initial area of concern showing the spatial extent of methyl bromide indoor structural uses based on 2001 – 2006 CALPUR data is presented separately in **Figure 2-9.** This map shows various classes of real estate development from sparsely developed to highly developed. This map depicts the initial area of concern for methyl bromide use in for multiple-purpose pest control commercial and residential lots.

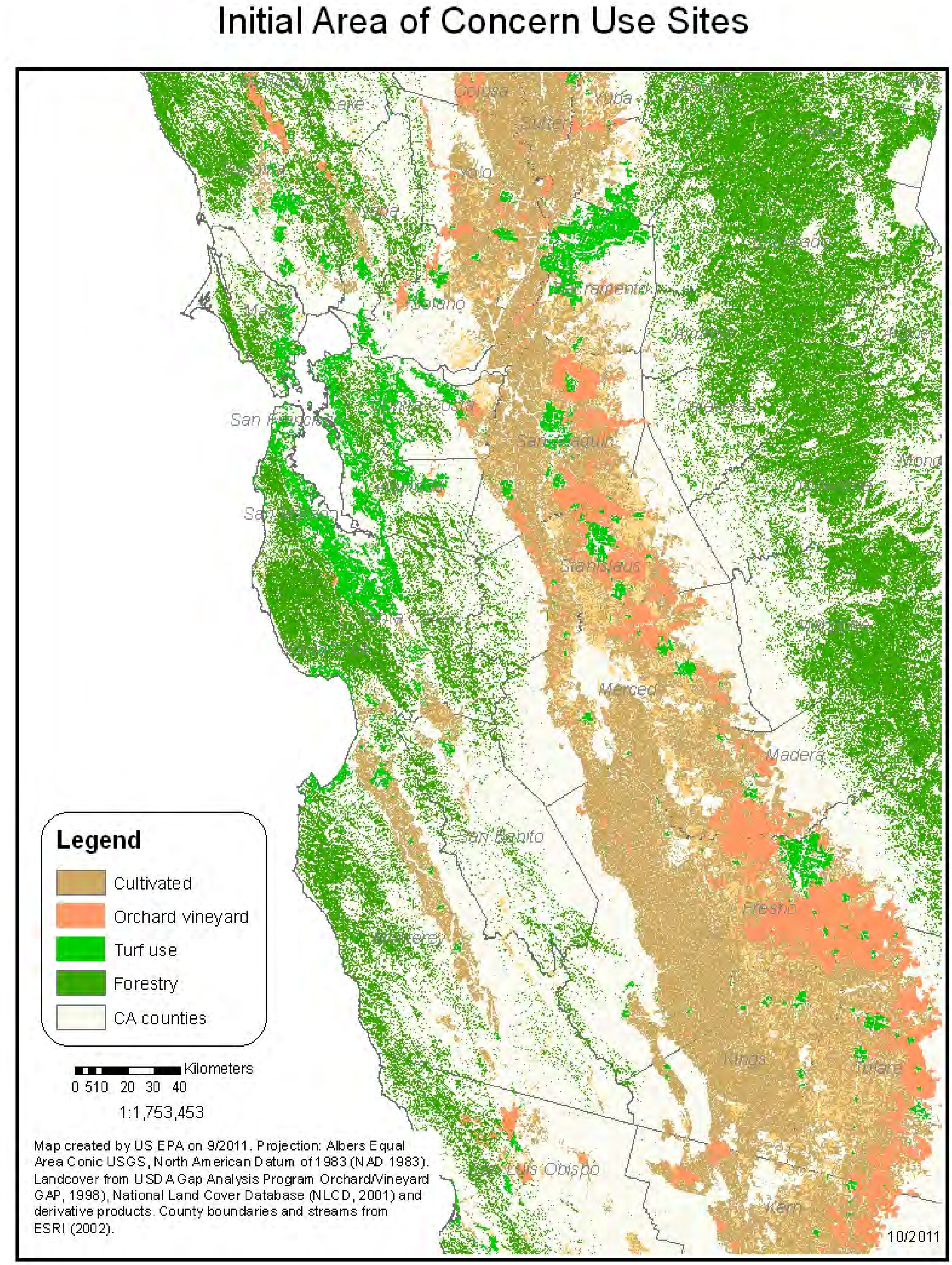


Figure 2-8. Initial area of concern, or "footprint" of potential outdoor uses, for methyl bromide.

* Methyl bromide indoor structural uses are not included in map

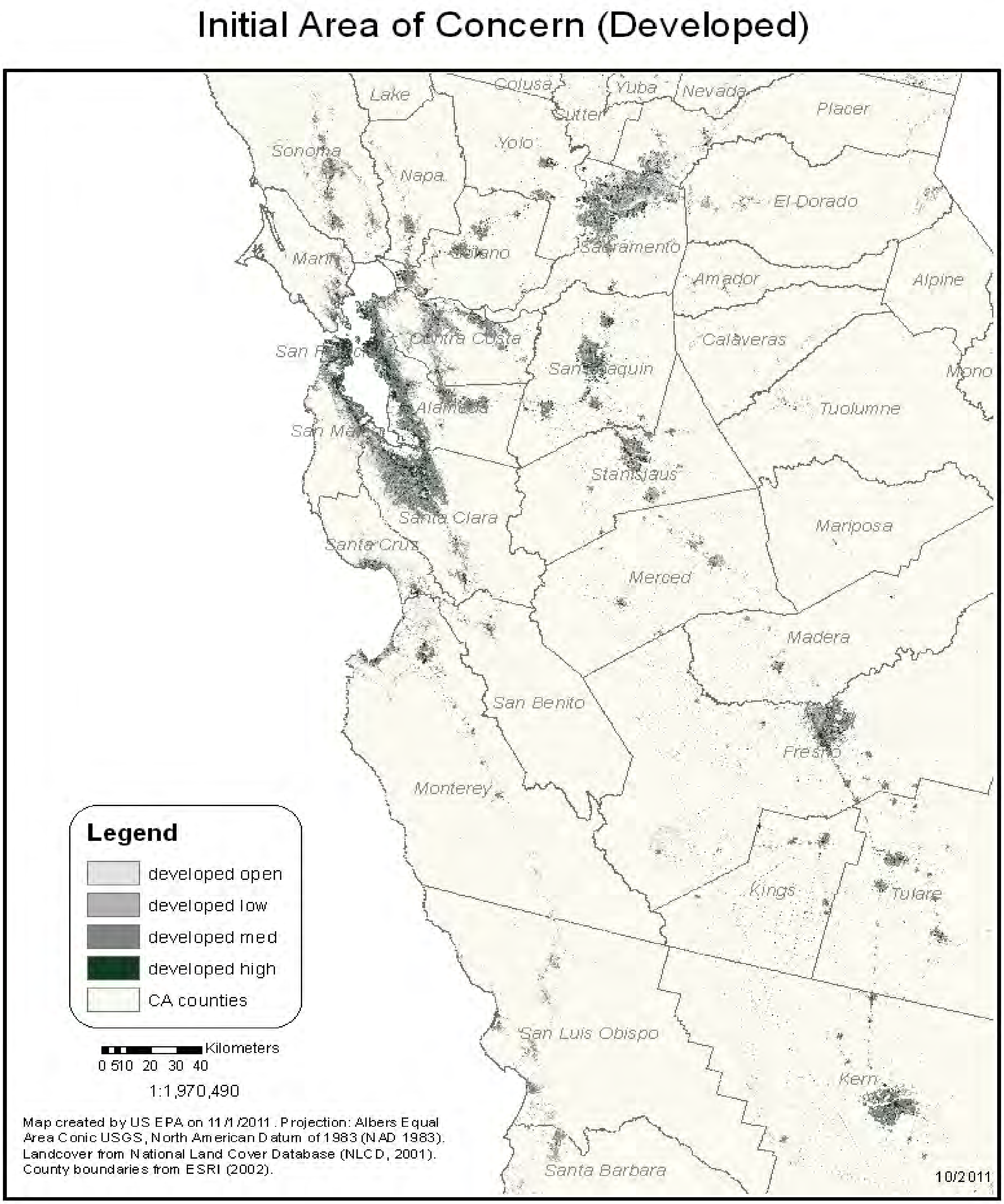


Figure 2-9. Initial area of concern, or "footprint" of potential indoor (structural production) uses, for methyl bromide.

Once the initial area of concern is defined, the next step is to define the potential boundaries of the Potential Area of LAA Effects by determining the extent of offsite transport via runoff where exposure of one or more taxonomic groups to the pesticide will result in exceedances of the listed species LOCs. An evaluation of usage information was conducted to determine the area where use of methyl bromide may impact the assessed species. This analysis is used to characterize where predicted exposures are most likely to occur, but does not preclude use in other portions of the action area. A more detailed review of the county-level use information was also completed. These data suggest that methyl bromide have historically been used on a wide variety of agricultural and non-agricultural uses.

2.8. Assessment Endpoints and Measures of Ecological Effect

2.8.1. Assessment Endpoints

A complete discussion of all the toxicity data available for this risk assessment, including resulting measures of ecological effect selected for each taxonomic group of concern, is included in **Section 4** of this document. **Table 2-9** identifies the taxa used to assess the potential for direct and indirect effects of methyl bromide on the CTS. The specific assessment endpoints used to assess the potential direct and indirect effects to CTS are provided in **Table 2-10**. For more information on the assessment endpoints, see **Attachment 1**.

Table 2-9. Taxa used in the analyses of direct and indirect effects for the CTS.

Listed Species	Birds	Mammals	Terr. Plants	Terr. Inverts.
California tiger salamander	Direct	Direct Indirect (prey/ habitat)	Indirect (habitat)	Indirect (prey)

Table 2-10. Taxa and assessment endpoints used to evaluate the potential for methyl bromide to result in direct and indirect effects to the CTS or modification of their critical habitat.

Taxa Used to Assess Direct and Indirect Effects to CTS and/or Modification to Critical Habitat	Assessed Listed Species	Assessment Endpoints	Measures of Ecological Effects
1 Birds	Direct Effect - CA Tiger Salamander	Survival, growth, and reproduction of individuals via direct effects	4a. Most sensitive mammal bird or terrestrial-phase amphibian acute LC_{50} (MRID 485156-01)**: Acute bird Inhalation 4 h LC50=561ppm. (Converted to 2,178,390 μg/m^3)** 4b. Most sensitive bird or terrestrial-phase amphibian chronic NOAEC: **None available**

Table 2-10. Taxa and assessment endpoints used to evaluate the potential for methyl bromide to result in direct and indirect effects to the CTS or modification of their critical habitat.

Taxa Used to Assess Direct and Indirect Effects to CTS and/or Modification to Critical Habitat	Assessed Listed Species	Assessment Endpoints	Measures of Ecological Effects
2. Mammals	Indirect Effect (prey/habitat from burrows/rearing sites) - CA Tiger Salamander	Survival, growth, and reproduction of individuals via direct effects	5a. Most sensitive laboratory mammalian acute 6 h LC_{50} **(MRID 425041-001):** Acute Mouse **Inhalation 6 h LC_{50} = 188ppm (Converts to 730,009 µg/m^3)** 5b. Most sensitive laboratory mammalian chronic NOAEC : (MRID 00160477) Rat Reproduction NOEC = 3ppm (converts to 11,649 µg/m^3)
3. Terrestrial Invertebrates	Indirect Effect (prey) - CA Tiger Salamander	Survival, growth, and reproduction of individuals or modification of critical habitat/habitat via indirect effects on terrestrial prey (mammals) and/or burrows/rearing sites Survival, growth, and reproduction of individuals via direct effects	8a. Most sensitive terrestrial invertebrate acute EC_{50} or LC_{50}**: Waiver request granted.** 8b. Most sensitive terrestrial invertebrate chronic NOAEC (guideline or ECOTOX): **None available**
4. Terrestrial Plants	Indirect Effect (food/habitat) (non-obligate relationship) - CA Tiger Salamander	Survival, growth, and reproduction of individuals or modification of critical habitat/habitat via indirect effects on terrestrial prey (terrestrial invertebrates) Survival, growth, and reproduction of individuals or modification of critical habitat/habitat via indirect effects on food and habitat (*i.e.*, riparian and upland vegetation)	9a. Distribution of seedling emergence EC_{25} for monocots: Waiver request granted. 9b. Distribution of seedling emergence EC_{25} for dicots: Waiver request granted. 9c. Vegetative vigor for monocots: No data available. 9d. Vegetative vigor for dicots: No data available.

Abbreviations: SF=San Francisco
*The most sensitive fish species across freshwater environments is used to assess effects for this species because they may be found in freshwater environments.
**Birds are usually used as a surrogate for terrestrial-phase amphibians and reptiles.

2.8.2. Assessment Endpoints for Designated Critical Habitat

As previously discussed, designated critical habitat is assessed to evaluate actions related to the use of methyl bromide that may alter the PCEs of the assessed species' designated critical habitat. PCEs for the assessed species were previously described in **Section 2.6**. Actions that may modify critical habitat are those that alter the PCEs and jeopardize the continued existence of the assessed species. Therefore, these actions are identified as assessment endpoints. It should be noted that evaluation of PCEs as assessment endpoints is limited to those of a biological nature (*i.e.*, the biological resource requirements for the listed species associated with the critical habitat) and those for which methyl bromide effects data are available.

Assessment endpoints used to evaluate potential for direct and indirect effects are equivalent to the assessment endpoints used to evaluate potential effects to designated critical habitat. If a potential for direct or indirect effects is found, then there is also a potential for effects to critical habitat. Some components of these PCEs are associated with physical abiotic features (*e.g.*, presence and/or depth of a water body, or distance between two sites), which are not expected to be measurably altered by use of pesticides.

2.9. Conceptual Model

2.9.1. Risk Hypotheses

Risk hypotheses are specific assumptions about potential adverse effects (*i.e.*, changes in assessment endpoints) and may be based on theory and logic, empirical data, mathematical models, or probability models (USEPA, 1998). For this assessment, the risk is stressor-linked, where the stressor is methyl bromide applications to the environment. The following risk hypotheses are presumed in this assessment:

The labeled use of methyl bromide within the action area may:

- Directly affect CTS by causing mortality or by adversely affecting their growth or fecundity;
- Indirectly affect CTS and/or modify their designated critical habitat by reducing or changing the composition of food supply;
- Indirectly affect CTS and/or modify their designated critical habitat by reducing shelter provided by mammal burrows or changing the composition of the plant community in the species' current range;

2.9.2. Risk Hypothesis Description and Diagram

The conceptual model is a graphic representation of the structure of the risk assessment. It specifies the methyl bromide release mechanisms, biological receptor types, and effects endpoints of potential concern. The conceptual model considers the potential exposure pathways determined by the fate and transport for stressors of concern and application methods to support the risk hypotheses.

As stated in Section 2.4, methyl bromide is used for pre-plant soil fumigation and structural indoor uses. This assessment considers the exposure of methyl bromide to the CTS from outdoor exposures resulting from soil fumigation and releases of methyl bromide from structural treatments. **Structural uses are being considered in this risk assessment since it is one of the**

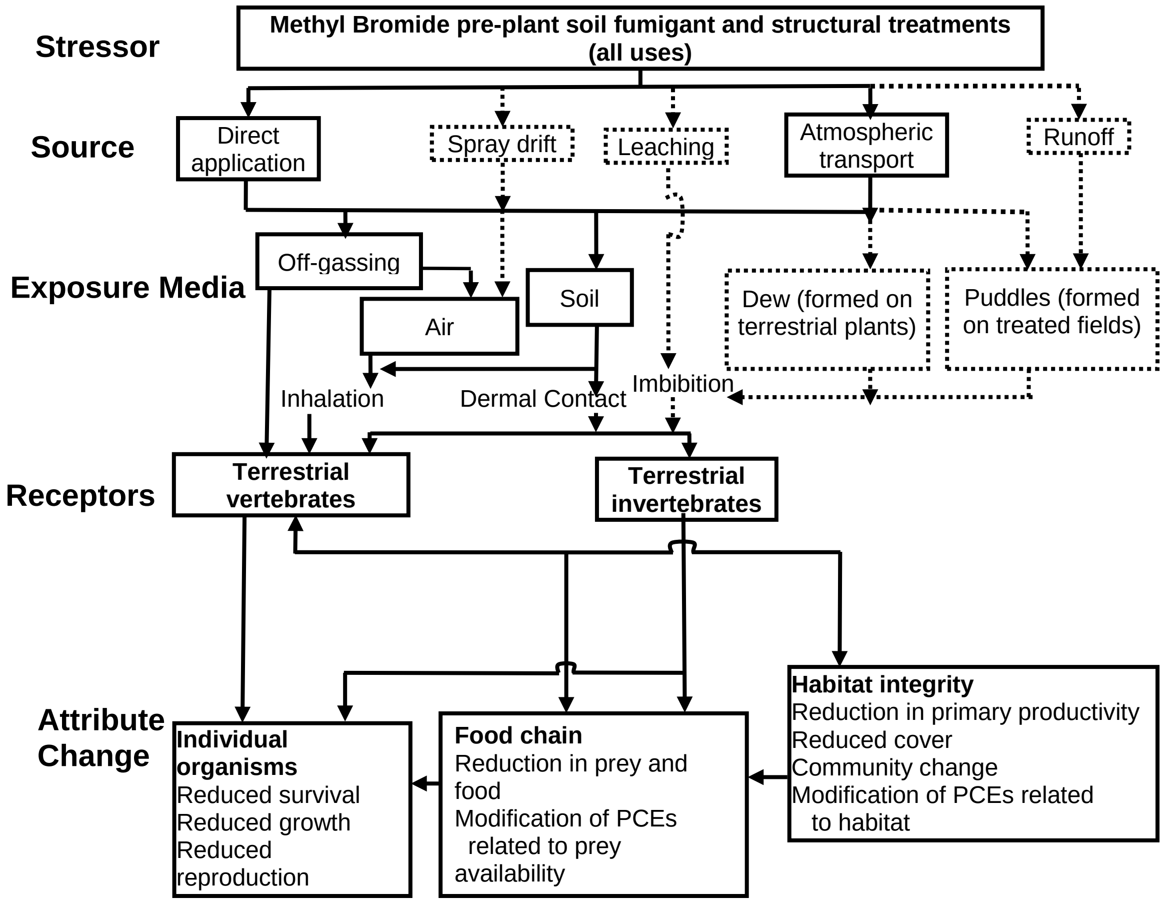
major uses in California as shown in Figure 2-3 and the QPS exemption allows for specific structural uses under the Montreal Protocol.

The primary mode of transport and route of exposure associated with soil fumigant uses for CTS habitats is via volatilization and subsequent diffusion from soil to the air after methyl bromide applications. This is evident given methyl bromide's high vapor pressure and substantial volatility flux rates measured from a large quantity of bare soil treated fields in California. In addition, inhalation exposure for CTS present nearby fields can exist associated with volatilization of methyl bromide soil residues on treated fields and downwind transport in the air. For structural fumigants, the route of exposure for CTS habitats occurs from releases of methyl bromide gas mainly through aeration of treated buildings or cargo holds to the lower atmosphere after fumigation treatments or via leakage from treated buildings during treatment to a lesser extent.

Exposure routes for burrowing CTS populations may include inhalation and dermal intake resulting from directly deposited methyl bromide in soil applications. Inhalation of methyl bromide gas may occur in burrows used for shelter by the CTS, and dermal contact with methyl bromide may occur on the field and potentially be transported off the treated field in soil via lateral diffusion.

The conceptual model for CTS terrestrial PCE components of critical habitat for methyl bromide outdoor soil fumigant uses and indoor structural uses is shown in **Figure** 2-10**.** Although the conceptual models for direct/indirect effects and modification of designated critical habitat PCEs are shown on the same diagrams, the potential for direct/indirect effects and modification of PCEs will be evaluated separately in this assessment.

Exposure routes shown in dashed lines are not quantitatively considered because the contribution of those potential exposure routes to potential risks to CTS and modification to designated critical habitat is expected to be negligible. As discussed further below, methyl bromide leaching to ground water is not expected to be of concern since methyl bromide will not likely be retained in the water for more than a small time period. In addition, direct CTS dietary exposure to methyl bromide residues are not expected since methyl bromide retention times in soil are short, and exposure to methyl bromide is expected to not exist given the plant-back interval of 14 days for methyl bromide applications. Indirect dietary exposure from CTS prey is not expected either due to the low potential for methyl bromide to bioaccumulate in its gaseous state and its low octanol-water partition coefficient. Spray drift is not expected given methyl bromide's incorporated application methods used in soil treatments and indoor application uses.



(Dotted lines indicate exposure pathways that have a low likelihood of contributing to ecological risk)

Figure 2-10. Conceptual model depicting stressors, exposure pathways, and potential effects to terrestrial organisms from the effects of methyl bromide applications.

Runoff and leaching from methyl bromide applications to water bodies and ground water are **not** expected to be significant transport modes resulting in aquatic and imbibition exposure given the current uses of methyl bromide. The following lines of evidence suggest that aquatic exposure is not of concern for **methyl bromide soil applications**:

1. There are numerous peer-reviewed studies in the open literature which suggest that methyl bromide dissipates from water bodies with volatilization half-lives of less than two hours (Gentile et al., 1999; Nelly et al., 1976). An experiment by Nelly et al., 1976 was able to determine a volatilization half-life of methyl bromide of 72 minutes. Therefore, significant loss of methyl bromide in any runoff or leaching water is expected during its transport time to the water body during a rain event.

   The labeled methyl bromide application method which is most susceptible to runoff is the bedded shank injection application. Infiltration of runoff water and subsequent translocation of methyl bromide to nearby water bodies is possible. Methyl bromide's 72-minute volatilization half life measured in water was used to investigate hourly concentrations of conservatively assuming an instantaneous release of 200 lbs. a.i./A (consistent with the percent crop treatment area equivalent application rate for bedded methyl bromide treatments) into a water body equivalent to the Georgia Farm Pond. Although the peak 24-hour water body methyl bromide estimated exposure concentration (EEC) from this scenario exceeded the LOC (level of concern) for aquatic invertebrates, the most sensitive aquatic species to methyl bromide known (MRID 42932901), hourly estimated water body concentrations fell below the LOC. Furthermore, considering the delay in transport time to the water body and concurrent dissipation of methyl bromide in the runoff water, it was determined that the peak EEC would fall below the LOC with transport times greater than or equal to only four hours after the application. This quantitative analysis and discussion presented for bedded tarped applications of methyl bromide is also provided in **Appendix D**.

2. Although highly variable in terms of volatile mass fraction, methyl bromide flux from soil has been measured in large quantities in all cases. Application methods such as tarps certainly attenuate the flux of methyl bromide in some cases. However, even with the tarps, some loss of methyl bromide from soil was measured ultimately reducing the availability of methyl bromide to runoff. Please refer to **Appendix D** for a further description.

3. The rapid biodegradation under tarps are another factor reducing methyl bromide availability to runoff. Broadcast shank injection applications require tarps which fully prevents infiltration of runoff water and subsequent translocation of the chemical for broadcast tarp uses during the time which the tarp is covering the field. Tarps are required to cover the fields for a minimum of five days after the application for broadcast shank injection applications. After 5 days, the tarp is removed and the treated field can then exposed to runoff water. However, methyl bromide appears to degrade sufficiently after 5 days to limit its availability to runoff. Please refer to **Appendix D** for a discussion on the quantitative method using the Pesticide Root Zone Model and Exposure Analysis Modeling System (PRZM/EXAMS) to arrive at this conclusion for labeled methyl bromide tarped broadcast shank injection applications.

4. Another factor limiting the availability of methyl bromide to runoff is that deep shank injection (untarped) and tarped shank injection broadcast application require substantial depths of chemical incorporation into the soil. The deep shank injection (untarped) and tarped broadcast shank injection application methods require injection depths of 18 cm and 8 cm below the surface, respectively. Therefore, the amount of methyl bromide in the runoff extraction zone is reduced during rainfall events. Please refer to **Appendix D** for a discussion on the quantitative method using the PRZM/EXAMS model to arrive at this conclusion for methyl bromide labeled deep shank untarped applications and further support for this conclusion related to broadcast shank injection applications.

5. Further evidence of methyl bromide's characteristic rapid volatilization from water can be observed from some cases provided by aquatic toxicity studies conducted for methyl bromide. In order to conduct the rainbow trout toxicity study form methyl bromide, the only method that could be used to obtain the toxicological endpoint involved placing fish inside a closed sealed chamber with water treated with methyl bromide without a

headspace (MRID 43066701). Otherwise, methyl bromide was not able to remain dissolved in the water column.

6. No known quantifiable detections of methyl bromide in surface water have been reported in the United States. Methyl bromide was detected in 0.07 percent out of 26,149 total groundwater samples at various targeted rural watershed monitoring and well sites at levels $\leq$ 0.5 ppb. The description of this monitoring data is discussed in **Appendix E.**

For **methyl bromide structural uses**, emissions are **not** expected to contribute to aquatic exposure or groundwater contamination either. Methyl bromide gas is expected to remain airborne after above-ground releases as suggested by its high vapor pressure and Henry's Law Constant.

2.10. Analysis Plan

In order to address the risk hypothesis, the potential for direct and indirect effects to the assessed species, prey items, and habitat is estimated based on a taxon-level approach. In the following sections, the use, environmental fate, and ecological effects from methyl bromide applications and subsequent exposure to methyl bromide as the stressor of concern from releases and transport in the air are characterized and integrated to assess the risks.

Since runoff and leaching of methyl bromide due to labeled applications are not expected to occur in large quantities, aquatic exposure and drinking water exposure models such as PRZM/EXAMS and SCIGROW are not used for risk determinations related to the CTS in this risk assessment.

The routine models used to estimate dietary risk are not used because no dietary exposure is expected. The routine model to estimate terrestrial plant effects in the CTS habitat is not used because no terrestrial plant toxicity data are available. Due to the absence of amphibian toxicity data, data from bird studies are routinely used to assess the effects of methyl bromide to terrestrial-phase amphibians.

The main expected route of methyl bromide exposure for terrestrial organisms is from inhalation in air. Off-gassing of methyl bromide from treated fields is known to occur in significant quantities for all applications, even those with tarped applications, as described in **Section 2.3**. Methyl bromide gas emitted from the soil may accumulate in air as the elements are blown downwind towards the edge of the field. This phenomenon is illustrated in **Figure 2-11**. In addition, exposure of CTS populations nearby structures and residences treated with methyl bromide may occur after treated concurrent with aeration practices. Although releases often occur from tops of structures and hence are elevated above the ground, it is well known that building downwash as well as convective downdrafts in the wake of buildings may force the emitted plume downwards towards ground level (USEPA, 1995b). This plume behavior in the atmosphere is shown in **Figure 2-12**.

Soil-borne exposure resulting directly from methyl bromide soil fumigation applications also exists for the terrestrial-phase CTS and its prey. Inhalation of methyl bromide gas may occur in burrows used for shelter by the CTS, and dermal contact with methyl bromide may occur on the field and potentially be transported off the treated field in soil via lateral diffusion. At this time, there is no model currently implemented to evaluate dermal and inhalation exposures in the soil. However, peak soil concentrations resulting from incorporation of methyl bromide in soil fumigant applications are calculated in **Section 3.1.3** and qualitatively characterized in **Section 5.2.1.** Since only inhalation toxicological data are available and that there is no tool currently available to extrapolate this data to a dermal toxicological endpoint, dermal exposure cannot be evaluated at this time, and is therefore not addressed in this risk assessment.

The integration between exposure and toxicity is accomplished using a risk quotient (ratio of exposure concentration to effects concentration) approach to quantitatively determine risk. Although risk is often defined as the likelihood and magnitude of adverse ecological effects, the risk quotient-based based approach does not provide a quantitative estimate of likelihood and/or magnitude of an adverse effect. RQS for both screening level and refined models are used to estimate risk to the CTS. If RQs exceed the LOC of 0.1 for endangered species using the SCREEN3 air exposure model in the screening-level analysis, the PERFUM air exposure model is used to further refine the analysis. However, as outlined in the Overview Document (USEPA, 2004b), the likelihood of effects to individual organisms from particular uses of methyl bromide is estimated using the probit dose-response slope and either the level of concern (discussed below) or actual calculated risk quotient value.

Descriptions of routine procedures for evaluating risk to the San Francisco Bay Species are provided in **Attachment 1**.

2.10.1. Measures of Exposure

Measures of exposure from methyl bromide treatments to terrestrial-phase CTS are derived from the utilization of fate and transport models for soil and air media. Peak EECs are compared to avian and mammal acute inhalation data. In addition, given there is no tool currently in place to assess chronic exposure, the peak EEC is also compared to chronic mammalian toxicological data as an upper-bound EEC. Ambient air monitoring data in targeted air sheds over California where methyl bromide use volumes are high are used to provide a lower-bound estimate to represent chronic air concentrations. Refer to **Section 3.1.2** for details on ambient air monitoring data values measured in California. Exposure to the aquatic-phase CTS are not evaluated in this risk assessment, as discussed in the previous section.

Figure 2-11 shows the exposure scenario being evaluated in this risk assessment related to methyl bromide soil fumigant applications. In this scenario, air exposure resulting from volatilization loss from soil after methyl bromide applications is initially evaluated for various soil fumigant uses using the SCREEN3 model in the screening approach. This approach utilizes a peak flux (or off-gassing) rate observed in application method-specific field volatility studies coupled with worst-case meteorological conditions (light wind speeds, stagnate conditions) to arrive at a worst-case EEC. For those uses exceeding the LOCs, the PERFUM (Probablistic Exposure and Risk Model to Fumigants) model is used in the refined approach. PERFUM utilizes a distribution of flux rates based on application method-specific field volatility studies and 5-years of meteorological data representative of when the off-gassing occurs to determine the peak (hourly) upper 90th percentile EEC in air. As depicted in **Figure 2-11**, both SCREEN3 and PERFUM EECs are representative of air concentrations occurring directly downwind from source.

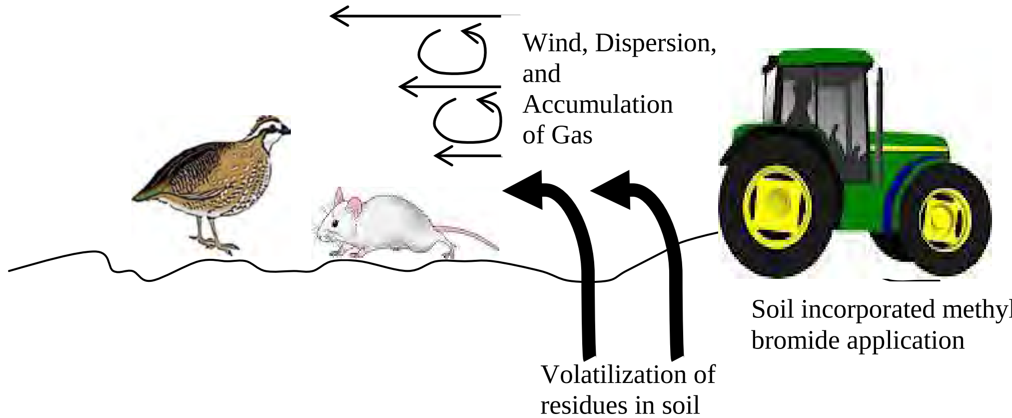


Figure 2-11. Schematic showing evaluated methyl bromide soil fumigant air exposure scenario in this risk assessment.

Figure 2-12 shows the exposure scenario being evaluated in this risk assessment related to methyl bromide for structural fumigant applications. Like soil fumigants, outdoor exposures to methyl bromide from structural applications are dependent on the emissions from structures during aeration necessary after treatment. In addition, exposure to methyl bromide may occur via emissions through building leakage from cracks during treatment. The magnitude of emissions are dependent in part on the application rate inside of the building in this case. However, unlike for soil fumigations, emissions data are not directly available for treated structures with methyl bromide nor are they specified on the label. Only methyl bromide indoor concentrations are available and have been used to develop empirical exponential decline models for fumigant releases from buildings (Chayaprasert et al., 2007; Schneider et al., 2000; Cryer, 2007). The emissions equations for passive of active fumigant releases from methyl bromide treated structures are presented in **Section 3.1**. Once emitted, methyl bromide may be transported to ground level via building downwash and convective downdrafts in the wake of buildings.

A screening approach can utilize an estimate of maximum emissions assuming a catastrophic release scenario where all of the emissions inside of the building are released within one hour to determine a worst-case air EEC. This emission rate can be calculated using the following equation:

$$\text{Emission Rate (lbs./min.)} = \text{Maximum labeled application rate on the label (lbs./1,000 ft.}^3\text{)} \times \text{Gas stream flow rate ventilated outdoors (ft.}^3\text{/min.)}$$

The gas stream flow rate is not specified on methyl bromide labels. Therefore, for this scenario, a flow rate of 10,000,000 ft.^{3} per hour or 166,667 ft.^{3}/min corresponding to a one-hour total release of methyl bromide from a 10,000,000 ft.^{3} building (large warehouse) is assumed. This screening approach possesses added conservatism given that release duration of 12 – 24 hours are typical from this large building size. Using the equation above, the resulting emission rate assuming the maximum application rate of 15 lbs./1,000 ft.^{3}, would therefore be 2,500 lbs. of methyl bromide per minute. This is an extraordinarily high emission rate which will most likely never occur under practical circumstances. Emissions will always be lower due to more controlled releases of methyl bromide which persist over many hours as treated structures are aerated. A catastrophic release is more plausible for a scenario such as a train derailment. Since a train derailment is an event not associated with the labeled use of methyl bromide, this is not considered for risk determinations.

Therefore, a refined approach whereby hourly emission temporal profiles are developed is utilized in this assessment as the basis for predicting air EECs. A temporal profile of emission rates are developed based on the following variables:

- Maximum application rate for each use
- Air exchange rates[2] determined by mechanical or passive ventilation techniques
- A matrix of building sizes (volumes)
- Appropriate release periods determined by building sizes – larger building sizes have larger release durations

All of the above mentioned factors are used to calculate a maximum emission rate which decline exponentially over time. Both mechanical and passive emission scenarios are calculated. Non-buoyant point source emission rates are derived for mechanical ventilation, and area flux rates are derived for passive ventilation. Half-loss times of methyl bromide gas in treated structures determined from indoor air monitoring as well as various other studies in the open literature related to structural fumigations empirically support these emissions calculations. Like the soil fumigants assessment, these distributions of emissions and flux rates are entered into PERFUM, and a 90th percentile upper-bound peak (hourly) air concentration and downwind distance to the avian and mammal endangered species LOC (if necessary) are identified in the same manner.

A detailed description of the emission scenarios and corresponding derived emission and flux rates used in the exposure analysis for structural methyl bromide use, PERFUM modeling inputs, and PERFUM EEC results are provided in **Section 3.1.1**. Outdoor air monitoring conducted concurrent with treatment and aeration of structures treated with methyl bromide providing evidence of this exposure scenario is provided in **Section 3.1.2**. Further details about the SCREEN3 and PERFUM models are provided in **Appendix M.**

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[2] The air exchange rate is the defined as the frequency of total air replacement cycles in a certain volume per unit time.

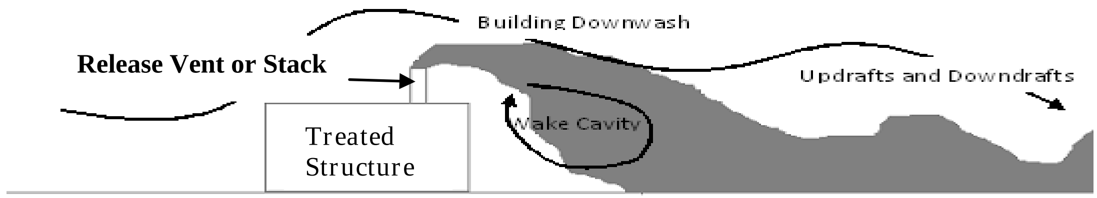


Figure 2-12. Schematic showing evaluated methyl bromide structural fumigant air exposure scenario in this risk assessment.

In addition, terrestrial-phase CTS dermal and inhalation exposure to methyl bromide may occur due to the direct application of methyl bromide in soil. There is no approved model that currently exists to determine EECs related to the dermal route of exposure. However, peak soil gas concentrations due to methyl bromide incorporation into soil and inhalation EECs can be calculated using the maximum application rate, soil bulk density, and incorporation depth of the fumigant. This calculation and resulting EEC values are shown in **Section 3.1.3**. Risks due to this route of exposure are qualitatively described in **Section 5.2.1**.

2.10.2. Measures of Effect

Data identified in **Section 4** are used as measures of effect for direct and indirect effects. Data were obtained from registrant submitted studies or from literature studies identified by ECOTOX. More information on the ECOTOXicology (ECOTOX) database and how toxicological data are used in EPA's ecological risk assessments is available in **Attachment 1**.

2.10.3. Integration of Exposure and Effects

Risk characterization is the integration of exposure and ecological effects characterization to determine the potential ecological risk from agricultural uses of methyl bromide, and the likelihood of direct and indirect effects to the assessed species in aquatic and terrestrial habitats. The exposure and toxicity effects data are integrated in order to evaluate the risks of adverse ecological effects on non-target species. The risk quotient (RQ) method is used to compare exposure and measured toxicity values. EECs are divided by acute and chronic toxicity values. The resulting RQs are then compared to the Agency's levels of concern (LOCs) (USEPA, 2004b) (see **Appendix C)**. More information on standard assessment procedures is available in **Attachment 1.**

2.10.4. Data Gaps

There are many data gaps in the environmental fate database for methyl bromide. Much of the environmental fate data used as the basis for this risk assessment were retrieved from open literature sources to address these data gaps or unresolved issues which arose in supplemental studies submitted by the registrant. Please see **Section 6.1.2** for further details regarding these data gaps and the justification for how these use patterns are accounted in the existing analysis plan.

Ecological effects data gaps were also identified for methyl bromide in this assessment. Although estuarine/marine and aquatic plant toxicity tests were identified as data gaps in the RED, those studies are not necessary for the CTS assessment because the species occupies only freshwater habitat and methyl bromide is not expected to occur in aquatic systems (EFED memorandum to PRD, dated September 20, 2011).

There were no studies of acute or chronic terrestrial exposure effects (e.g., inhalation or dermal) on amphibians identified in the open literature. Acute avian inhalation data have been submitted since the previous risk assessment and were used in this assessment to estimate direct and indirect effects on the CTS from the use of methyl bromide.

Indirect terrestrial effects to the CTS due to reduction of terrestrial invertebrate prey would usually be estimated from the honey bee study as a surrogate for other terrestrial invertebrates. However, a waiver request was supported for the bee study. The waiver was supported based on the bees not being present during application because methyl bromide is used as in a preplant application. In addition, due to its volatile nature, methyl bromide residues are not anticipated to be prevalent in beehive colonies. Therefore, although not routinely used, efficacy toxicity data for insects was used to support the assumption of risk for terrestrial invertebrates. These insect toxicity endpoints are more representative for the CTS diet in the assessment for the reduction of prey. This investigation is discussed in **Section 5.2.2.**

A waiver request submitted for terrestrial plant studies was supported for seedling emergence, but denied for vegetative vigor, and the data gap for these studies remains given the likely phytotoxic properties of methyl bromide given its herbicidal properties and its potential to drift as a gas after its release from soil to areas off of a treated field.

3. Exposure Assessment

As discussed in the problem formulation in **Section 2.9.2**, the only routes of exposure of concern to ecological receptors are releases of methyl bromide gas from treated soil and structures to the air as well as exposure in soil resulting directly from methyl bromide applications. For agricultural uses of methyl bromide (soil fumigation), specific management practices are required to reduce exposure to volatilized chemical, such as application of tarps and maintaining shank injection depths. These management practices along with the application methods of broadcast tarped shank injection, deep untarped shank injection, bedded tarped shank injection, and hot gas tarped chemigation tarped applications are taken into account in determining EECs for soil fumigation uses of methyl bromide. Field volatility studies for agricultural uses of methyl bromide have been conducted consistent with these application methods and field management practices. These field volatility studies form the basis for air EECs for agricultural uses.

For structural uses of methyl bromide, currently available labels only specify maximum application rates. They do not provide any specifications for release parameters such as emission rates or gas stream flow rates. In addition, there is limited information on the structure sizes and air exchange rates for methyl bromide treated structures. There is some guidance related to compliance requirements associated with aeration of treated structures from the State of California (CALEPA, 1994). However, there are no requirements specified related specifically to the critical parameters of air exchange rates or emission rates maintained from buildings. Furthermore, there are no emissions monitoring data directly available for structures treated with methyl bromide. Therefore, for the purposes of this risk assessment, emission rates for structural uses are calculated using exponential decline emissions models developed empirically form indoor air monitoring data. These models apply to passive and mechanical aeration scenarios as well as the consideration of building leakage of methyl bromide during treatment. Refer to **Section 3.1** on the equations developed for each release type, and **Section 3.1.2** for the indoor air monitoring data used to develop these equations. Exposure scenarios for structural fumigation releases consider a combination of building size classes along with controlled release periods (see background discussions in **Sections 2.4, 2.9.1**, and **3.1**). Air monitoring data outside of treated structures will be used to characterize the EECs considering these emission factors. This monitoring data is also provided and described in **Section 3.1.2.**

3.1. Terrestrial Animal Exposure Assessment

The terrestrial-phase CTS EECs in air are calculated using atmospheric dispersion models. For soil fumigant uses of methyl bromide, the SCREEN3 dispersion model is used in the screening approach to calculate peak EECs in the air. The PERFUM model (refined method) is used to determine the upper-bound air concentration considering on and off the field locations and treated structures along the downwind axis for both structural and soil uses. EECs for soil and structural methyl bromide uses are provided in **Section 3.1.1**. Furthermore, a downwind distance from the treated field or structure where there is no longer a concern for endangered species can also be estimated by dispersion models. The results for uses exceeding the endangered species LOC are shown in the risk estimation section, **Section 5.1**. Descriptions of the SCREEN3 and

PERFUM models along with relevant modeling results output are shown in **Appendix M**. The air exposure analyses for soil and structural fumigants are presented in **Section 3.1.1.**

The SCREEN3 atmospheric dispersion model (version 96043) from the EPA Office of Air Quality Planning and Standards (OAQPS)provides an estimate for inhalation intake from airborne methyl bromide gas (USEPA, 1995b) and is publically available at the following web site: http://www.epa.gov/scram001/dispersion_screening.htm. SCREEN3 is the same model as the screening version of the ISCST3 model used in the previous risk assessment supporting reregistration for methyl bromide. In this screening approach, the maximum peak flux rate, or methyl bromide mass emissions from soil per unit area and time, measured from field volatility studies is used in tandem with worst-case meteorological conditions (light winds with air stagnation) to arrive at a worst-case peak air EEC directly downwind from a treated field. Maximum application rates for treatments for each crop are evaluated by incorporating the appropriate flux rates into the model. The flux rates measured in the field volatility study are linearly scaled from the application rate in the field volatility study to the maximum application rate on the label in the modeling.

For those uses exceeding RQs, a more refined approach utilizing a time series of flux profiles measured in field volatility studies coupled with diurnally representative meteorological data is incorporated into the PERFUM model which outputs distributions of air concentration along the edge of and off of the treated field. The maximum upper 90th percentile predicted peak (hourly) air concentration of all distributions binned by time of day close to the edge of the field is selected as the EEC. Maximum concentrations are expected along the edge of the field since methyl bromide gas due to accumulation of off-gassed elements from the treated field as it is transported downwind. If the PERFUM EEC exceeds the LOC for endangered avian and mammal species, then the downwind distance to where concentrations fall below the LOC is determined using the 90th percentile peak (hourly) concentrations from the provided distributional air concentration output for multiple downwind distances from the treated field in PERFUM. The PERFUM model is also based on the ISCST3 model developed by the Agency's Office of Air Quality Planning and Standards (OAQPS). However, PERFUM has been developed using the refined mode of ISCST3 and is publically available at the website: http://www.exponent.com/perfum/. (Reiss, 2006). PERFUM has been used in the Agency for refined inhalation assessments to address human worker and bystander exposure (EPA 2007). The human health risk assessment is provided in **Appendix K.** Both SCREEN3 and PERFUM have been evaluated by the Agency for utilization in human health and ecological risk assessments at various FIFRA Science Advisory Panel Meetings (EPA, 2009; EPA, 2004c). It should be noted that SCREEN3 was the Agency's recommended screening tool to assess near-field air exposure. However, OAQPS recently replaced SCREEN3 with the AERSCREEN (American Meteorological Society/EPA Regulatory Screening Model) as the preferred screening model in the near field effective March 11, 2011. Since AERSCREEN has recently been released and is currently under review in EFED, SCREEN3 was used in this assessment as it has been reviewed by the FIFRA Science Advisory Panel.

For structural uses of methyl bromide, only a refined approach is used to calculate air EECs using the PERFUM model as justified in **Section 2.10.1**. In this approach, hourly emissions temporal profiles are developed and serve as the basis for predicting air EECs. Temporal profiles of emission rates are developed based on scenarios considering four variables including the **maximum application rate, air exchange rate, a matrix of building sizes, and a corresponding release period** for each use. A maximum application rate of 9 lbs./1,000 ft.^{3} applies for all post-harvest food and commodity fumigation QPS uses[3], and 15 lbs./1,000 ft.^{3} applies for tile and timber fumigation QPS uses and stockpile space fumigation uses. Air exchange rates used in this assessment are dependent on the aeration or release scheme. In the first release scheme, an air exchange rate of 1.0 replacement cycles per hour is assumed to represent mechanical aeration where air is circulated around a building to release methyl bromide from the structure to the outdoors. **For mechanical aeration, two scenarios are considered including a vertical release and a horizontal release from point sources such as vents or stacks on buildings.** For passive aeration, a lesser air exchange rate of 0.1 replacement cycles per hour is assumed to represent air being allowed to naturally flow into a structure in order to release methyl bromide to the outdoors. This air exchange rate could also represent a leakage exchange rate during treatment. **For the passive release scenario, the entire building is assumed to be the emission source.** For both mechanical and passive aeration scenarios, maximum building sizes of 250,000 ft.^{3} and 10,000,000 ft.^{3} represent maximum building sizes corresponding to 6-hour and 12-hour release durations, respectively. **Another release scenario evaluated is that occurring from a rail car or a cargo hold with multiple fumigation chambers.** An air exchange rate of 0.05 replacement cycles per hour represents air flow though a wide opening upon release. For rail cars or cargo releases, typical sizes of railcars up to 10,000 ft.^{3} is evaluated with a 6-hour release duration.

The modeling scenarios introduced above are described in detail below:

<u>Scenario 1.</u> **<u>Passive Aeration or Leakage Release:</u>** This scenario evaluates a situation where a fumigated building is aerated by allowing air to naturally flow into the structure by opening doors and windows. A relatively low air exchange rate of 0.1 replacement cycles per hour is assumed given that air is not being mechanically circulated throughout the building, and flows in a channelized manner through openings in the structure. This scenario can also be representative of leakage through cracks from the building during treatment. The building is assumed to be an area source for emissions, with no specific release points and is void of any flow forcing (momentum flux) or thermal forcing (buoyancy flux) from any particular points on the building. The modeled release height is assumed to be half of the building height accounting for the likely variation in individual release heights within the structure. Building sizes of 250,000 ft.^{3} at a release period of 6 hours and 10,000,000 ft.^{3} at a release period of 12 hours are evaluated.

<u>Scenario 2.</u> **<u>Mechanical (Active) Aeration, Vertical Release:</u>** This scenario evaluates a situation where a non-buoyant gas stream is forced through a stack or vent vertically. A higher air exchange rate of 1.0 replacement cycles per hour since air is used to pump the methyl bromide outside the building. The aerated building is assumed to be a point source for emissions from a stack at 10 ft. above the top of the building. This stack height is low to the ground than many stacks and therefore is a conservative factor for

[3] There are a few food and commodity uses listed in the LUIS Report (Appendix L) at an application rate of 12 lbs./1,000 ft.^{3} for grain mills. However, these uses are very limited at most in California as per the Health Effects Division Risk Assessment (Appendix K).

ground-level air EECs. The low stack height along with downwash from the stack and building (see **Figure 2-12**) are expected to contribute to ground-level air concentrations. Building sizes of 250,000 $ft.^3$ at a release period of 6 hours and 10,000,000 $ft.^3$ at a release period of 12 hours are also evaluated in this scenario.

Scenario 3. **Mechanical (Active) Aeration, Horizontal Release:** This scenario evaluates a situation where a non-buoyant gas stream is forced through a stack or vent horizontally. An air exchange rate of 1.0 replacement cycles per hour is also assumed in this scenario. The aerated building is assumed to be a point source for emissions occurring essentially at the base of the building from a stack at 3 ft. above ground level. The horizontal release is simulated by removing any contribution of gas stream flow to the release, removing the momentum flux necessary for vertical plume rise. The low stack height and horizontal release are conservative factors for ground-level air EECs. Building sizes of 250,000 $ft.^3$ at a release period of 6 hours and 10,000,000 $ft.^3$ at a release period of 12 hours are also evaluated in this scenario.

Scenario 4. **Railcars and Cargo Hold/Fumigation Chamber Release:** This scenario essentially assumes a situation where treated railcars are aerated passively. Given the likely very small flow associated with unforced air circulation, the air exchange rate of 0.05 replacement cycles per hour is assumed. The emissions source is parameterized as an area source with release height half of the structure height assumed. However, unlike the passive aeration scenario, emissions from multiple sources being fumigated simultaneously are modeled. The assumption is made that exponential decline of emissions (see flux equation below) from one source (railcar) over time is offset by another emissions source becoming available. The emissions time series for this scenario assumes that emission sources build every hour to the point that there can be as much as six emitting sources (railcars) at a time, and that emissions from each source will decline according to the flux equation above according to a six hour release. The total emissions profile time series lasts twelve hours total as hour 12 is the last hour when a railcar emits methyl bromide for this scenario. Given information available from CSX related to the typical size of railcars, a smaller structure size of 10,000 $ft.^3$ is evaluated. This information can be accessed at:
http://www.csx.com/index.cfm/customers/equipment/railroad-equipment/. Release durations of 6 hours are evaluated.

Table 3-1 below summarizes the matrix of release scenarios in refined PERFUM modeling for methyl bromide structural fumigant uses.

Table 3-1. Matrix of release scenarios in refined PERFUM modeling for methyl bromide structural fumigant uses.						
			Building Aeration Emission Scenarios			Railcars and Cargo Aeration Emissions
Use Types and Montreal Protocol Designation	Application Rate (lbs./ 1,000 ft.^{3})	Structure Volume (ft.^{3}) and Release Period (hrs.)	**Scenario 1** Exponential Emissions Decline, Single Source, AXR = 0.1, Passive Aeration, No Stack	**Scenario 2** Exponential Emissions Decline, Single Source, AXR = 1.0, Active Aeration, 10 ft. Vertical Stack	**Scenario 3** Exponential Emissions Decline, Single Source, AXR = 1.0, Active Aeration, 3 ft. Horizontal Portable Stack	**Scenario 4** Exponential Emissions Decline, Multiple Source, AXR = 0.05, Passive Aeration, No Stack
• Post Harvest Indoor Food Fumigation (QPS) • Commodity Indoor Fumigation (QPS)	9	10,000 ft^3 for 6 hrs.				**X**
		250,000 ft^3 for 6 hrs.	**X**	**X**	**X**	
		10,000,000 ft.^{3} for 12 hrs.	**X**	**X**	**X**	
• Timber and Tile Indoor Fumigation (QPS) • Space Fumigation (SP)	15	10,000 ft^3 for 6 hrs.				**X**
		250,000 ft^3 for 6 hrs.	**X**	**X**	**X**	
		10,000,000 ft.^{3} for 12 hrs.	**X**	**X**	**X**	

[1] Montreal Protocol Designation Codes: CUE – Critical Use Exemption; QPS – Quarantine and Pre-Shipment Exemption; SP – Stockpile

Time series of emissions are developed for each scenario using the equation for flux related to passive scenarios presented in scenarios 1 and 4 above, and for the emission rate (ER) for mechanical ventilation scenarios presented in scenarios 2 and 3 above. The equations are presented below. The indoor air monitoring data used to support these emissions calculations is presented in **Section 3.1.2.**

$$Flux(\mu g / m^2 s) = \frac{C_0 \times V \times \left[\exp(-AXR \times t_{n-1}) - \exp(-AXR \times t_n)\right]}{3{,}600 \times \frac{A}{1{,}000{,}000}}$$

$$ER(g / s) = \frac{C_0 \times V \times \left[\exp(-AXR \times t_{n-1}) - \exp(-AXR \times t_n)\right]}{3{,}600}$$

where

<u>ER</u> is the emission rate for point source during **<u>mechanical ventilation</u>** (g/s) at time t_n,
<u>Flux</u> is the flux rate for area source during **<u>passive aeration</u>** (μg/m^{2}s) at time t_n. For purposes of this assessment, this flux value also represents the magnitude of release resulting from building leakage during treatment
<u>C_o</u> is the indoor concentration application rate (g/m^3),
<u>V</u> is the volume of building (m^3)
<u>AXR</u> is the air exchange rate (hr^{-1}),
<u>t_n</u> is the timestep of interest in the flux or emissions temporal profile
<u>t_{n-1}</u> is the previous timestep of interest in the flux temporal profile
<u>A</u> is the area of the building footprint (m^2)

Since there are no specific release periods required on labels and there is little usage information related to sizes of buildings treated with methyl bromide, scenarios are developed by considering a matrix of building sizes and release periods that result in release scenarios which are a protective reprentation of EECs. **It is important to note that values for parameters such as air exchange rates, building sizes, and release durations within these scenarios are not specified on labels.** However, all of this information is necessary to determine outdoor exposures due to the controlled release of methyl bromide from treated structures. Therefore, the emissions profiles along with the resulting EECs in air are based on the assumptions described above. The equations for exponential decline of emissions with passive and mechanical aeration above are supported empirically by indoor air monitoring of methyl bromide during aeration periods. This information is presented in **Section 3.1.2** below. Although direct emissions testing has not been conducted for methyl bromide treated structures, the exponential decline in indoor air concentrations observed during the air monitoring studies is directly related to emission rates to the outdoors. In addition, some of these scenarios include stack forcing parameters (see description in footnotes under **Table 3-12**) such as **stack height, stack diameter, and gas stream flow rate** which are important for determining the initial plume height and therefore are instrumental in influencing air EECs at ground-level where CTS populations exist. Five years of meteorological data input and the temporal emission profile into PERFUM are also used to determine EECs at ground level. Like soil fumigant uses, the upper 90th percentile peak (hourly)

EEC is used for risk estimation. As mentioned in **Section 2.10.1**, this refined approach for structural fumigation has been utilized by the Agency to assess human health risk impacts for workers and bystanders who are potentially exposed nearby treated facilities with methyl bromide. This assessment is included in **Appendix K**.

3.1.1. Atmospheric Dispersion Modeling Analysis

Soil Fumigant Uses

For methyl bromide soil fumigant uses, a combination of screening and refined approaches was used to calculate EECs in air. In the screening approach, the SCREEN3 model was used. Each application method was addressed separately corresponding to maximum peak methyl bromide measured field volatility flux data from studies for each application method including broadcast tarped shank injection, deep untarped shank injection, bedded tarped shank injection, and hot gas tarped chemigation applications. These field volatility studies, described in **Table 2-4 and Section 2.3**, account for all tarping and shank injection field management requirements on the label as described in **Section 2.4**. The field volatility studies used for the basis of the SCREEN3 modeling incorporate the composite fluxes for each flux profile calculated from CALDPR for deep shank injection untarped, bedded shank injection tarped, and hot gas chemigation tarped application methods. For broadcast tarped shank injection methods, the Wasco, CA field volatility study on Field 1 was used as the basis for air EECs. The maximum peak flux rates from these studies were linearly scaled from the field volatility application rate to the maximum labeled application rate and is input into SCREEN3 and run concurrently with worst-case meteorological conditions (e.g., light winds under stagnate conditions) to obtain peak EECs, for a 1-hour averaging period.

The input parameters for the SCREEN3 model are shown in **Table 3-2.** As specified on the labels and described in **Section 2.4**, field flux in SCREEN3 originates from a 100 acre maximum treated field for broadcast and bedded tarped applications, 40 acre field for deep shank injection untarped applications, and a 10 acre field for hot gas tarped chemigation applications. The flux rates input by crop as determined by the maximum labeled application rate by crop use are shown in **Table 3-3.** SCREEN3 peak EECs in air are shown in **Table 3-4**. All maximum EECs occurring along the edge of a treated field are shown in this table.

Table 3-2. SCREEN3 inputs for methyl bromide soil fumigant air exposure modeling for all simulations.	
Input Parameter	**Option/Value**
Source Type	Area
Averaging Period	1-hour
Flux Rates ($\mu g/m^2s$)	See Table 3-3
Source Height (m)	0 (Ground-level)
Field Dimension Lengths (m)	Broadcast Shank Injection: 636.1 (100 acre square field) Bedded Shank Injection: 636.1 (100 acre square field) Deep Shank Untarped: 402.3 (40 acre square field) Hot Gas Tarped Chemigation: 201.2 (10 acre square field)
Downwind Distance Range	0 – 1 km
Receptor Height (m)	0 (Ground-level)
Meteorological Conditions	Wind Speed = 1 m/s (minimum) Stability Class = 6 (stagnate conditions)

Table 3-3. SCREEN3 use rate specific flux rate inputs for methyl bromide soil fumigant air exposure modeling.					
Crops and Montreal Protocol Designation	**Peak Flux Rates in Air For Application Methods ($\mu g/m^2s$)**				
	Deep Shank Injection Untarped [1]	**Shank Injection Broadcast Tarped [2]**	**Shank Injection Bedded Tarped [3,5]**	**Hot Gas Tarped Chemigation [4]**	**Comments**
Orchard Replant (CUE)	206.90	*No Uses*	*No Uses*	*No Uses*	Application Rate = 400 lbs. a.i./A
Forestry Nursery (CUE)	*No Uses*	497.91	827.57	1,377.87	Application Rate = 400 lbs. a.i./A
Nursery and Ornamentals (CUE)					
Sweet Potatoes (CUE)					
Golf Courses and Athletic Fields (SP)					

Table 3-3. SCREEN3 use rate specific flux rate inputs for methyl bromide soil fumigant air exposure modeling.					
Crops and Montreal Protocol Designation	**Peak Flux Rates in Air For Application Methods ($\mu g/m^2s$)**				
	Deep Shank Injection Untarped [1]	**Shank Injection Broadcast Tarped [2]**	**Shank Injection Bedded Tarped [3,5]**	**Hot Gas Tarped Chemigation [4]**	**Comments**
Peppers (CUE)	*No Uses*	492.93	819.30	1,364.09	Application Rate = 396 lbs. a.i./A
Strawberries (CUE)	*No Uses*	351.03	583.44	971.40	Application Rate = 282 lbs. a.i./A
Tomatoes (CUE)	*No Uses*	328.62	546.20	909.39	Application Rate = 264 lbs. a.i./A
Eggplant (CUE)	*No Uses*	298.75	496.54	826.72	Application Rate = 240 lbs. a.i./A
Cucurbits (CUE)					
Berries (SP)					

[1] Peak flux rates scaled from CALDPR composites for deep shank untarped method application method normalized to 430 lbs. a.i./A from Johnson and Segawa, 2000.
[2] Peak flux rates scaled from CALDPR composites for broadcast tarp shank injection method normalized to 430 lbs. a.i./A from Johnson, 1999.
[3] Peak flux rates scaled from field volatility study at Wasco, CA (field 1) measured at an application rate = 180 lbs. a.i./A (MRID 48006001).
[4] Peak flux rates scaled from CALDPR individual composites for bedded tarp and broadcast tarp methods normalized to 430 lbs. a.i./A from Johnson, 2004.
[5] Maximum application rate considered in modeling. Application rate is not adjusted for the percent field treated.

Table 3-4. SCREEN3 peak estimated exposure concentrations in air for methyl bromide soil fumigant use.					
Crops and Montreal Protocol Designation	**Application Rate (lbs. a.i./A)**	**Peak EECs in Air For Application Methods ($\mu g/m^3$)**			
		Deep Shank Injection Untarped (40 acres)	**Shank Injection Broadcast Tarped (100 acres)**	**Shank Injection Bedded Tarped [3] (100 acres)**	**Hot Gas Tarped Chemigation (10 acres)**
Orchard Replant (CUE)	400	36,560	*No Uses*	*No Uses*	*No Uses*

Table 3-4. SCREEN3 peak estimated exposure concentrations in air for methyl bromide soil fumigant use.					
Crops and Montreal Protocol Designation	**Application Rate (lbs. a.i./A)**	**Peak EECs in Air For Application Methods ($\mu g/m^3$)**			
		Deep Shank Injection Untarped (40 acres)	**Shank Injection Broadcast Tarped (100 acres)**	**Shank Injection Bedded Tarped [3] (100 acres)**	**Hot Gas Tarped Chemigation (10 acres)**
Forestry Nursery (CUE)	400	*No Uses*	**99,582**	**165,514**	**200,342**
Nursery and Ornamentals (CUE)					
Sweet Potatoes (CUE)					
Golf Courses and Athletic Fields (SP)					
Peppers (CUE)	396	*No Uses*	**98,586**	**163,859**	**198,339**
Strawberries (CUE)	282	*No Uses*	**70,205**	**116,688**	**141,241**
Tomatoes (CUE)	264	*No Uses*	**65,724**	**109,239**	**132,226**
Eggplant (CUE)	240	*No Uses*	**59,749**	**99,309**	**120,205**
Cucurbits (CUE)					
Berries (SP)					

[1]Montreal Protocol Designation Codes: CUE – Critical Use Exemption; QPS – Quarantine and Pre-Shipment Exemption; SP – Stockpile
[2]PERFUM model refinement conducted for results shown in bold face. Please refer to risk estimation in Section 5.1 which presents the RQs exceeding the LOC for avian endangered species.
[3] Maximum application rate considered in modeling. Application rate is not adjusted for the percent field treated.
[4] Maximum peak EECs are shown in table occurring at ground-level along the edges of the treated fields.

In order to address risk estimation presented in **Section 5.1**, the PERFUM model refined approach was used for hot gas chemigation tarped applications, bedded tarped shank injection applications, and broadcast tarped shank injection applications. The 90th percentile maximum upper-bound peak (hourly) EECs were calculated along the edge of the field directly downwind from the treated field, where accumulated methyl bromide is expected to exist at maximum levels. PERFUM considers a temporal profile of flux rates measured in field volatility studies in tandem with five years of meteorological data. PERFUM calculates upper 90th percentile peak (hourly) EECs along the edge of the field throughout all averaging periods throughout the day, which in this risk assessment is every hour. A combination of the magnitude of flux and concurrent meteorological conditions is used to determine the time when the maximum upper 90th percentile peak concentration may occur.

Table 3-5 shows the input parameters used in PERFUM. Like the screening approach, the maximum allowable treated fields of 100 acres for broadcast and bedded shank injection applications, and 10 acres for hot gas tarped chemigation applications were parameterized into PERFUM. For this risk assessment, five years of meteorological data at Bakersfield, CA (1999 – 2003), representative of the Central Valley growing region, and Ventura, CA (1995- 1999), representative of the Coastal growing region, were used. The time series of flux values input into PERFUM for broadcast shank injection, bedded shank injection, and hot gas chemigation applications are shown in **Table 3-6, Table 3-7, and Table 3-8**, respectively. There are two days worth of hourly flux data. These flux values are extracted from CALDPR's composite flux profiles as these values resulted in the maximum upper-bound air EECs in PERFUM for each application method. This flux profile time series is representative with the time of day of concurrent meteorological data associated with it. The flux profile time series is repeated in its entirety (Days 1 and 2 time series) concurrent with the five years of meteorological data. PERFUM maximum peak (hourly) upper 90th percentile EECs are shown in **Table 3-9.** PERFUM maximum EECs occurring within 5 meters from the edge of the field are shown in this table.

Table 3-5. Input parameters utilized in PERFUM.

Input Parameter	Value
Source Type	Area
Averaging Period	1-hour
Application Start Time	10:00 am[1]
Flux Rates (μg/m^{2}s)	Broadcast Shank Injection: See **Table 3-6** Bedded Shank Injection: See **Table 3-7** Hot Gas Tarped Chemigation: See **Table 3-8**
Source Height (m)	0
Field Dimension Lengths (m)	Broadcast Shank Injection: 636.1 (100 acre square field) Bedded Shank Injection: 636.1 (100 acre square field) Hot Gas Chemigation: 201.2 (10 acre square field)
Downwind Distance of EEC Receptors Around Field (m)	5, 7, 10, 15, 20, 30, 50, 70, 80, 90, 100, 120, 150, 180, 210, 240, 270, 300, 360, 420, 480, 540, 600, 720, 840, 960, 1080, 1200, 1320, 1400[2]
Receptor Height (m)	1.5[2]
Meteorological Data Locations	Bakersfield (CA), Ventura (CA)

[1]Model start time assumed based upon known typical application practices. Model start time does not impact results given the 1-hour averaging time.
[2]Values cannot be controlled in the current version of PERFUM.

Table 3-6. Temporal flux profiles utilized in PERFUM for methyl bromide broadcast tarped shank injection applications.						
		Application Rate = 400 lbs. a.i./A	Application Rate = 396 lbs. a.i./A	Application Rate = 282 lbs. a.i./A	Application Rate = 264 lbs. a.i./A	Application Rate = 240 lbs. a.i./A
Time Series Day	Hour of Day in Timeseries	Flux Rate ($\mu g/m^2s$)	Flux Rate ($\mu g/m^2s$)	Flux Rate ($\mu g/m^2s$)	Flux Rate ($\mu g/m^2s$)	Flux Rate ($\mu g/m^2s$)
1	10 am – 11 am	170.42	168.71	120.15	112.48	102.25
	11 am – 12 pm	169.16	167.47	119.26	111.65	101.50
	12 pm – 1 pm	167.25	165.57	117.91	110.38	100.35
	1 pm – 2 pm	164.8	163.15	116.18	108.77	98.88
	2 pm – 3 pm	161.93	160.31	114.16	106.87	97.16
	3 pm – 4 pm	158.73	157.14	111.9	104.76	95.24
	4 pm – 5 pm	155.27	153.72	109.47	102.48	93.16
	5 pm – 6 pm	151.64	150.12	106.90	100.08	90.98
	6 pm – 7 pm	0.19	0.18	0.13	0.12	0.11
	7 pm – 8 pm	4.31	4.26	3.04	2.84	2.58
	8 pm – 9 pm	17.25	17.07	12.16	11.38	10.35
	9 pm – 10 pm	36.87	36.50	25.99	24.33	22.12
	10 pm – 11 pm	59.09	58.50	41.66	39.00	35.45
	11 pm – 12 am	81.02	80.21	57.12	53.48	48.61
	12 am – 1 am	101.03	100.02	71.23	66.68	60.62
	1 am – 2 am	118.38	117.20	83.46	78.13	71.03
	2 am – 3 am	132.87	131.54	93.67	87.69	79.72
	3 am – 4 am	144.56	143.11	101.91	95.41	86.73
	4 am – 5 am	153.68	152.15	108.35	101.43	92.21
	5 am – 6 am	160.53	158.92	113.17	105.95	96.32
	6 am – 7 am	165.4	163.74	116.6	109.16	99.24
	7 am – 8 am	168.57	166.88	118.84	111.25	101.14
	8 am – 9 am	170.32	168.61	120.07	112.41	102.19
	9 am – 10 am	170.87	169.16	120.46	112.77	102.52

Table 3-6. Temporal flux profiles utilized in PERFUM for methyl bromide broadcast tarped shank injection applications.						
		Application Rate = 400 lbs. a.i./A	Application Rate = 396 lbs. a.i./A	Application Rate = 282 lbs. a.i./A	Application Rate = 264 lbs. a.i./A	Application Rate = 240 lbs. a.i./A
Time Series Day	Hour of Day in Timeseries	Flux Rate ($\mu g/m^2 s$)	Flux Rate ($\mu g/m^2 s$)	Flux Rate ($\mu g/m^2 s$)	Flux Rate ($\mu g/m^2 s$)	Flux Rate ($\mu g/m^2 s$)
2	10 am – 11 am	90.27	89.37	63.64	59.58	54.16
	11 am – 12 pm	87.35	86.48	61.58	57.65	52.41
	12 pm – 1 pm	84.52	83.68	59.59	55.78	50.71
	1 pm – 2 pm	81.79	80.97	57.66	53.98	49.07
	2 pm – 3 pm	79.14	78.35	55.80	52.24	47.49
	3 pm – 4 pm	76.60	75.83	54.00	50.55	45.96
	4 pm – 5 pm	74.12	73.38	52.26	48.92	44.47
	5 pm – 6 pm	71.74	71.02	50.58	47.35	43.04
	6 pm – 7 pm	147.86	146.38	104.24	97.59	88.72
	7 pm – 8 pm	144.01	142.57	101.53	95.05	86.41
	8 pm – 9 pm	140.09	138.69	98.77	92.46	84.06
	9 pm – 10 pm	136.17	134.81	96.00	89.87	81.70
	10 pm – 11 pm	132.24	130.92	93.23	87.28	79.35
	11 pm – 12 am	128.35	127.07	90.49	84.71	77.01
	12 am – 1 am	124.49	123.25	87.77	82.17	74.70
	1 am – 2 am	120.70	119.49	85.09	79.66	72.42
	2 am – 3 am	116.98	115.81	82.47	77.20	70.19
	3 am – 4 am	113.32	112.19	79.89	74.79	67.99
	4 am – 5 am	109.76	108.66	77.38	72.44	65.85
	5 am – 6 am	106.28	105.22	74.93	70.14	63.77
	6 am – 7 am	102.88	101.85	72.53	67.90	61.73
	7 am – 8 am	99.59	98.59	70.21	65.73	59.75
	8 am – 9 am	96.39	95.43	67.96	63.62	57.83
	9 am – 10 am	93.28	92.35	65.77	61.57	55.97

[1] Flux rates scaled from CALDPR composite flux profile for hot gas chemigation tarped applications normalized to 430 lbs. a.i./A from Johnson, 1999.
[2] CALDPR composite flux profile chosen consistent with larger PERFUM results than using Wasco, CA flux profiles (MRID No. 48006001).

Table 3-7. Temporal flux profiles utilized in PERFUM for methyl bromide bedded tarped shank injection applications.

Time Series Day	Hour of Day in Timeseries	Application Rate = 400 lbs. a.i./A Flux Rate ($\mu g/m^2 s$)	Application Rate = 396 lbs. a.i./A Flux Rate ($\mu g/m^2 s$)	Application Rate = 282 lbs. a.i./A Flux Rate ($\mu g/m^2 s$)	Application Rate = 264 lbs. a.i./A Flux Rate ($\mu g/m^2 s$)	Application Rate = 240 lbs. a.i./A Flux Rate ($\mu g/m^2 s$)
1	10 am – 11 am	94.05	93.11	66.31	62.07	56.43
	11 am – 12 pm	86.52	85.65	60.99	57.10	51.91
	12 pm – 1 pm	79.85	79.06	56.30	52.70	47.91
	1 pm – 2 pm	73.93	73.19	52.12	48.79	44.36
	2 pm – 3 pm	68.63	67.94	48.38	45.29	41.18
	3 pm – 4 pm	63.87	63.23	45.03	42.16	38.32
	4 pm – 5 pm	59.58	58.99	42.01	39.33	35.75
	5 pm – 6 pm	55.71	55.15	39.28	36.77	33.43
	6 pm – 7 pm	827.57	819.3	583.44	546.20	496.54
	7 pm – 8 pm	807.66	799.58	569.40	533.05	484.59
	8 pm – 9 pm	628.17	621.88	442.86	414.59	376.9
	9 pm – 10 pm	500.14	495.14	352.6	330.09	300.08
	10 pm – 11 pm	408.77	404.68	288.18	269.79	245.26
	11 pm – 12 am	341.33	337.92	240.64	225.28	204.80
	12 am – 1 am	289.96	287.06	204.42	191.38	173.98
	1 am – 2 am	249.80	247.30	176.11	164.87	149.88
	2 am – 3 am	217.71	215.53	153.48	143.69	130.62
	3 am – 4 am	191.6	189.68	135.08	126.46	114.96
	4 am – 5 am	170.03	168.33	119.87	112.22	102.02
	5 am – 6 am	151.98	150.46	107.15	100.31	91.19
	6 am – 7 am	136.7	135.33	96.37	90.22	82.02
	7 am – 8 am	123.65	122.41	87.17	81.61	74.19
	8 am – 9 am	112.39	111.26	79.23	74.17	67.43
	9 am – 10 am	102.61	101.58	72.34	67.72	61.56

Table 3-7. Temporal flux profiles utilized in PERFUM for methyl bromide bedded tarped shank injection applications.						
		Application Rate = 400 lbs. a.i./A	Application Rate = 396 lbs. a.i./A	Application Rate = 282 lbs. a.i./A	Application Rate = 264 lbs. a.i./A	Application Rate = 240 lbs. a.i./A
Time Series Day	Hour of Day in Timeseries	Flux Rate (µg/m^{2}s)	Flux Rate (µg/m^{2}s)	Flux Rate (µg/m^{2}s)	Flux Rate (µg/m^{2}s)	Flux Rate (µg/m^{2}s)
2	10 am – 11 am	22.43	22.21	15.82	14.81	13.46
	11 am – 12 pm	21.48	21.26	15.14	14.17	12.89
	12 pm – 1 pm	20.57	20.37	14.5	13.58	12.34
	1 pm – 2 pm	19.72	19.53	13.91	13.02	11.83
	2 pm – 3 pm	18.92	18.73	13.34	12.49	11.35
	3 pm – 4 pm	18.17	17.99	12.81	11.99	10.90
	4 pm – 5 pm	17.46	17.28	12.31	11.52	10.47
	5 pm – 6 pm	16.78	16.61	11.83	11.08	10.07
	6 pm – 7 pm	52.2	51.67	36.8	34.45	31.32
	7 pm – 8 pm	48.99	48.5	34.54	32.34	29.40
	8 pm – 9 pm	46.07	45.61	32.48	30.41	27.64
	9 pm – 10 pm	43.40	42.96	30.59	28.64	26.04
	10 pm – 11 pm	40.94	40.53	28.86	27.02	24.56
	11 pm – 12 am	38.69	38.3	27.27	25.53	23.21
	12 am – 1 am	36.60	36.24	25.81	24.16	21.96
	1 am – 2 am	34.68	34.33	24.45	22.89	20.81
	2 am – 3 am	32.90	32.57	23.19	21.71	19.74
	3 am – 4 am	31.25	30.94	22.03	20.62	18.75
	4 am – 5 am	29.71	29.42	20.95	19.61	17.83
	5 am – 6 am	28.29	28.00	19.94	18.67	16.97
	6 am – 7 am	26.96	26.69	19.00	17.79	16.17
	7 am – 8 am	25.71	25.45	18.13	16.97	15.43
	8 am – 9 am	24.54	24.30	17.30	16.20	14.73
	9 am – 10 am	23.46	23.22	16.54	15.48	14.07

[1] Flux rates scaled from CALDPR composite flux profile for hot gas chemigation tarped applications normalized to 430 lbs. a.i./A from Johnson, 1999.
[2] Maximum application rate considered in modeling. Application rate is not adjusted for the percent field treated.

Table 3-8. Temporal flux profiles utilized in PERFUM for methyl bromide hot gas tarped chemigation applications.						
		Application Rate = 400 lbs. a.i./A	**Application Rate = 396 lbs. a.i./A**	**Application Rate = 282 lbs. a.i./A**	**Application Rate = 264 lbs. a.i./A**	**Application Rate = 240 lbs. a.i./A**
Time Series Day	**Hour of Day in Timeseries**	**Flux Rate (μg/m²s)**	**Flux Rate (μg/m²s)**	**Flux Rate (μg/m²s)**	**Flux Rate (μg/m²s)**	**Flux Rate (μg/m²s)**
1	10 am – 11 am	283.48	280.64	199.85	187.10	170.09
	11 am – 12 pm	224.58	222.34	158.33	148.23	134.75
	12 pm – 1 pm	177.77	175.99	125.33	117.33	106.66
	1 pm – 2 pm	140.71	139.31	99.20	92.87	84.43
	2 pm – 3 pm	111.46	110.34	78.58	73.56	66.87
	3 pm – 4 pm	88.39	87.50	62.31	58.34	53.03
	4 pm – 5 pm	70.20	69.50	49.49	46.33	42.12
	5 pm – 6 pm	55.86	55.30	39.38	36.87	33.52
	6 pm – 7 pm	44.54	44.09	31.40	29.40	26.72
	7 pm – 8 pm	0.14	0.13	0.10	0.09	0.08
	8 pm – 9 pm	27.21	26.94	19.19	17.96	16.33
	9 pm – 10 pm	236.57	234.21	166.78	156.14	141.94
	10 pm – 11 pm	653.96	647.42	461.04	431.61	392.37
	11 pm – 12 am	1,063.66	1,053.03	749.88	702.02	638.2
	12 am – 1 am	1,310.93	1,297.82	924.21	865.22	786.56
	1 am – 2 am	1,377.87	1,364.09	971.4	909.39	826.72
	2 am – 3 am	1,313.54	1,300.40	926.04	866.93	788.12
	3 am – 4 am	1,176.15	1,164.39	829.19	776.26	705.69
	4 am – 5 am	1,010.31	1,000.21	712.27	666.81	606.19
	5 am – 6 am	843.83	835.39	594.90	556.93	506.30
	6 am – 7 am	691.39	684.48	487.43	456.32	414.84
	7 am – 8 am	559.11	553.51	394.17	369.01	335.46
	8 am – 9 am	448.13	443.65	315.93	295.76	268.88
	9 am – 10 am	357.08	353.51	251.74	235.67	214.25

Table 3-8. Temporal flux profiles utilized in PERFUM for methyl bromide hot gas tarped chemigation applications.						
		Application Rate = 400 lbs. a.i./A	Application Rate = 396 lbs. a.i./A	Application Rate = 282 lbs. a.i./A	Application Rate = 264 lbs. a.i./A	Application Rate = 240 lbs. a.i./A
Time Series Day	Hour of Day in Timeseries	Flux Rate (μg/m^{2}s)	Flux Rate (μg/m^{2}s)	Flux Rate (μg/m^{2}s)	Flux Rate (μg/m^{2}s)	Flux Rate (μg/m^{2}s)
2	10 am – 11 am	1.64	1.63	1.16	1.08	0.98
	11 am – 12 pm	1.36	1.35	0.96	0.90	0.82
	12 pm – 1 pm	1.13	1.12	0.80	0.75	0.68
	1 pm – 2 pm	0.94	0.93	0.67	0.62	0.57
	2 pm – 3 pm	0.79	0.78	0.56	0.52	0.47
	3 pm – 4 pm	0.66	0.65	0.46	0.43	0.40
	4 pm – 5 pm	0.55	0.55	0.39	0.36	0.33
	5 pm – 6 pm	0.46	0.46	0.33	0.31	0.28
	6 pm – 7 pm	0.39	0.39	0.28	0.26	0.23
	7 pm – 8 pm	35.59	35.24	25.09	23.49	21.35
	8 pm – 9 pm	28.51	28.22	20.1	18.81	17.10
	9 pm – 10 pm	22.89	22.66	16.13	15.11	13.73
	10 pm – 11 pm	18.42	18.23	12.99	12.16	11.05
	11 pm – 12 am	14.86	14.71	10.48	9.81	8.92
	12 am – 1 am	12.02	11.90	8.47	7.93	7.21
	1 am – 2 am	9.74	9.65	6.87	6.43	5.85
	2 am – 3 am	7.92	7.84	5.58	5.23	4.75
	3 am – 4 am	6.45	6.39	4.55	4.26	3.87
	4 am – 5 am	5.27	5.22	3.72	3.48	3.16
	5 am – 6 am	4.31	4.27	3.04	2.85	2.59
	6 am – 7 am	3.54	3.50	2.50	2.34	2.12
	7 am – 8 am	2.91	2.88	2.05	1.92	1.75
	8 am – 9 am	2.40	2.38	1.69	1.58	1.44
	9 am – 10 am	1.98	1.96	1.40	1.31	1.19

[1] Flux rates scaled from CALDPR composite flux profile for hot gas chemigation tarped applications normalized to 430 lbs. a.i./A from Johnson, 2004.

Table 3-9. PERFUM upper 90th percentile peak estimated exposure concentrations in air for methyl bromide soil fumigant use.					
Crops and Montreal Protocol Designation	**Application Rate (lbs. a.i./A)**	**EECs in Air For Application Methods (μg/m³)**			
		Shank Injection Broadcast Tarped [2] (100 acres)	**Shank Injection Bedded Tarped [3,4] (100 acres)**	**Hot Gas Tarped Chemigation [2] (10 acres)**	
Forestry Nursery (CUE)	400	8,936	15,929	16,706	
Nursery and Ornamentals (CUE)					
Sweet Potatoes (CUE)					
Golf Courses and Athletic Fields (SP)					
Peppers (CUE)	396	8,156	15,121	16,706	
Strawberries (CUE)	282	5,828	11,267	12,044	
Tomatoes (CUE)	264	5,828	10,490	11,267	
Eggplant (CUE)	240	5,051	8,936	9,713	
Cucurbits (CUE)					
Berries (SP)					

[1]Montreal Protocol Designation Codes: CUE – Critical Use Exemption; QPS – Quarantine and Pre-Shipment Exemption; SP – Stockpile
[2] EECs based on upper 90th percentile PERFUM modeling using 5-years of Ventura, CA meteorological data.
[3] EECs based on upper 90th percentile PERFUM modeling using 5-years of Bakersfield, CA meteorological data.
[4] Maximum application rate considered in modeling. Application rate is not adjusted for the percent field treated.
[5] PERFUM upper bound EEC shown at 5 meters from the edge of the field, 1.5 meters above ground level.

Structural Fumigant Uses

The refined PERFUM model is used to calculate upper 90th percentile peak (hourly) EECs from a distribution of air concentrations, based on a distribution emission rates based on aeration scenarios of controlled released described above in the introduction. **Table 3-10** shows the modeling input parameters used in PERFUM for all structural release scenarios. Like for the PERFUM modeling for soil fumigants, meteorological data at Bakersfield, CA (1999 – 2003), representative of the Central Valley growing region, and Ventura, CA (1995- 1999), representative of the Coastal growing region, were used. **Table 3-11** shows the time series of flux values input into PERFUM. These flux values are calculated from the assumption of exponential decline for emissions for a 12-hour and 6-hour releases from 10,000,000 $ft.^3$ and 250,000 $ft.^3$ buildings, respectively. The equations for flux and emission rates are shown above and are incorporated into PERFUM according to the aeration scenario modeled. **Table 3-12** shows other source release parameter values input into the modeling for each scenario.

Table 3-10. PERFUM input parameters utilized in all simulations for methyl bromide structural fumigation releases.

Input Parameter	Value
Averaging Period	1-hour
Application Start Time	9:00 am[1]
Flux Rates ($\mu g/m^2 s$)	See **Table 3-11**
Source Parameters	See **Table 3-12**
Downwind Distance of EEC Receptors Around Field (m)	5, 7, 10, 15, 20, 30, 50, 70, 80, 90, 100, 120, 150, 180, 210, 240, 270, 300, 360, 420, 480, 540, 600, 720, 840, 960, 1080, 1200, 1320, 1400[2]
Receptor Height (m)	1.5[2]
Meteorological Data Locations	Bakersfield (CA), Ventura (CA)

[1]Model start time assumed based upon known typical application practices. Model start time does not impact results given the 1-hour averaging time.
[2]Values cannot be controlled in the current version of PERFUM.

Table 3-11. PERFUM emissions time series input for emission scenarios described above.								
Hour of Day in Timeseries	Structure Size = 10,000,000 ft.^{3}, 12 hour release				Structure Size = 250,000 ft.^{3}, 6 hour release			
	Scenario 1 [1]		Scenarios 2 and 3 [2]		Scenario 1 [1]		Scenarios 2 and 3 [2]	
	Application Rate = 15 lbs./1,000 ft.^{3}	Application Rate = 9 lbs./1,000 ft.^{3}	Application Rate = 15 lbs./1,000 ft.^{3}	Application Rate = 9 lbs./1,000 ft.^{3}	Application Rate = 15 lbs./1,000 ft.^{3}	Application Rate = 9 lbs./1,000 ft.^{3}	Application Rate = 15 lbs./1,000 ft.^{3}	Application Rate = 9 lbs./1,000 ft.^{3}
	Flux Rate (μg/m^{2}s)		Emission Rate (g/s)		Flux Rate (μg/m^{2}s)		Emission Rate (g/s)	
9 am – 10 am	193,593	116,156	11,947	7,168	145,194	87,117	299	179
10 am – 11 am	175,170	105,102	4,395	2,637	131,377	78,826	110	66
11 am – 12 pm	158,500	95,100	1,617	970	118,875	71,325	40	24
12 pm – 1 pm	143,417	86,050	595	357	107,563	64,538	15	9
1 pm – 2 pm	129,769	77,861	219	131	97,327	58,396	5	3
2 pm – 3 pm	117,420	70,452	80	48	88,065	52,839	2	1
3 pm – 4 pm	106,246	63,748	30	18	145,194	87,117	299	179
4 pm – 5 pm	96,135	57,681	11	7	131,377	78,826	110	66
5 pm – 6 pm	86,987	52,192	4	2	118,875	71,325	40	24
6 pm – 7 pm	78,709	47,225	1	1	107,563	64,538	15	9
7 pm – 8 pm	71,219	42,731	1	0	97,327	58,396	5	3
8 pm – 9 pm	64,441	38,665	0	0	88,065	52,839	2	1
9 pm – 10 pm	193,593	116,156	11,947	7,168	145,194	87,117	299	179
10 pm – 11 pm	175,170	105,102	4,395	2,637	131,377	78,826	110	66
11 pm – 12 am	158,500	95,100	1,617	970	118,875	71,325	40	24
12 am – 1 am	143,417	86,050	595	357	107,563	64,538	15	9
1 am – 2 am	129,769	77,861	219	131	97,327	58,396	5	3
2 am – 3 am	117,420	70,452	80	48	88,065	52,839	2	1
3 am – 4 am	106,246	63,748	30	18	145,194	87,117	299	179
4 am – 5 am	96,135	57,681	11	7	131,377	78,826	110	66
5 am – 6 am	86,987	52,192	4	2	118,875	71,325	40	24
6 am – 7 am	78,709	47,225	1	1	107,563	64,538	15	9
7 am – 8 am	71,219	42,731	1	0	97,327	58,396	5	3
8 am – 9 am	64,441	38,665	0	0	88,065	52,839	2	1

Table 3-11 (continued). PERFUM emissions time series input for emission scenarios described above.		
Hour of Day in Timeseries	Structure Size = 10,000 ft.[3], 6 hour release	
	Scenario 4 [3]	
	Application Rate = 15 lbs./1,000 ft.[3]	Application Rate = 9 lbs./1,000 ft.[3]
	Flux Rate (μg/m²s)	
9 am – 10 am	24,804	14,882
10 am – 11 am	48,398	29,039
11 am – 12 pm	70,842	42,505
12 pm – 1 pm	92,191	55,314
1 pm – 2 pm	112,498	67,499
2 pm – 3 pm	131,816	79,089
3 pm – 4 pm	107,012	64,207
4 pm – 5 pm	83,418	50,051
5 pm – 6 pm	60,974	36,584
6 pm – 7 pm	39,625	23,775
7 pm – 8 pm	19,317	11,590
8 pm – 9 pm	24,804	14,882
9 pm – 10 pm	48,398	29,039
10 pm – 11 pm	70,842	42,505
11 pm – 12 am	92,191	55,314
12 am – 1 am	112,498	67,499
1 am – 2 am	131,816	79,089
2 am – 3 am	107,012	64,207
3 am – 4 am	83,418	50,051
4 am – 5 am	60,974	36,584
5 am – 6 am	39,625	23,775
6 am – 7 am	19,317	11,590
7 am – 8 am	0	0
8 am – 9 am	0	0

[1]Flux rates are calculated according to flux equation shown in scenario description above.
[2]Emission rates are calculated according to emission rate equation shown in scenario description above.
[3]Flux rates are calculated according to flux equation shown in scenario description above. To account for multiple source emissions, the emissions time series for this scenario assumes that hourly emissions build over time to the point that there can be as much as six emitting sources (railcars) at a time, and that emissions from each source will decline according to the flux equation above according to a six hour release.

Table 3-12. PERFUM source parameter input values for scenarios discussed above.

Source Parameter	Scenario 1		Scenario 2		Scenario 3	
Structure Size = 10,000,000 ft.^{3}, 12 hour release						
Source Parameter	**Application Rate = 15 lbs./1,000 ft.^{3}**	**Application Rate = 9 lbs./1,000 ft.^{3}**	**Application Rate = 15 lbs./1,000 ft.^{3}**	**Application Rate = 9 lbs./1,000 ft.^{3}**	**Application Rate = 15 lbs./1,000 ft.^{3}**	**Application Rate = 9 lbs./1,000 ft.^{3}**
Source Type	Area		Point		Point	
Source Length (m)	96.4		96.4		96.4	
Source Width (m)	96.4		96.4		96.4	
Relase Height (m)	15.2 [1]		33.5 [5]		0.46	
Stack Diameter (m)	NA		15 [6]		316.47[3]	
Gas Stream Flow Velocity (m/s)	NA		0.445 [2]		0.001 [3]	
Stack Gas Temperature (K)	NA		Equivalent to Ambient Temperature		Equivalent to Ambient Temperature	
Structure Size = 250,000 ft.^{3}, 6 hour release						
	Scenario 1		**Scenario 2**		**Scenario 3**	
Source Parameter	**Application Rate = 15 lbs./1,000 ft.^{3}**	**Application Rate = 9 lbs./1,000 ft.^{3}**	**Application Rate = 15 lbs./1,000 ft.^{3}**	**Application Rate = 9 lbs./1,000 ft.^{3}**	**Application Rate = 15 lbs./1,000 ft.^{3}**	**Application Rate = 9 lbs./1,000 ft.^{3}**
Source Type	Area		Point		Point	
Source Length (m)	22.9		22.9		22.9	
Source Width (m)	22.9		22.9		22.9	
Release Height (m)	11.4 [1]		25.9 [5]		0.46	
Stack Diameter (m)	NA		2 [6]		50.04[3]	
Gas Stream Flow Velocity (m/s)	NA		0.626 [2]		0.001[3]	
Stack Gas Temperature (K)	NA		Equivalent to Ambient Temperature		Equivalent to Ambient Temperature	

Table 3-12 (continued). PERFUM source parameter input values for scenarios discussed above.		
Structure Size = 10,000 ft.^{3}, 6 hour release		
	Scenario 4	
Source Parameter	**Application Rate = 15 lbs./1,000 ft.^{3}**	**Application Rate = 9 lbs./1,000 ft.^{3}**
Source Type	Area	
Source Length (m)	6.1	
Source Width (m)	6.1	
Release Height (m)	3.8 [1]	
Stack Diameter (m)	NA	
Gas Stream Flow Velocity (m/s)	NA	
Stack Gas Temperature (K)	NA	

[1.] Release height half of the building height assumed for passive aeration scenarios.

[2] $$\text{Gas Stream Flow Velocity (m/sec)} = \text{Gas Stream Flow Rate} \left(\frac{m^3}{sec}\right) \times \frac{4}{\pi * [\text{Stack Diameter (m)}]^2}$$

where $$\text{Gas Stream Flow Rate } (m^3/sec) = \frac{\text{Building Volume } (ft.^3) \times \frac{m^3}{35.31\ ft.^3} \times \text{AXR} \left(\frac{1}{hr.}\right)}{\frac{3{,}600 \text{ seconds}}{hr.}}$$

[3.] Gas Stream Flow Velocity = 0.001 m/sec to simulate horizontal release. Modeled stack diameter back-calculated using equations in footnote 2 above.

[4] NA means not applicable for passive aeration scenario.

[5] Release height is the stack height of 10 ft. plus the building height for mechanical aeration scenarios.

[6] The stack diameter value for mechanical aeration accounts for a composite of multiple stacks or vents that may exist on methyl bromide treated structures.

As in the soil fumigants modeling, the PERFUM maximum upper 90th percentile predicted peak (hourly) concentrations are selected as EECs resulting from the uses with labeled application rates of 9 lbs. a.i./A and 15 lbs. a.i./A. The PERFUM EECs are shown in **Table 3-13.** Risk quotients and downwind distances to the level of concern are presented in **Section 5.1** where appropriate.

Table 3-13. PERFUM upper-bound EEC in air for methyl bromide structural fumigation applications and downwind distance to maximum application.

Use Types and Montreal Protocol Designation	Application Rate (lbs./ 1,000 ft.^{3})	Structure Volume (ft.^{3}) and Release Period (hrs.)	Building Aeration Emission Scenarios			Railcars and Cargo Aeration Emissions [4]
			Scenario 1 Exponential Emissions Decline, Single Source, AXR = 0.1, Passive Aeration, No Stack	**Scenario 2** Exponential Emissions Decline, Single Source, AXR = 1.0, Active Aeration, 10 ft. Vertical Stack	**Scenario 3** Exponential Emissions Decline, Single Source, AXR = 1.0, Active Aeration, 3 ft. Horizontal Portable Stack	**Scenario 4** Exponential Emissions Decline, Multiple Source, AXR = 0.05, Passive Aeration, No Stack
• Post Harvest Indoor Food Fumigation (QPS) • Commodity Indoor Fumigation (QPS)	9	10,000 ft^3 for 6 hrs.	ND	ND	ND	1,554 $\mu g/m^3$ at 1,440 m
		250,000 ft^3 for 6 hrs.	1,554 $\mu g/m^3$ at 1,440 m	1,554 $\mu g/m^3$ at 1,440 m	**141,369 $\mu g/m^3$ at 7 m**	N/A
		10,000,000 ft.^{3} for 12 hrs.	47,397 $\mu g/m^3$ at 50 m	**137,529 $\mu g/m^3$ at 50 m**	31,857 $\mu g/m^3$ at 7 m	N/A
• Timber and Tile Indoor Fumigation (QPS) • Space Fumigation (SP)	15	10,000 ft^3 for 6 hrs.	ND	ND	ND	1,554 $\mu g/m^3$ at 1,440 m
		250,000 ft^3 for 6 hrs.	1,554 $\mu g/m^3$ at 1,440 m	1,554 $\mu g/m^3$ at 1,440 m	**237,686 $\mu g/m^3$ at 7 m**	N/A
		10,000,000 ft.^{3} for 12 hrs.	**78,477 $\mu g/m^3$ at 50 m**	**230,769 $\mu g/m^3$ at 50 m**	55,l67 $\mu g/m^3$ at 7 m	N/A

[1] Montreal Protocol Designation Codes: CUE – Critical Use Exemption; QPS – Quarantine and Pre-Shipment Exemption; SP – Stockpile
[2].N/ A means not applicable.
[3] ND means not modeled.
[4] Modeling at 5,000 ft.3 and 10,000 ft.3 representative of railcar and cargo hold structure sizes per CSX website (http://www.csx.com/index.cfm/customers/equipment/railroad-equipment/).
[5] Maximum upper 90th percentile air concentration refers to the maximum of PERFUM generated air concentration distributions binned by time of day (one hour averaging periods) and receptor ring.
[6] PERFUM EECs based on 5 years of Bakersfield, CA meteorological data. Upper-bound EECs for simulations with Bakersfield, CA meteorological data were higher than simulations conducted with Ventura, CA meteorological data.
[7] EECs in bold - please refer to risk estimation in Section 5.1.1 which present the direct effect and indirect acute RQs exceeding the LOCs for avian endangered and mammalian species.

3.1.2. Atmospheric Monitoring Data

A wide variety of air monitoring datasets for methyl bromide are available. These consist of air monitoring concurrent with methyl bromide applications and nearby application sites, ambient air monitoring targeted within air sheds concurrent with applications, and global ambient air monitoring. Air monitoring data are available for soil fumigation applications. For structural fumigations, air monitoring data are available for indoor and outdoor treated structures. Application air monitoring as well as ambient datasets targeting high use air sheds are available in the vicinity of both structural and soil fumigant uses. The available monitoring data are presented below. In addition, the comparison of risk quotients using monitoring data to risk quotients using modeled air EECs are qualitatively characterized in **Section 5.2.1**.

Global Ambient Air Monitoring Data

There are many short-term and several long-term atmospheric methyl bromide monitoring datasets which quantify ambient levels on a global scale. These data provide measures of the baseline concentrations (natural background plus anthropogenic concentrations) of methyl bromide in the atmosphere and indicate levels of continuous exposure of methyl bromide for the CTS. However, it is important to note that these data are not intrinsic to just pesticide applications, but are also reflective of other sources emitting methyl bromide. **Table 3-14** shows existing non-targeted air monitoring data for methyl bromide nationwide. Methyl bromide levels were measured as high as 55,000 ppt. However, this was in an urban center in traffic-filled streets which could have contributed to methyl bromide emissions. The next highest methyl bromide level of 560 ppt was measured in an agricultural region in a dataset spanning over a three-year period. The 560 ppt concentration most likely represents a background level of methyl bromide not directly influenced by a pesticide application**.** Other similar datasets indicate methyl bromide ambient levels of between <5 – 280 ppt.

There is a robust dataset on halocarbon trace gases from the NOAA Earth System Research Laboratory Global Monitoring Division that encompasses a span of up to 18 years from 15 stations located throughout the world. Many of the following locations where methyl bromide is sampled are isolated from locations where methyl bromide is used as a pesticide: Alert (Nunavut, Canada), Point Barrow (Alaska), Park Falls (Wisconsin), Niwot Ridge (Colorado), Cape Kumukahi (Hawaii), Mauna Loa (Hawaii), Cape Matatula (America Samoa), Cape Grim (Tasmania, Australia), Palmer Station (Antarctica), the South Pole, Harvard University (Cambridge, MA), Mace Head (Ireland), Trinidad Head (California), Tierra del Fuego (Ushauia, Argentina), and Summit (Greenland). These data provide insight regarding the potential impact of declining methyl bromide use in Northern Hemisphere and how this may contribute to the overall decline of methyl bromide observed in the global atmosphere. The time series of methyl bromide concentrations are shown for all stations in the plots provided in **Figure 3-1** (Montzka et al., 2003; Yvon-Lewis et al., 2009; Montzka et al., 2011).

Table 3-14. Methyl bromide air ambient monitoring data non-targeted for pesticide use.				
Observed Concentration (ppt)	**Location**	**Date**	**Comments**	**Reference**
<5	Pacific Northwest	1974 - 1975		Grimsrud and Rasmussen, 1975
14.4	Norwegian Arctic	1982 - 1983		Hov et al. 1984
18,000 – 55,000	Washington (State)	1976	Auto exhaust using leaded gas and no catalytic converter	Harsch and Rasumussen, 1977
<10 - 185	Washington (State)	1976	Street with heavy traffic	Harsch and Rasumussen, 1977
<10	Washington (State)	1976	Street with heavy traffic	Harsch and Rasumussen, 1977
100	Houston, TX	1980		Singh et al., 1982
81	St. Louis, MO	1980		Singh et al., 1982
124	Denver, CO	1980		Singh et al., 1982
259	Riverside, CA	1980		Singh et al., 1982
84	Staten Island, NY	1981		Singh et al., 1982
41	Pittsburgh, PA	1981		Singh et al., 1982
47	Chicago, IL	1981		Singh et al., 1982
20	Minnesota (State)	1990		Pratt et al., 2000
50, 10, 280, 560	Phoenix, Payson, Casa Grande, and Tuscon, respectively	1994 - 1996	Phoenix and Tuscon are major metro areas, Payson represents a rural mountain area, Casa Grande represents a rural agricultural area	Zielinska et al., 1998

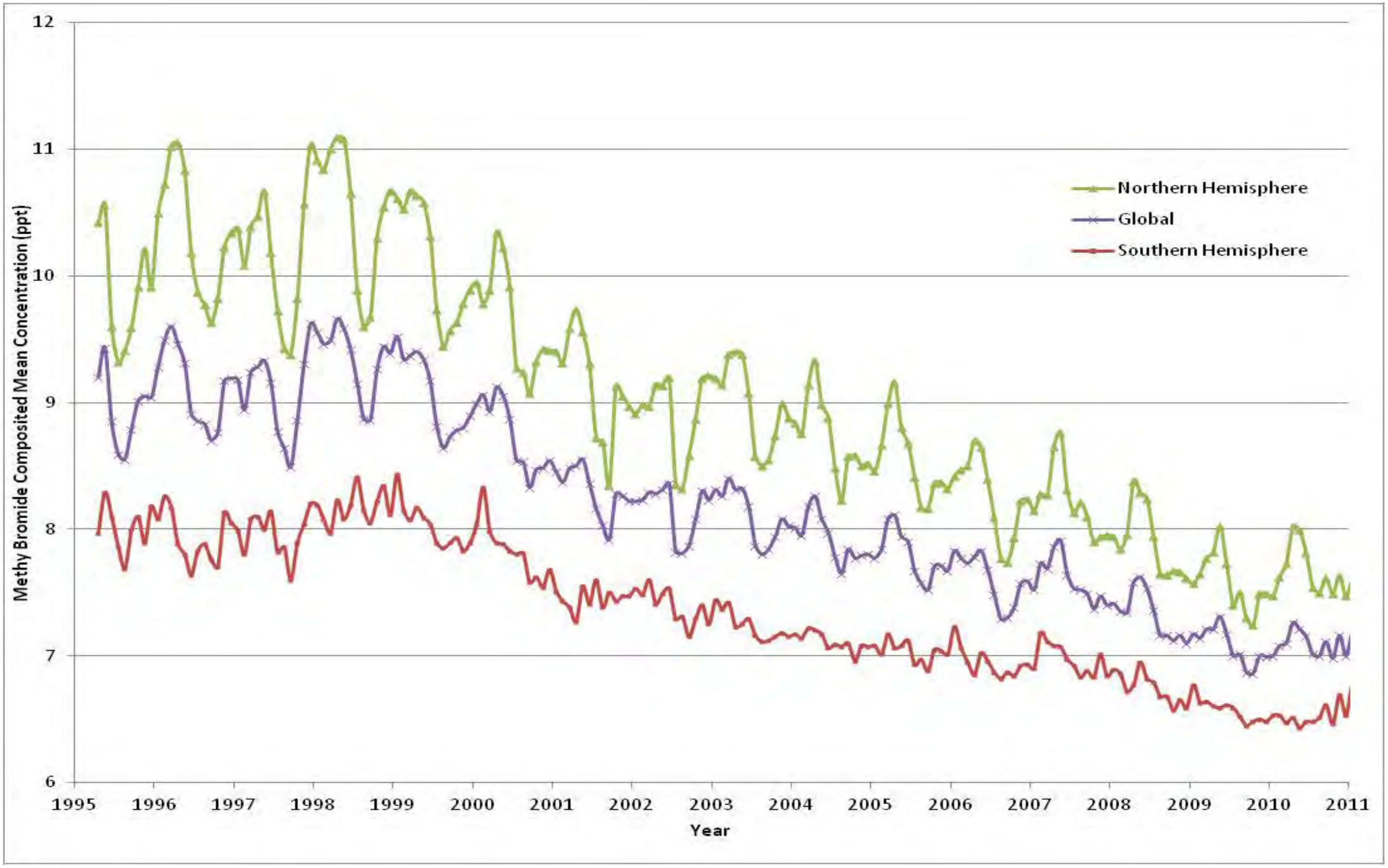


Figure 3-1. Hemispheric and global composited time series plots of methyl bromide trace gas atmospheric concentrations monitored at sites encompassing the NOAA/ESRL/GMD halocarbon global monitoring network.

Figure 3-1 shows that methyl bromide levels are highest in the northern hemisphere, despite the fact that ocean coverage is much lower in the northern hemisphere than the southern hemisphere. The likely main contributing reason appears to be due to fumigation and anthropogenic sources, the signature of which can also be observed in the higher amplified intra-annual oscillations of methyl bromide levels in the northern hemisphere as compared to the southern hemisphere. Another reason for this intra-annual oscillation observed in both hemispheres includes seasonal variations in temperature which contribute to methyl bromide emissions surpluses. Overall, the underlying trend suggests that methyl bromide levels have been steadily decreasing throughout the globe since 1998, which corresponds to the beginning of the reduction of methyl bromide use from baseline levels prior to that year.

Ambient Air Monitoring Data in Targeted Air Sheds with Methyl Bromide Applications

There is also a wealth of air monitoring data within California air sheds where methyl bromide soil and structural uses are prevalent. **Table 3-15** shows the levels of methyl bromide observed in the atmosphere in various California air sheds targeted at times of methyl bromide use. The monitoring concentrations were measured at varying averaging periods ranging from between 24 hours and 54-hour average concentrations. The values were compared to an upper 90th percentile peak hourly PERFUM modeled estimated air concentrations. Modeled estimated air concentrations for soil fumigant and structural uses ranged from between 1,544 $\mu g/m^3$ – 237,686 $\mu g/m^3$ (400 – 61,211.53 ppb)[4] for all uses. The highest monitored concentration observed of 30.8 ppb was approximately an order of magnitude lower than the minimum EEC of 390 ppb.

Table 3-15. Methyl bromide ambient air monitoring data targeted to areas for pesticide use.

Observed Maximum Monitored Concentration (ppb) and Magnitude Departure from Minimum EEC	Location	Date	Averaging Period	Reference
30.8 (12.98)	Monterey and Santa Cruz Counties, CA	2000	24-hour maximum concentrations	California Department of Pesticide Regulation, 2001
7.7 (51.94)	Monterey and Santa Cruz Counties, CA	2000	54-day average concentrations	California Department of Pesticide Regulation, 2001

[4] Ideal gas law used to convert between modeling units of $\mu g/m^3$ and ppb. $ppb = \mu g/m^3 \times \frac{24.45\ m^3/kmol}{94.94\ kg/kmol}$

Table 3-15. Methyl bromide ambient air monitoring data targeted to areas for pesticide use.				
Observed Maximum Monitored Concentration (ppb) and Magnitude Departure from Minimum EEC	**Location**	**Date**	**Averaging Period**	**Reference**
14.2 (28.16)	Kern County, CA	2000	54-day average concentrations	California Department of Pesticide Regulation, 2001
2.2 (181.81)	Kern County, CA	2000	24-hour maximum concentrations	California Department of Pesticide Regulation, 2001
1.420 (281.69)	Monterey, CA	1995	24-hour maximum concentrations	Honaganahalli and Seiber, 1999
1.025 (390.25)	Monterey, CA	1986	Unknown	Baker et al., 1996
Median = 0.15 95th %ile = 2.50 (160) [2]	Oxnard/Camarillo, CA	2001	Unknown	MRID 45644201
Median = 0.42 95th %ile = 3.80 (105.26) [2]	Santa Maria, CA	2001	Unknown	MRID 45644201

[1] Maximum monitored concentration shown in bold-face.

[2] Magnitude departure from EEC = $\frac{\text{Minimum EEC (ppb)}}{\text{Maximum Monitored Concentration (ppb)}}$

[3] 95th percentile monitored concentration value compared to minimum air EEC.

Application Air Monitoring Data for Methyl Bromide Soil Fumigant Applications

There are numerous air monitoring data collocated with methyl bromide soil fumigant applications. **Table 3-16** generally shows that levels of methyl bromide observed in the atmosphere concurrent with methyl bromide applications in California ranged from between 0.001 – 3.35 ppm. The concentrations were measured at varying averaging periods ranging from between hourly and 24-hour average concentrations and compared to hourly peak upper 90th percentile PERFUM estimated air concentrations. PERFUM estimated air concentrations for soil uses ranged from between 5,051 μg/m^3 – 16,706 μg/m^3 ppm)[5] for all uses; these values are at least double the magnitude compared to the highest monitored concentration observed at 3.35 ppm. In 2 out of 12 cases, monitored concentrations exceeded the minimum of modeling EECs for soil uses of methyl bromide. In 3 other cases, minimum refined modeling EECs for soil uses exceeded maximum monitored concentrations be a magnitude of between 1.59 – 2.05. However, the maximum refined modeled estimated air concentration was higher than the maximum monitored air value by at least a magnitude of 1.28. It should be noted that there are uncertainties in treated field sizes and field management practices (e.g., the specific combination of application methods and corresponding incorporation depths) with respect to the application monitoring sites. The modeling results reflect restrictions in field sizes and incorporation of required field management practices inherent in flux profiles developed from field volatility studies for each application method. The current labeled application requirements were not necessarily taken into account for the application monitoring studies.

Table 3-16. Methyl bromide application air monitoring data in California for methyl bromide soil fumigant use.

Observed Maximum Monitored Concentration (ppm) and Magnitude Departure from Minimum EEC/ Magnitude Departure from Maximum EEC (in parenthesis)	Date	Application and Measurement Details	Averaging Period	Reference
Monitoring data from non-tarped field applications				
0.001 (1,300/4,300)	October 1992	Measured 40 cm above the field, 392 kg/ha application rate, injected at 25 – 30 cm	24-hour maximum concentration	Majewski et al., 1995
0.70 (1.85/6.14)	1993 - 1998	Measured 80 – 600 ft. from application, non-tarped, deep injection, 348 – 450 lbs./acre	24-hour maximum concentrations	California Department of Pesticide Regulation, 2002

[5] Ideal gas law used to convert between modeling units of μg/m^3 and ppm. ppm = μg/m^3 x $\frac{0.02445 \text{ m}^3/\text{mol}}{94.94 \text{ g/mol}}$

Table 3-16. Methyl bromide application air monitoring data in California for methyl bromide soil fumigant use.				
Observed Maximum Monitored Concentration (ppm) and Magnitude Departure from Minimum EEC/ Magnitude Departure from Maximum EEC (in parenthesis)	**Date**	**Application and Measurement Details**	**Averaging Period**	**Reference**
Monitoring data from tarped field applications				
0.15 (8.67/28.67)	1992 - 1998	Measured 25 – 600 ft. from application, tarp, shallow injection, 180 – 392 lbs./A	24-hour maximum concentrations	California Department of Pesticide Regulation, 2002
1.7 (0.76/2.52)	1993 - 1997	Measured 30 – 330 ft. from application, tarp, bed application, 160 – 200 lbs./A	24-hour maximum concentrations	California Department of Pesticide Regulation, 2002
0.634 (2.05/6.78)	1982	Measured 25 feet downwind from field, no application rate reported, tarp, injected 8 inches below surface	Hourly averages	MRID 00159653
0.396 (3.28/10.85)	September 1983	Measured 25 - 45 feet downwind from field, no application rate reported, tarp, injected 8 inches below surface	Hourly averages	MRID 00159600
0.814 (1.59/5.28)	August 1983	Measured 0 – 1,250 feet downwind from field, no application rate reported, tarp, injected 8 inches below surface	Hourly Averages	MRID 00159600

Table 3-16. Methyl bromide application air monitoring data in California for methyl bromide soil fumigant use.				
Observed Maximum Monitored Concentration (ppm) and Magnitude Departure from Minimum EEC/ Magnitude Departure from Maximum EEC (in parenthesis)	**Date**	**Application and Measurement Details**	**Averaging Period**	**Reference**
0.001 (1,300/4,300)	October 1992	Measured 40 cm above the field, 392 kg/ha application rate, tarp, injected at 25 – 30 cm	Peak Value	Majewski et al., 1995
0.156 (8.33/27.60)	June 1994	Measured 0.5 cm above the field, 322 kg/ha, app. rate, tarp, injected at 27 inches (68 cm)	Peak Value	Yates et al., 1997
3.35 (0.38/1.28)	June 1994	Measured 0.5 m above the field, 322 kg/ha application rate, tarp, injected at 11 inches (28 cm)	Peak Value	Yates et al., 1997
0.12 (10.83/35.83)	June 2009	Measured 0 – 80 feet downwind from field, 180 lbs./A, LDPE tarp, injected 12 inches below surface	4-hour Peak Value	MRID 48006001
0.05 (26.0/86.0)	June 2009	Measured 0 – 80 feet downwind from field, 180 lbs./A, HDPE tarp, injected 12 inches below surface	4-hour Peak Value	MRID 48006001

[1] Maximum monitored concentration shown in bold-face.

[2] Magnitude departure from EEC = $\frac{\text{Minimum or Maximum EEC (ppm)}}{\text{Maximum Monitored Concentration (ppm)}}$

Application Air Monitoring Data for Methyl Bromide Structural Fumigant Applications

There is substantial evidence of near-ground levels of methyl bromide which results from either leakage of methyl bromide measured during treatment and aeration periods from monitoring. **Table 3-17** generally shows that levels of methyl bromide observed nearby treated structures ranged from between 0.012 – 27 ppm. The concentrations were measured at varying averaging periods ranging from between 5-minute to 24-hour average concentrations and compared to the upper 90th percentile PERFUM modeled peak (hourly) estimated air concentration. PERFUM estimated air concentrations for structural uses ranged from between 1,544 $\mu g/m^3$ – 230,769 $\mu g/m^3$ (0.4 – 59.43 ppm)[6] for all uses was as much as two orders of magnitude lower as compared to the highest monitored concentration observed at 27 ppm. However, the highest EEC still exceeded the highest monitoring concentration by a factor of 2 for a 5-minute average monitored concentration value, and almost an order of magnitude for the next highest monitored concentration value of 6.79 ppm. The reason for various higher monitored concentrations than EECs in some of the scenarios is likely due to uncertainty in aeration methods, application rates, and release periods of monitoring outside of treated structures. This information can further qualify the monitoring data enabling for more definitive comparisons to the modeling results for structural fumigation.

Table 3-17. Methyl bromide application monitoring data in unspecified location for methyl bromide structural fumigant use.

Observed Maximum Monitored Concentration (ppm) and Magnitude Departure from Minimum EEC/Magnitude Departure from Maximum EEC (in parenthesis)	Application and Measurement Details	Averaging Period	Reference
27.0 (0.01/2.2)	Measured 25 m away from mill fumigated with methyl bromide	5 -90 minutes Averages	Bond and Dumas, 1987
6.79 (0.05/8.75)	Measured 2 – 108 meters from stack, mechanical aeration, 12, 1,262 lbs. methyl bromide used in chamber	Peak Values	California Department of Pesticide Regulation, 2002

[6] Ideal gas law used to convert between modeling units of $\mu g/m^3$ and ppm. $ppm = \mu g/m^3 \times \frac{0.02445\ m^3/mol}{94.94\ g/mol}$

Table 3-17. Methyl bromide application monitoring data in unspecified location for methyl bromide structural fumigant use.			
Observed Maximum Monitored Concentration (ppm) and Magnitude Departure from Minimum EEC/Magnitude Departure from Maximum EEC (in parenthesis)	**Application and Measurement Details**	**Averaging Period**	**Reference**
0.228 (1.75/260.65)	Measured 12 meters from stack, mechanical aeration, 22 - 32 lbs. methyl bromide used in chamber	Peak Value	California Department of Pesticide Regulation, 2002
4.7 (0.09/12.64)	0 – 5 meters downwind from greenhouse, Application rate 117 g/m^2	24-hour Average One Day After Treatment	De Vreede et al., 1998
0.28 (1.42/212.25)	5 - 10 meters from greenhouse, Application rate 117 g/m^2	24-hour Average One Day After Treatment	De Vreede et al., 1998
5.7 (0.07/10.43)	10 - 20 meters from greenhouse, Application rate 117 g/m^2	24-hour Average One Day After Treatment	De Vreede et al., 1998
1.4 (0.29/38.87)	20 – 40 meters from greenhouse, Application rate 117 g/m^2	24-hour Average One Day After Treatment	De Vreede et al., 1998
1.5 (0.27/39.62)	> 40 meters from greenhouse, Application rate 117 g/m^2	24-hour Average One Day After Treatment	De Vreede et al., 1998

Table 3-17. Methyl bromide application monitoring data in unspecified location for methyl bromide structural fumigant use.			
Observed Maximum Monitored Concentration (ppm) and Magnitude Departure from Minimum EEC/Magnitude Departure from Maximum EEC (in parenthesis)	**Application and Measurement Details**	**Averaging Period**	**Reference**
1.7 (0.24/34.95)	Unspecified distance, mechanical aeration, Application rate ~ 1 lb./1,000 ft.[3] from 1.3 million ft.[3] treated structure	2 – hour Peak Value	MRID 47420302

[1] Maximum monitored concentration shown in bold-face.

[2] Magnitude departure from EEC = $\frac{\text{Minimum EEC or Maximum EEC (ppm)}}{\text{Maximum Monitored Concentration (ppm)}}$

[3] All monitored concentrations measured at various heights near the ground.

Indoor Air Monitoring Data and Emission Rates for Methyl Bromide Structural Fumigant Applications

Although this assessment focuses on outdoor exposure of the CTS to methyl bromide releases, indoor air monitoring data from treated structures are valuable for determining the decline of indoor concentrations during the releases. The decline of indoor air concentrations inside of a building are directly related to the emission or flux rates from treated structures. The Methyl Bromide Industry Panel has conducted a series of studies demonstrating that emissions from mechanical and passive aeration techniques generally decline exponentially with time (MRID Nos. 47472501 and 47420302 for mechanical and passive aeration monitoring, respectively). This is also further supported in numerous studies in the open literature (Chayaprasert et al., 2007; Schneider et al., 2000; Cryer, 2007). **Figure 3-2** and **Figure 3-3** show the decline in indoor concentrations of methyl bromide monitored using fumiscopes inside of a passively aerated building and inside the stack of a mechanically aerated building, respectively. Both plots of methyl bromide generally show an exponential decline in emission rates. These observations support the equations developed to estimate flux rates (passive aeration) and emission rates (mechanical aeration) of methyl bromide releases shown in **Section 3.1.1.**

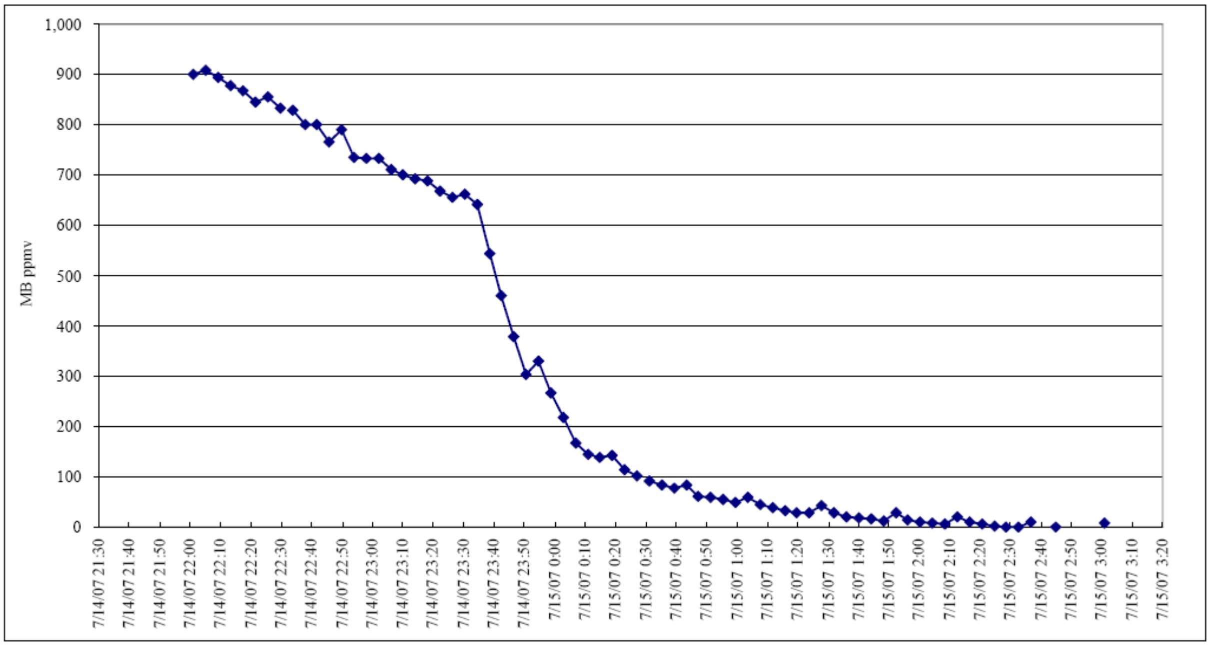
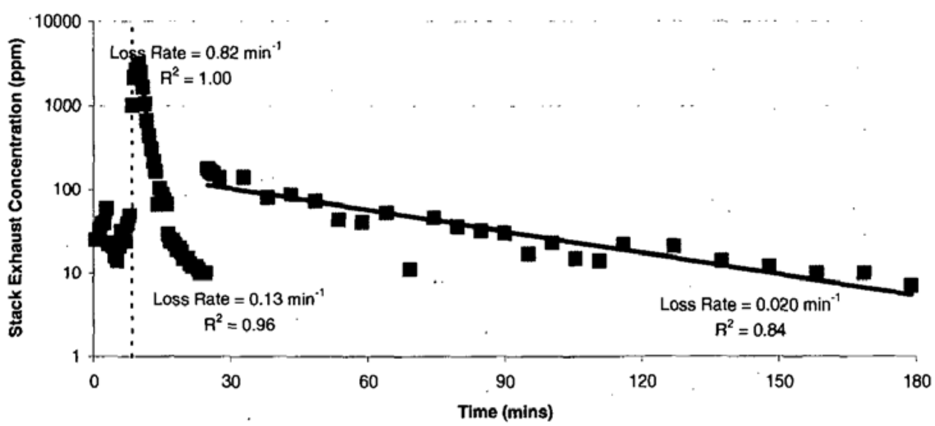


Figure 3-2. Methyl bromide monitored concentration during passive aeration inside of a treated building (1.3 million cubic foot flour mill).



* Exponential decrease of methyl bromide concentrations evident between 0 – 25 minutes during release. Bifurcation of monitored stack air concentrations at around 25 minutes may have been due to an unconventional practices such as opening of windows or pumping in more methyl bromide into the building during the mechanical ventilation.

Figure 3-3. Methyl bromide monitored concentration during mechanical ventilation inside of a treated building (18,350 cubic foot chamber).

3.1.3. Soil Exposure

As discussed in the problem formulation in **Section 2.9.2**, incorporation of methyl bromide onto soil may also be an important exposure pathway for the CTS from soil fumigant application of methyl bromide. However, there is no approved model to quantify this route of exposure at this time. Therefore, peak EECs in soil assuming instantaneous exposure directly after application are calculated within the treated field using the following equation:

Peak Soil Pore-Space EEC (mg/m^3) =

$$\frac{\text{Application Rate }(\frac{\text{mg}}{\text{m}^2})}{\text{Soil Incorporation Depth (m)}} \times 1 - \left(\frac{\text{Soil Bulk Density }(\frac{\text{g}}{\text{cm}^3})}{\text{Soil Particle Density }(\frac{\text{g}}{\text{cm}^3})}\right)$$

This EEC represents the upper-bound level of methyl bromide which can exist in the pore space between soil particles including in spaces such as small mammal burrows where CTS may inhabit. This estimated EEC assumes no loss of methyl bromide due to volatility. However, the assumption is made that methyl bromide is distributed evenly throughout the field within the depth of application, which is plausible given the diffusion of methyl bromide gas in the soil and tarp covering for some applications. In addition, it is assumed that no methyl bromide residue absorbs to soil particles, and that all methyl bromide mass resides within soil pores which is also plausible given its expected gaseous state and highly mobile characteristics. A soil bulk density value of 1.5 g/cm^3 and soil particle density value of 3.0 g/cm^3 are assumed to be representative for soils in California. **Table 3-18** shows the peak EECs calculated for soil for the various soil fumigation uses. These values are used qualitatively to assess dermal and inhalation exposure of methyl bromide to CTS populations and prey items and/or mammals which may inhabit the soil. Methyl bromide soil pore concentrations range from between 49,031,066 – 882,559,185 µg/m^3 for all soil fumigant uses of methyl bromide.

Table 3-18. Peak EECs of methyl bromide in soil.

Soil Fumigation Application Method	Treated Field Application Rate[1] (lbs. a.i./A)	Incorporation Depth of Methyl Bromide in Soil (inches)	Soil Bulk Density (g/cm^3)	Soil Particle Density (g/cm^3)	Soil Pore Space EEC (µg/m^3)
Deep Shank Injection Untarped Applications	400	18[2]			49,031,066
Broadcast Tarped Shank Injection Applications	400	8[2]	1.5	3.0	110,319,898
Hot Gas Tarped Chemigation Applications	400	1[3]			882,559,185
Bedded Tarped Shank Injection Applications	200[4]	1[2]			441,279,593

[1] Maximum application rates for application methods only evaluated. Individual crops not shown in this evaluation.

[2] Incorporation depths required on labels for specific application methods. Refer to Section 2.4 for further details.
[3]A one-inch incorporation depth is assumed for hot gas tarped chemigation application given soil treatment with tarp covering over surface applied chemical.
[4.]Maximum application rate adjusted for percent treated area of 0.5 assumed for bedded tarped applications.
[5]Appropriate unit conversions not shown in table.

3.2. Aquatic Exposure Assessment

3.2.1. Surface Water and Ground Water Exposure

As discussed in the problem formulation in **Section 2.9.2 and Appendix D**, exposure to the aquatic-phase CTS is not expected in surface water or ground water. The retention time of methyl bromide in runoff water or water bodies is short (e.g., aquatic volatilization half life of 72 minutes). In addition, a reduced quantity of methyl bromide is expected to be available for runoff and leaching, based on deep shank untarped and broadcast shank injection tarped applications. Furthermore, for bedded shank injection tarped and hot gas shank injection tarped applications, methyl bromide is also not expected to be retained in runoff or leaching water and, consequently, ground water or water bodies.

3.2.2. Existing Water Monitoring Data

Surface water and ground water monitoring data from the United States Geological Survey (USGS) NAWQA (http://water.usgs.gov.nawqa), EPA STORET (Storage and Retrieval) database, and the California Department of Pesticide regulation (CDPR) programs were accessed and downloaded. No known quantifiable detections of methyl bromide in surface water have been reported in the United States. Methyl bromide was detected in 0.07 percent out of 26,149 total groundwater samples at various targeted rural watershed monitoring and well sites at levels $\leq$ 0.5 ppb. The description of this monitoring data is discussed in Appendix E.

3.3. Changes in Previous Risk Assessment of Methyl Bromide

In this assessment, there are many changes in the exposure assessment from the exposure assessment presented in the risk assessment supporting the reregistration of methyl bromide due to the new labels distributed as a result of reregistered uses of methyl bromide along with the implementation of exemptions from the Montreal Protocol. In particular, structural uses are specifically added in this assessment since the QPS exemption specifically addressing these uses. The previous risk assessment was based on the labels on the market prior to reregistration. In addition, there have been several changes in the tools and data that were used as the basis of the reregistration risk assessment. Most notably, SCREEN3 was chosen for the screening–level air exposure estimation tool, which is equivalent to the screening version of the ISCST3 model used in the Reregistration assessment. In addition, the refined tool PERFUM was chosen to evaluate those uses exceeding the LOC for endangered species birds and mammals using the SCREEN3 model. Furthermore, the additional field volatility study conducted for broadcast tarped shank injection applications of methyl bromide at Wasco, CA (MRID No. 48006001) was considered in calculating EECs in air. Finally, for the structural uses, PERFUM and accompanying temporal flux rate profiles were utilized to estimate exposure due to methyl bromide releases during and after treatments.

4. Effects Assessment

This assessment evaluates the potential for methyl bromide to directly or indirectly affect CTS or modify their designated critical habitat. Assessment endpoints for the effects determination of each assessed species include direct toxic impact on the survival, reproduction, and growth, as well as indirect effects, such as reduction of the prey base or modification of its habitat. In addition, potential modification of critical habitat is assessed by evaluating effects to the PCEs, which are components of the critical habitat areas that provide essential life cycle needs of each assessed species. There is no aquatic exposure anticipated; therefore, the summaries of aquatic toxicity data are presented in **Appendix G.**

Inhalation is considered to be the primary route of terrestrial exposure due to the rapid volatilization of methyl bromide. Acute and chronic toxicity information is characterized based on registrant-submitted studies and a comprehensive review of the open literature on methyl bromide.

The risk assessment evaluating direct effects assumes that avian toxicity would be protective for the terrestrial phase CTS; therefore, the avian toxicity test results are used to represent that life cycle of the CTS. The avian toxicity data are also used to evaluate indirect effects for amphibian prey. Mouse and rat data are utilized to assess indirect acute and chronic effects, respectively, for mammals as prey and for potential reduction in the availability of mammal burrows for shelter in this assessment.

4.1. Ecotoxicity Study Data Sources

Toxicity endpoints are established based on data generated from guideline studies submitted by the registrant, and from open literature studies that meet the criteria for inclusion into the ECOTOX database maintained by EPA/Office of Research and Development (ORD) (USEPA, 2004a). Open literature data presented in this assessment were obtained from registrant-submitted studies as well as ECOTOX information obtained on August 2, 2011. In order to be included in the ECOTOX database, papers must meet the following minimum criteria:

(1) the toxic effects are related to single chemical exposure;
(2) the toxic effects are on an aquatic or terrestrial plant or animal species;
(3) there is a biological effect on live, whole organisms;
(4) a concurrent environmental chemical concentration/dose or application rate is reported; and
(5) there is an explicit duration of exposure.

Open literature toxicity data for other "target" insect species (not including bees, butterflies, beetles and non-insect invertebrates including soil arthropods and worms) and 'target' terrestrial plant species, which include efficacy studies, are not currently considered in deriving the most sensitive endpoint for terrestrial insects and plants, respectively. Efficacy studies do not typically provide endpoint values that are useful for risk assessment (*e.g.*, NOAEC, EC50, etc.), but rather are intended to identify a dose that maximizes a particular effect (*e.g.,* EC_{100}). Therefore, efficacy data and non-efficacy toxicological target data are not included in the

ECOTOX open literature summary table provided in Appendix H. For the purposes of this assessment, "target" insect species are defined as all terrestrial insect pests with the exception of bees, butterflies, beetles and non-insect invertebrates (i.e., soil arthropods, worms, etc.) which are included in ECOTOX, along with the terrestrial plant studies. The list of citations including toxicological and/or efficacy data on plant and insect species not considered in this assessment is provided in **Appendix I.**

Data that pass the ECOTOX screen are evaluated along with the registrant-submitted data, and may be incorporated qualitatively or quantitatively into this endangered species assessment. In general, effects data in the open literature that are more conservative than the registrant-submitted data are considered. The degree to which open literature data are quantitatively or qualitatively characterized for the effects determination is dependent on whether the information is relevant to the assessment endpoints (*i.e.*, survival, reproduction, and growth) identified in **Appendix C**. For example, endpoints such as behavior modifications are likely to be qualitatively evaluated, because quantitative relationships between modifications and reduction in species survival, reproduction, and/or growth are not available. Although the effects determination relies on endpoints that are relevant to the assessment endpoints of survival, growth, or reproduction, it is important to note that the full suite of sub-lethal endpoints potentially available in the effects literature (regardless of their significance to the assessment endpoints) are considered, as they are relevant to the understanding of the area with potential effects, as defined for the action area.

Efficacy toxicity studies are usually not considered in deriving the most sensitive endpoint. Efficacy studies do not typically provide endpoint values that are useful for risk assessment (*e.g.*, NOAEC, EC50, etc.), but rather are intended to identify a dose that maximizes a particular effect (*e.g.,* EC_{100}).

Citations of all open literature not considered as part of this assessment because they were either rejected by the ECOTOX screen or accepted by ECOTOX but not used (*e.g.*, the endpoint is less sensitive) are included in **Appendix I. Appendix I** also includes a rationale for rejection of those studies that did not pass the ECOTOX screen and those that were not evaluated as part of this endangered species risk assessment.

A detailed spreadsheet of the available ECOTOX open literature data, including the full suite of lethal and sublethal endpoints is presented in **Appendix J.**

In addition to registrant-submitted and open literature toxicity information, other sources of information, including use of the acute probit dose response relationship to establish the probability of an individual effect and reviews of ecological incident data, are considered to further refine the characterization of potential ecological effects associated with exposure to methyl bromide. A summary of the available terrestrial ecotoxicity information and the incident information for methyl bromide are provided in **Sections 4.2 through 4.4**.

4.2. Toxicity of Methyl Bromide to Terrestrial Organisms

Table 4-1 summarizes the most sensitive terrestrial toxicity endpoints, based on an evaluation of both the submitted studies and the open literature. A brief summary of submitted and open literature data considered relevant to this ecological risk assessment is presented below. Additional information is provided in **Appendix G.** Avian toxicity data are used to assess potential direct effects of methyl bromide to the terrestrial-phase CTS. Indirect effects as reduction in prey to the terrestrial-phase CTS are assessed for mammals using data from the rat inhalation study and for amphibians and reptiles using the avian inhalation study. Toxicity data was requested for the honey bee as a condition of the RED, but the registrant submitted a waiver request. After re-evaluation of methyl bromide re-registered uses, EFED has since supported the waiver request. Therefore, there are no submitted toxicity data for the honey bee due to a supported waiver request**.** In addition, there are no acceptable toxicity data available to estimate indirect effects to the CTS from methyl bromide exposure to terrestrial plants.

Table 4-1. Terrestrial Toxicity Profile for Methyl Bromide.

Endpoint	**Acute/ Chronic**	**Species**	**Toxicity Value Used in Risk Assessment**	**Citation MRID/ ECOTOX reference No.**	**Comment**
Birds (used as a surrogate for terrestrial phase CTS)	Acute	Bobwhite Quail (*Colinus virginianus*)	4 h Inhalation LC50 of561 ppm	48115601	Acceptable
Mammals	Acute	Mouse (*Mus musculus*)	4 h Inhalation LC50 of 780 ppm	Kato et al 1986.	Acceptable
	Chronic	Norway Rat (*Rattus norvegicus*	11 week reproductive and juvenile survival NOEAC of 3 ppm	00160477	Acceptable
Terrestrial invertebrates	Acute Contact		No data submitted		Waiver request accepted given presumed lack of exposure of honey bees to treated sites.
Terrestrial plants	n/a	Seedling Emergence Monocots	No data submitted		Waiver request accepted given presumed lack of exposure of seeds in or near treated sites
	n/a	Seedling Emergence Dicots			
	n/a	Vegetative Vigor Monocots	No data submitted		No toxicity studies have been submitted. Waiver request was rejected based on potential exposure of terrestrial plants near treated sites.
	n/a	Vegetative Vigor Dicots			

n/a: not applicable; ND = not determined; bw = body weight

Although there is a system to classify acute toxicity for terrestrial animals, it reflects dietary exposure, not inhalation exposure (USEPA, 2004). Toxicity categories for terrestrial plants have not been defined.

4.2.1. Toxicity to Birds, Reptiles and Terrestrial-Phase Amphibians

As specified in the Overview Document, the Agency uses birds as a surrogate for reptiles and terrestrial-phase amphibians when toxicity data for each specific taxon are not available (USEPA, 2004). A summary of acute bird data, including data published in the open literature, describing lethal and sublethal effects is provided.

4.2.1.a Birds: Acute Exposure (Mortality) Studies

Inhalation is expected to be the primary route of exposure for methyl bromide. Dietary exposure is not expected with methyl bromide. An acceptable non-guideline avian inhalation study (MRID 485156-01) was reviewed using the OSCPP 870.1300 guidelines. This study, which is discussed below, is used to determine direct effects of methyl bromide to structural and soil applications on the CTS.

There are several physiological differences between amphibians and birds that are the cause for uncertainty in this assessment. There is uncertainty due to the lower inhalation rate for amphibians versus birds. Differences in lung physiology also increase the uncertainty. Amphibian lungs are tidal systems as opposed to bird lungs which are unidirectional. The skin of the terrestrial-phase CTS also acts as an inhalation membrane. The available avian inhalation toxicity data does not account for simple diffusion across the skin. Nonetheless, given these uncertainties, the acute avian inhalation data are used as a surrogate for the terrestrial-phase TS, given the information available for methyl bromide.

Nonguideline Avian Inhalation Toxicity Study

A single four hour exposure followed by a 14 d post-exposure observation period using the Northern bobwhite quail resulted in a 4 h LC_{50}=561 ppm. Five males and five females were exposed to measured treatment concentrations of 258, 505 and 788 ppm.

Although no sublethal effects were reported in the controls, sublethal effects, as well as delayed mortality, were reported in the treatment concentrations during and after the 4 hour exposure. Ataxia, hyperactivity and partial closure of the eyes was reported during the study for all treatment concentrations. Twitching and excessive head shaking was also reported in the 788 ppm treatment concentration (the highest concentration tested).

Immediately following the 4 hour exposure, ataxia and labored respiration were observed for all treatment concentrations. Observations of partial closure of the eyes and hyperactivity were also reported for 505 ppm treatment concentration group. Hyperactivity, tremors, prostration, twitching, unkempt appearance, body cool to the touch, and closure of the eyes were also reported in the highest treatment concentration of 788 ppm. One of the birds in the treatment concentration of 505 ppm was found dead on Day 1 as well as all of the animals in the 788 ppm treatment concentration.

In addition to the submitted study, the open literature was reviewed for more sensitive endpoints to use in the assessment. There were no valid inhalation studies located in the open literature that reported endpoints on birds that are more sensitive than the selected measures of effect summarized in **Appendix G**. Therefore, the Northern bobwhite quail 4-hour LC_{50} of 561 ppm (MRID 48515601) is used to calculate RQs that determine acute direct effects and indirect dietary effects to terrestrial-phase CTS.

4.2.1.b. Toxicity to Terrestrial-Phase Amphibians

There were no acute terrestrial-phase amphibian studies located for methyl bromide from the open literature. Therefore, avian data is used to represent the effects of methyl bromide applications to terrestrial-phase amphibians.

4.2.2. Toxicity to Mammals

Indirect effects to the CTS include reduction in prey, as well as alteration in habitat from a reduction in mammal burrows used by the CTS for shelter. The diet of the CTS includes small mammals; therefore, mammal data is used to evaluate acute effects of methyl bromide to the CTS. Mammalian data is also used to represent alteration in habitat through the reduction in mammal burrows available for shelter. A summary of acute mammalian data reviewed by the Agency's Health Effects Division (HED) is provided below in **Table 4-2**. The acute inhalation study is used to assess indirect effects to the CTS. A complete analysis of toxicity data to mammals, which is HED's 2005 RED, is provided in **Appendix K**.

Table 4-2. Acute Toxicity Data on Methyl Bromide Technical

Guideline No.	Study Type	MRID # (s)	Results	Toxicity Category
870.1100	Acute oral (liquid MeBr)	43510301	LD_{50} = 120-160 mg/kg (males) LD_{50} = 86 mg/kg (females)	II
870.1200	Acute dermal	N/A	No data available	N/A
870.1300	Acute inhalation	Kato et al. (1986)[a]	LC_{50} = 780ppm, 4 hr exposure	IV
870.2400	Primary eye irritation	Alexeef, G.; Kilgore, W. (1983)[b] and Hezemans-Boer et al (1988)[c]	Severe irritation following accidental exposure to humans	I

Table 4-2. Acute Toxicity Data on Methyl Bromide Technical				
Guideline No.	**Study Type**	**MRID # (s)**	**Results**	**Toxicity Category**
870.2500	Primary skin irritation	Alexeef, G.; Kilgore, W. (1983) and Hezemans-Boer et al (1988)	Severe irritation following accidental exposure to humans	I
870.2600	Skin sensitization	N/A	No data available	N/A

N/A: Acute dermal toxicity and dermal sensitization potential studies were not required because there is already clear evidence that severe irritation to skin occurs after acute dermal exposure to methyl bromide.a: Kato, N.; Morinobu, S.; Ishizu, S. (1986) Subacute inhalation Experiment for Methyl Bromide in Rats. Industr. Health. 24: 87-103.
b: Alexeef, G.; Kilgore, W. (1983) Methyl Bromide. In: Gunther, F.; Gunther, J., ed. Residue Reviews. Residues of Pesticides and Other Contaminants in the Total Environment, Vol. 88, p. 102-153. New York, Springer Verlag.
c: Hezemans-Boer, M; Toonstra, J.; Meulenbelt, J.; et al. (1988) Skin Lesions Due to Exposure to Methyl Bromide. Arch. Derm. 124:917-921.

Mammalian toxicity data (reviewed by HED) indicate that methyl bromide has an acute inhalation four hour LC_{50} of 780 ppm, the equivalent of 3.03 mg/L (Kato *et al* 1986). Rats were exposed to methyl bromide at concentrations of 502, 622, 667,799 and 896 ppm. Observations for sublethal effects included decreased activity and ataxia. Based on the above results of an acute oral toxicity study in rats, EFED considers methyl bromide to be moderately toxic to mammals.

Since the CTS mainly preys on mouse pups, a 6-hour mouse inhalation study is selected in lieu of the acute inhalation rat study described above to assess acute inhalation risk for indirect effects from methyl bromide soil and structural treatments to the CTS. In addition, to assess chronic risk from methyl bromide structural fumigation treatments leading to indirect effects to the CTS, an 11-week rat reproduction study was used. Both studies are described below.

<u>870.4200- Inhalation Toxicity - Mouse</u>

Toxicity data from a mouse inhalation study was used to assess the acute indirect effects of reduction in mammalian prey and burrows as habitat from methyl bromide The OSCPP 870-4200 chronic toxicity guideline indicates that chronic toxicity tests are defined as daily exposures, rather than a single exposure. The guideline allows alterations in the stated duration of 18 months minimum for mice after review by EPA. The study resulted in a 6-hour LC_{50} of 188 ppm, the equivalent of 730,009 µg/L. Mice were exposed to methyl bromide at treatment concentrations of 12, 25, 50, 100 and 200 ppm. Fifteen mice (nine male and six female) were exposed to the highest tested concentration of 200 ppm methyl bromide died during the study. There were no other mortalities reported. Observations for sublethal effects included jumpiness and paralysis in all treatment groups, but were more pronounced in the three highest treatment groups (50, 100 and 200 ppm). The results from this acute toxicity study are used in the assessment to evaluate the effects of methyl bromide on smaller mammals as prey items.

870.3800 Reproduction and Fertility Effects - Rat

An acceptable reproductive rat toxicity study has been reviewed by HED and satisfies the guideline requirements for a multi-generation reproduction study (83-4) in rats. The study resulted in a 11-week NOAEL for parental/systemic toxicity of 30 ppm (24 mg/kg/day) and a LOAEL of 90 ppm (73 mg/kg/day) based on reduced body weight during gestation. The study also reported a NOAEL for reproductive toxicity of 3 ppm (2.8 mg/kg/day) and a LOAEL of 30 ppm (24 mg/kg/day) based on reduced pregnancy rates (F2b generation). The NOAEL for offspring toxicity is 3 ppm (2.8 mg/kg/day) and the LOAEL is 30 ppm (24 mg/kg/day) based on reduced pup weight on post-natal day 21 (F1a, F2a, F2b generations) ranging from 10-20%.

In a two-generation reproduction study (MRID 00160477; Accession No. 261736-261742), methyl bromide as vapor was administered to male and female CD Sprague-Dawley rats by whole body exposure at concentrations of 0, 3.0, 30 or 90 ppm (Males - 0, 2.4, 24 or 73 mg/kg/day; Females - 0, 2.8, 28 or 85 mg/kg/day) for two successive generations (6 hrs/day, 5 days/week). F0 males and females were exposed for 8 weeks prior to mating. Exposure of the F1 and F2 generations was initiated at 29-33 days of age and was continued for 11 weeks. Females were not exposed from Day 21 of gestation to Day 4 of lactation.

Other toxicity studies submitted also reported sublethal effects for mammals. An acceptable developmental toxicity study in rabbits (MRID 415804-01) resulted in a 10 day maternal NOAEL = 40 ppm. Twenty-six New Zealand White rabbits were exposed to concentrations of 0, 20, 40 or 80 ppm methyl bromide gas for 6h/day on Days 6-16 of gestation. Sublethal effects reported in this study included decreased appetite, lethargy, right side head tilt, slight ataxia and slight lateral recumbency at 80 ppm, the highest concentration tested. Although, the test duration for this study is longer than the expected exposure periods of methyl bromide to be evaluated in this assessment, the study provides additional information on sublethal effects.

In addition to studies reviewed by HED, the ECOTOX open literature data was evaluated to determine if any endpoints were more sensitive than those described above. No acute or chronic mammal inhalation studies listed in the open literature summary resulted in more sensitive endpoints. The most sensitive endpoint from the six hour acute inhalation study and the two generation rat study are used for the inhalation analyses.

4.2.3. Toxicity to Terrestrial Invertebrates

Methyl bromide applications are labeled to control terrestrial soil invertebrates. In response to the RED request for the honey bee toxicity study, the registrant submitted a waiver request. The waiver was supported based on the application method of methyl bromide. The method of application is not expected to result in direct contact of foraging bees. First, methyl bromide is used as a pre-plant fumigant to kill all organisms in surficial soil (including plants) from the field prior to planting. Therefore, no flowering plants would be present at the time of application to attract honey bees. Second, there are numerous data available for insects described below, and the honey bee toxicity study is not anticipated to result in any alteration to risk determinations.

However, there may be some uses which result in exposure to terrestrial invertebrates, which are part of the diet for the CTS (worms, soil invertebrates). Therefore open literature is reviewed to provide additional information for risk characterization. Open literature includes non-guideline toxicity studies, such as efficacy studies. One study (Rajendran 1992) provided an indication of the effects as resistance buildup measured as mortality from methyl bromide for four life stages of the rust-red flour beetle. Results are noted in the assessment for the most sensitive endpoint for exposure to eggs and the least sensitive as exposure to the pupae life stages for the same 24 hour test exposure period. This study provides information on the variability of methyl bromide exposure across life stages. This study resulted in a 24-hr LD50 of 0.86 mg/L for mortality. Six generations of 1-2 day old eggs were treated with an application of 0.81 mg/L. The results of the treatments were compared to the control. The study also reported a 24- hr LD50 of 4.62 mg/l for the effects of methyl bromide on the pupae stage using the same test design.

4.2.4. Toxicity to Terrestrial Plants

Impacts to riparian and upland (i.e., grassland, woodland) vegetation may result in indirect effects to CTS, as well as modification to designated critical habitat PCEs via increased sedimentation, alteration in water quality, and reduction in of riparian habitat that provides shade and predator avoidance.

Plant toxicity data from both registrant-submitted studies and studies in the scientific literature were reviewed for this assessment. Registrant-submitted studies are conducted under conditions and with species defined in EPA toxicity test guidelines.

No acceptable plant studies have been submitted nor were any found in the open literature. A waiver for the terrestrial plant studies has been submitted. The seedling emergence toxicity study waiver request was supported because runoff is not expected and the application method of methyl bromide includes a plant back period. The request to waive the vegetative vigor toxicity study was rejected, based on methyl bromide’s known phytotoxic properties.

4.3. Toxicity of Chemical Mixtures

As previously discussed, the results of available toxicity data for mixtures of methyl bromide with other pesticides are not available. All the mixture products discussed include methyl bromide and chloropicrin.

4.4. Incident Database Review

A review of the Ecological Incident Information System (EIIS, version 2.1), the Incident Data System (IDS) ,maintained by the Information Technology and Resource Management Division, the Aggregate Summary Module (ASM) (v.1.0) of Office of Pesticide Program’s Incident database maintained by the Information Technology and Resource Management Division, and the Avian Monitoring Information System (AIMS) for ecological incidents involving methyl bromide applications was completed on 14 October 2011. The results of this review are also discussed below.

A review of the EIIS database was completed on October 14, 2011. There were no aquatic, terrestrial or plant incidents were reported in the database. A second EPA incident data base, the Incident Data System also reports major incidents. This data base was reviewed on October 14, 2011 and indicates no incidents for methyl bromide. The ASM database has more limited information and includes numbers of minor incidents. This data base was accessed on October 14, 2011 and resulted in one minor plant incident from the use of methyl bromide from 8/1/2005 to 10/31/2005. There are no further details provided in the minor report.

In addition to the EPA incident databases, a review of incidents on October 14, 2011 from the AIMS database also indicated no incidents. This database only reports incidents to birds.

4.5. Use of Probit Slope Response Relationship to Provide Information on the Endangered Species Levels of Concern

The Agency uses the probit dose response relationship as a tool for providing additional information on the potential for acute direct effects to individual listed species and aquatic animals that may indirectly affect the listed species of concern (USEPA, 2004). As part of the risk characterization, an interpretation of acute RQs for listed species is discussed. This interpretation is presented in terms of the chance of an individual event (*i.e.*, mortality or immobilization) should exposure at the EEC actually occur for a species with sensitivity to methyl bromide on par with the acute toxicity endpoint selected for RQ calculation. To accomplish this interpretation, the Agency uses the slope of the dose response relationship available from the toxicity study used to establish the acute toxicity measures of effect for each taxonomic group that is relevant to this assessment. The individual effects probability associated with the acute RQ is based on the mean estimate of the slope and an assumption of a probit dose response relationship. In addition to a single effects probability estimate based on the mean, upper and lower estimates of the effects probability are also provided to account for variance in the slope, if available. The probit analysis for acute effects from methyl bromide on birds is further discussed in **Section 5.2.1.**

Individual effect probabilities are calculated based on an Excel spreadsheet tool IECV1.1 (Individual Effect Chance Model Version 1.1) developed by the U.S. EPA, OPP, Environmental Fate and Effects Division (June 22, 2004). The model allows for such calculations by entering the mean slope estimate (and the 95% confidence bounds of that estimate) as the slope parameter for the spreadsheet. In addition, the acute RQ is entered as the desired threshold.

5. Risk Characterization

Risk characterization is the integration of the exposure and effects characterizations. Risk characterization is used to determine the potential for direct and/or indirect effects to the CTS or for modification to their designated critical habitat from the use of methyl bromide in CA. The risk characterization provides an estimation (**Section 5.1**) and a description (**Section 5.2**) of the likelihood of adverse effects; articulates risk assessment assumptions, limitations, and uncertainties; and synthesizes an overall conclusion regarding the likelihood of adverse effects to the assessed species or their designated critical habitat (*i.e.*, “no effect,” “likely to adversely affect,” or “may affect, but not likely to adversely affect”). In the risk estimation section, risk quotients for are calculated using standard EFED procedures and models. RQs for the terrestrial phase CTS for direct and indirect effects based on inhalation are presented in the risk estimation section, and additional analyses conducted to help characterize the potential for risk is provided in the risk description section.

5.1. Risk Estimation

Risk is estimated by calculating the ratio of exposure to toxicity. The resulting ratio is termed the risk quotient (RQ). Risk quotients are then compared to pre-established acute and chronic risk levels of concern (LOCs) for each category evaluated (**Appendix C**). For acute exposures to listed birds (and, thus, terrestrial-phase amphibians) and mammals, the LOC is 0.1. For acute exposures to listed terrestrial invertebrates, the acute risk LOC is 0.05. The chronic LOC for all terrestrial organisms is 1.0. The LOC for evaluating risks to plants is 1.0.

As described in **Section 2** (Problem Formulation), risks to aquatic-phase CTS and chronic risk to terrestrial phase CTS were not assessed because ecologically significant aquatic and chronic exposure to methyl bromide were presumed highly unlikely due to its extremely high volatility, rapid soil degradation, and application methods. Therefore, only acute risks to the terrestrial-phase CTS were estimated quantitatively based on methyl bromide EECs predicted in air from soil and structural fumigation treatments shown in **Table 3-4** and appropriate toxicity endpoint from **Table 4-1.**

It is further noted that terrestrial-phase CTS that reside in burrows may be exposed to methyl bromide on treated fields through both the dermal absorption and respiration via the lungs. Currently, there is the potential for dermal exposure; however, no dermal exposure model has been developed and approved for use in EFED risk assessments to date. In-burrow inhalation exposure in soil is estimated in the risk description section (**Section 5.2**).

5.1.1. Exposures in the Terrestrial Habitat

5.1.1.a. Direct Effects to Terrestrial-phase CTS and Indirect Effects to CTS (Amphibian Prey)

Soil Fumigant Uses

As previously discussed in **Section 2.5**, the potential for direct effects to the terrestrial-phase CTS are assessed based on direct acute effects to birds as a surrogate, due to the absence of amphibian toxicity data.

Potential direct risks to the terrestrial-phase CTS through inhalation of methyl bromide from soil fumigant applications are evaluated using the SCREEN3 and PERFUM dispersion models and acute toxicity data for the most sensitive bird toxicity values for which data are available. Predicted EECs in air (µg/m^3) are divided by the acute avian inhalation LC_{50} value (2,178,390 µg/m^3, converted from 561 ppm using the Ideal Gas Law) to estimate acute inhalation concentration-based RQs. Screening level acute risk quotients calculated for soil fumigant uses with the SCREEN3 model are presented in **Table 5-1.**

Table 5-1. Screening level acute risk quotients used to determine potential direct effects to the terrestrial-phase CTS from soil fumigant applications of methyl bromide using the SCREEN3 model.

Crop, App. Rate (lbs. a.i./A), and Montreal Protocol Designations	Application Scenario	Maximum Peak SCREEN3 EEC (µg/m^3)	Acute Risk Quotient
Orchard Replant (400) (CUE)	Deep Shank Untarped	36,560	0.02
Peppers (396) (CUE)	Shallow Shank Broadcast Tarp	98,586	0.04
	Shallow Shank Bedded Tarp	163,859	0.07
	Hot Gas Chemigation Tarp	198,339	**0.09**
Eggplant (240) (CUE)	Shallow Shank Broadcast Tarp	59,749	0.03
	Shallow Shank Bedded Tarp	99,309	0.04
	Hot Gas Chemigation Tarp	120,205	0.05

Table 5-1. Screening level acute risk quotients used to determine potential direct effects to the terrestrial-phase CTS from soil fumigant applications of methyl bromide using the SCREEN3 model.

Crop, App. Rate (lbs. a.i./A), and Montreal Protocol Designations	Application Scenario	Maximum Peak SCREEN3 EEC ($\mu g/m^3$)	Acute Risk Quotient
Cucurbits (240) (CUE)	Shallow Shank Broadcast Tarp	59,749	0.03
	Shallow Shank Bedded Tarp	99,309	0.04
	Hot Gas Chemigation Tarp	120,205	0.05
Forestry Nursery (400) (CUE)	Shallow Shank Broadcast Tarp	99,582	0.04
	Shallow Shank Bedded Tarp	165,514	0.07
	Hot Gas Chemigation Tarp	200,342	**0.09**
Nursery and Ornamentals (400) (CUE)	Shallow Shank Broadcast Tarp	99,582	0.04
	Shallow Shank Bedded Tarp	165,514	0.07
	Hot Gas Tarped Chemigation	200,342	**0.09**
Strawberries (282) (CUE)	Shallow Shank Broadcast Tarp	70,205	0.03
	Shallow Shank Bedded Tarp	116,688	0.05
	Hot Gas Tarped Chemigation	141,241	0.06
Berries (240) (SP)	Shallow Shank Broadcast Tarp	59,749	0.03
	Shallow Shank Bedded Tarp	99,309	0.04
	Hot Gas Tarped Chemigation	120,205	0.05
Sweet Potatoes (400) (CUE)	Shallow Shank Broadcast Tarp	99,582	0.04
	Shallow Shank Bedded Tarp	165,514	0.07
	Hot Gas Tarped Chemigation	200,342	**0.09**

Table 5-1. Screening level acute risk quotients used to determine potential direct effects to the terrestrial-phase CTS from soil fumigant applications of methyl bromide using the SCREEN3 model.			
Crop, App. Rate (lbs. a.i./A), and Montreal Protocol Designations	**Application Scenario**	**Maximum Peak SCREEN3 EEC ($\mu g/m^3$)**	**Acute Risk Quotient**
Tomatoes (264) (CUE)	Shallow Shank Broadcast Tarp	65,724	0.03
	Shallow Shank Bedded Tarp	109,239	0.05
	Hot Gas Tarped Chemigation	132,226	0.06
Golf Courses and Athletic Fields (400) (SP)	Shallow Shank Broadcast Tarp	99,582	0.04
	Shallow Shank Bedded Tarp	165,514	0.07
	Hot Gas Tarped Chemigation	200,342	**0.09**

[1] Montreal Protocol Designation Codes: CUE – Critical Use Exemption; QPS – Quarantine and Pre-Shipment Exemption; SP – Stockpile
[2]Acute inhalation 4 h LC_{50} value based on bird inhalation toxicological value of 561 ppm for bobwhite quail (MRID No. 485156-01) converted to 2,178,390 $\mu g/m^3$ using the Ideal Gas Law.
[3]Bolded RQ indicates the maximum value.
[4].Maximum application rate adjusted for percent treated area of 0.5 assumed for bedded tarped applications.
[5] Maximum ground-level EECs occurring along the edge of the field are shown in the table.

Acute inhalation RQs for the orchard replant, peppers, eggplant, cucurbits, forestry and nursery, nursery and ornamentals, strawberries, berries, sweet potato, tomato, golf course and athletic field uses do not exceed the listed species LOC of 0.1 for any of the four application methods modeled (**RQ < 0.09**). However, all broadcast tarp shank injection, bedded tarped shank injection, and hot gas tarped chemigation uses were refined to address risk concerns with indirect effects (refer to **Section 5.1.1.b**) using PERFUM 90th percentile peak (hourly) EECs in air. The resulting refined acute RQs are shown in **Table 5-2.** As expected, none of the refined acute RQs exceeded the endangered species acute risk LOC as RQ values were less than 0.01 for all uses.

Chronic exposure is not expected for soil fumigant applications. Only one application per season occurs at treated sites. Therefore, chronic RQs are not presented for methyl bromide soil fumigant applications.

Table 5-2. Refined acute risk quotients used to determine potential direct effects to the terrestrial-phase CTS from soil fumigant applications of methyl bromide using the PERFUM model.			
Crop, App. Rate (lbs. a.i./A), and Montreal Protocol Designations	**Application Scenario**	**Upper 90th percentile PERFUM Peak EEC ($\mu g/m^3$)**	**Acute Risk Quotient**
Orchard Replant (400) (CUE)	Deep Shank	No Refinement	See **Table 5-1**
Peppers (396) (CUE)	Shallow Shank Broadcast Tarp	8,156	< 0.01
	Shallow Shank Bedded Tarp	15,121	< 0.01
	Hot Gas Tarped Chemigation	16,706	< 0.01
Eggplant (240) (CUE)	Shallow Shank Broadcast Tarp	5,051	< 0.01
	Shallow Shank Bedded Tarp	8,936	< 0.01
	Hot Gas Tarped Chemigation	9,713	< 0.01
Cucurbits (240) (CUE)	Shallow Shank Broadcast Tarp	5,051	< 0.01
	Shallow Shank Bedded Tarp	8,936	< 0.01
	Hot Gas Tarped Chemigation	9,713	< 0.01
Forestry Nursery (400) (CUE)	Shallow Shank Broadcast Tarp	8,936	< 0.01
	Shallow Shank Bedded Tarp	15,929	< 0.01
	Hot Gas Tarped Chemigation	16,706	< 0.01
Nursery and Ornamentals (400) (CUE)	Shallow Shank Broadcast Tarp	8,936	< 0.01
	Shallow Shank Bedded Tarp	15,929	< 0.01
	Hot Gas Tarped Chemigation	16,706	< 0.01

Table 5-2. Refined acute risk quotients used to determine potential direct effects to the terrestrial-phase CTS from soil fumigant applications of methyl bromide using the PERFUM model.			
Crop, App. Rate (lbs. a.i./A), and Montreal Protocol Designations	**Application Scenario**	**Upper 90th percentile PERFUM Peak EEC ($\mu g/m^3$)**	**Acute Risk Quotient**
Strawberries (282) (CUE)	Shallow Shank Broadcast Tarp	5,828	< 0.01
	Shallow Shank Bedded Tarp	11,267	< 0.01
	Hot Gas Tarped Chemigation	12,044	< 0.01
Berries (240) (SP)	Shallow Shank Broadcast Tarp	5,051	< 0.01
	Shallow Shank Bedded Tarp	8,936	< 0.01
	Hot Gas Tarped Chemigation	9,713	< 0.01
Sweet Potatoes (400) (CUE)	Shallow Shank Broadcast Tarp	8,936	< 0.01
	Shallow Shank Bedded Tarp	15,929	< 0.01
	Hot Gas Tarped Chemigation	16,706	< 0.01
Tomatoes (264) (CUE)	Shallow Shank Broadcast Tarp	5,828	< 0.01
	Shallow Shank Bedded Tarp	10,490	< 0.01
	Hot Gas Tarped Chemigation	11,267	< 0.01
Golf Courses and Athletic Fields (400) (SP)	Shallow Shank Broadcast Tarp	8,936	< 0.01
	Shallow Shank Bedded Tarp	15,929	< 0.01
	Hot Gas Tarped Chemigation	16,706	< 0.01

[1] Montreal Protocol Designation Codes: CUE – Critical Use Exemption; QPS – Quarantine and Pre-Shipment Exemption; SP – Stockpile

[2]Acute inhalation 4 h LC_{50} value based on bird inhalation toxicological value of 561 ppm (converted to 2,178,390 μg/m3 using the ideal gas law) from bird study (MRID No. 485156-01).

[3] Maximum EECs occurring within 5 meters from the edge of the field at a height of 5 meters above the ground are shown in the table.

Structural Uses

Structural applications are also evaluated using upper 90th percentile PERFUM peak (hourly) EECs in air for various exposure scenarios pertaining to food, commodity fumigation, as well as tile, timber and space fumigation. As described in **Section 2.10.1**, these structural use exposure scenarios were constructed to reflect a range of factors considered important in determining potential exposure to non-target terrestrial organisms (e.g., application rate, building size, method of ventilation, stack height, release duration and release direction).

Acute RQs from the various exposure scenarios of modeled structural uses of methyl bromide are presented in **Table 5-3.** For food and commodity exposure scenarios, none of the acute RQs exceeded the acute risk LOC for endangered avian species (0.1). Acute RQs ranged **from <0.01 to 0.06** for food and commodity uses (maximum application rate of 9 lb/1000ft^3). For the tile, timber and space fumigation uses (maximum application rate =15 lb/1000ft^3), acute RQs exceeded the acute risk LOC only for both active (mechanical) fumigant release scenarios. Acute RQs calculated for all seven modeled tile, timber and space fumigation scenarios ranged from **<0.01 to 0.11**. **Table 5-3** also presents the downwind distance (m) from the structure needed for the RQ to fall below the endangered species LOC, which is **70 m (230 ft.) for the 6 -hour horizontal mechanical aeration from 250,000 ft.^{3} building scenario and 70 m (230 ft.) for the 12-hour vertical aeration from 10,000,000 ft.^{3} building scenario**. The EECs corresponding to these acute RQ values are presented in **Table 3-13**.

Chronic exposure is possible to CTS due to repeat releases possible from treated structures. However, no chronic toxicological data exist for any relevant surrogate species to the CTS. Therefore, no chronic RQs delineating direct effects to the CTS are presented here. However, chronic RQs applicable to the reduction of mammalian prey relevant for indirect effects to the CTS are presented in **Section 5.1.1.c.** Indirect Effects to CTS (Mammalian Prey), and its relevance to direct effects to the CTS is discussed in **Section 5.2.1.**

Table 5-3. Acute risk quotients (dimensionless) used to determine potential direct effects to the terrestrial-phase CTS from structural applications of methyl bromide using the PERFUM model and downwind distances to the LOC (m).

Use Types and Montreal Protocol Designation	Application Rate (lbs./1,000 ft.^{3})	Structure Volume (ft.^{3}) and Release Period (hrs.)	Building Aeration Emission Scenarios			Railcars and Cargo Aeration Emissions [3]
			Scenario 1 Exponential Emissions Decay, Single Source, AXR = 0.1, Passive Aeration, No Stack	Scenario 2 Exponential Emissions Decay, Single Source, AXR = 1.0, Active Aeration, 10 ft. Vertical Stack	Scenario 3 Exponential Emissions Decay, Single Source, AXR = 1.0, Active Aeration, 3 ft. Horizontal Portable Stack	Scenario 4 Exponential Emissions Decay, Multiple Source, AXR = 0.05, Passive Aeration, No Stack
• Post Harvest Indoor Food Fumigation (QPS) • Commodity Indoor Fumigation (QPS)	9	10,000 ft^3 for 6 hrs.	ND	ND	ND	< 0.01 / 0 m
		250,000 ft^3 for 6 hrs.	< 0.01 / 0 m	< 0.01 / 0 m	0.06	N/A
		10,000,000 ft.^{3} for 12 hrs.	0.02	0.06 / 0 m	0.01 / 0 m	N/A
• Timber and Tile Indoor Fumigation (QPS) • Space Fumigation (SP)	15	5,000 ft.^{3} for 6 hrs.	ND	ND	ND	< 0.01 / 0 m
		250,000 ft^3 for 6 hrs.	< 0.01 / 0 m	< 0.01/ 0 m	**0.11 /70 m**	**N/A**
		10,000,000 ft.^{3} for 12 hrs.	0.03	**0.10 / 70 m**	0.07 / 0 m	N/A

[1] Montreal Protocol Designation Codes: CUE – Critical Use Exemption; QPS – Quarantine and Pre-Shipment Exemption; SP – Stockpile

[2.] RQs exceeding avian endangered species LOC = 0.1 calculated by the PERFUM EEC divided by the LC_{50} = 2,178,390 µg/m^3 (MRID No. 48515601) shown in bold face.

[3] N/A means not applicable. ND means not modeled.

[4] Modeling at 5,000 ft.3 and 10,000 ft.3 representative of railcar and cargo hold structure per CSX website (http://www.csx.com/index.cfm/customers/equipment/railroad-equipment/).

[5] Distance from the edge of the building based on the distribution of PERFUM 90th upper percentile peak (hourly) air concentrations along each receptor ring for the worst time of day (hourly average).

[6] PERFUM EECs are presented in Table 3-13.

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5.1.1.b. Indirect Effects to CTS (Amphibian Prey)

Indirect effects to the terrestrial-phase CTS that consume amphibians as prey are evaluated using the same EECs in air and acute avian inhalation toxicity endpoint (used as a surrogate for amphibians) as described in **Section 5.1.1.a** for direct effects. Therefore, acute RQs derived for direct effects to the CTS are identical to those for indirect effects resulting from potential reduction in amphibian prey.

5.1.1.c. Indirect Effects to CTS (Mammalian Prey)

Soil Fumigant Uses

An acute inhalation 6-hour LC_{50} value, based on mammalian inhalation toxicological value of 730,009 µg/m^3 from the mouse acute inhalation study (MRID 425041-01), was used to estimate the effect of air concentrations of methyl bromide calculated using the SCREEN3 air exposure model. Acute inhalation RQs ranging from **0.05-0.27** for all soil fumigant uses for reduction in prey represented by mammals are presented in **Table 5-4.** Bedded tarp and hot gas tarped applications for all crop uses exceeded the LOC of 0.1, with RQs ranging from 0.13 to 0.27). Broadcast tarp application RQs for eggplant (0.08), cucurbits (0.8), berries (0.08) and tomatoes (0.09) approach the LOC of 0.1. There was no LOC exceedance for orchard replant based on the RQ of 0.05.

Given the LOC exceedances identified in **Table 5-4,** refined RQs were calculated from 90th percentile upper-bound air exposure peak (one-hour) concentrations using the PERFUM model for all broadcast tarped shank injection, bedded tarped, and hot gas chemigation applications. **Table 5-5** presents the RQs from the refined analysis using PERFUM model EECs and the mouse toxicity value. No RQs (range < 0.01-0.02) exceeded the LOC of 0.1 for any crop uses for bedded tarp and hot gas tarped applications of methyl bromide.

Table 5-4. Screening level acute risk quotients used to define potential indirect effects to the CTS based on risks to mammalian prey exposed to methyl bromide via soil fumigation using the SCREEN3 model.

Crop, App. Rate (lbs. a.i./A), and Montreal Protocol Designations	Application Scenario	Maximum Peak SCREEN3 EEC (µg/m^3)	Acute Risk Quotient
Orchard Replant (400) (CUE)	Deep Shank Injection Untarped	36,560	0.05
Peppers (396) (CUE)	Shallow Shank Broadcast Tarp	98,586	**0.13**
	Shallow Shank Bedded Tarp	163,859	**0.22**
	Hot Gas Tarped Chemigation	198,339	**0.27**

Table 5-4. Screening level acute risk quotients used to define potential indirect effects to the CTS based on risks to mammalian prey exposed to methyl bromide via soil fumigation using the SCREEN3 model.

Crop, App. Rate (lbs. a.i./A), and Montreal Protocol Designations	Application Scenario	Maximum Peak SCREEN3 EEC (µg/m³)	Acute Risk Quotient
Eggplant (240) (CUE)	Shallow Shank Broadcast Tarp	59,749	0.08
	Shallow Shank Bedded Tarp	99,309	**0.14**
	Hot Gas Tarped Chemigation	120,205	**0.16**
Cucurbits (240) (CUE)	Shallow Shank Broadcast Tarp	59,749	0.08
	Shallow Shank Bedded Tarp	99,309	**0.14**
	Hot Gas Tarped Chemigation	120,205	**0.16**
Forestry Nursery (400) (CUE)	Shallow Shank Broadcast Tarp	99,582	**0.14**
	Shallow Shank Bedded Tarp	165,514	**0.23**
	Hot Gas Tarped Chemigation	200,342	**0.27**
Nursery and Ornamentals (400) (CUE)	Shallow Shank Broadcast Tarp	99,582	**0.14**
	Shallow Shank Bedded Tarp	165,514	**0.23**
	Hot Gas Tarped Chemigation	200,342	**0.27**
Strawberries (282) (CUE)	Shallow Shank Broadcast Tarp	70,205	**0.10**
	Shallow Shank Bedded Tarp	116,688	**0.16**
	Hot Gas Tarped Chemigation	141,241	**0.19**
Berries (240) (SP)	Shallow Shank Broadcast Tarp	59,749	0.08
	Shallow Shank Bedded Tarp	99,309	**0.14**
	Hot Gas Tarped Chemigation	120,205	**0.16**
Sweet Potatoes (400) (CUE)	Shallow Shank Broadcast Tarp	99,582	**0.14**
	Shallow Shank Bedded Tarp	165,514	**0.23**
	Hot Gas Tarped Chemigation	200,342	**0.27**
Tomatoes (264) (CUE)	Shallow Shank Broadcast Tarp	65,724	0.09
	Shallow Shank Bedded Tarp	109,239	**0.15**
	Hot Gas Tarped Chemigation	132,226	**0.18**
Golf Courses and Athletic Fields (400) (SP)	Shallow Shank Broadcast Tarp	99,582	**0.14**
	Shallow Shank Bedded Tarp	165,514	**0.23**
	Hot Gas Tarped Chemigation	200,342	**0.27**

[1] Montreal Protocol Designation Codes: CUE – Critical Use Exemption; QPS – Quarantine and Pre-Shipment Exemption; SP – Stockpile

2. Mammal endangered species RQ calculated by the PERFUM EEC divided by the LC_{50} = 730,009 μg/m³ (MRID 425041-01).
3 Bolded RQ values indicate uses where further refinements for RQ calculations from the screening analysis were necessary.
4 Maximum ground-level EECs occurring along the edge of the field are shown in the table.

Table 5-5. Refined acute risk quotients used to define potential indirect effects to the CTS based on risks to mammalian prey exposed to methyl bromide via soil fumigation.

Crop, App. Rate (lbs. a.i./A), and Montreal Protocol Designations	Application Scenario	Upper 90th Percentile Peak PERFUM EEC (μg/m³)	Acute Risk Quotient
Orchard Replant (400) (CUE)	Deep Shank	No Refinement	See **Table 5-4**
Peppers (396) (CUE)	Shallow Shank Broadcast Tarp	8,156	0.01
	Shallow Shank Bedded Tarp	15,121	0.02
	Hot Gas Tarped Chemigation	16,706	0.02
Eggplant (240) (CUE)	Shallow Shank Broadcast Tarp	5,051	< 0.01
	Shallow Shank Bedded Tarp	8,936	0.01
	Hot Gas Tarped Chemigation	9,713	0.01
Cucurbits (240) (CUE)	Shallow Shank Broadcast Tarp	5,051	< 0.01
	Shallow Shank Bedded Tarp	8,936	0.01
	Hot Gas Tarped Chemigation	9,713	0.01
Forestry Nursery (400) (CUE)	Shallow Shank Broadcast Tarp	8,936	0.01
	Shallow Shank Bedded Tarp	15,929	0.02
	Hot Gas Tarped Chemigation	16,706	0.02
Nursery and Ornamentals (400) (CUE)	Shallow Shank Broadcast Tarp	8,936	0.01
	Shallow Shank Bedded Tarp	15,929	0.02
	Hot Gas Tarped Chemigation	16,706	0.02
Strawberries (282) (CUE)	Shallow Shank Broadcast Tarp	5,828	< 0.01
	Shallow Shank Bedded Tarp	11,267	0.01
	Hot Gas Tarped Chemigation	12,044	0.02
Berries (240) (SP)	Shallow Shank Broadcast Tarp	5,051	< 0.01
	Shallow Shank Bedded Tarp	8,936	0.01
	Hot Gas Tarped Chemigation	9,713	0.01
Sweet Potatoes (400) (CUE)	Shallow Shank Broadcast Tarp	8,936	0.01
	Shallow Shank Bedded Tarp	15,929	0.02
	Hot Gas Tarped Chemigation	16,706	0.02

Table 5-5. Refined acute risk quotients used to define potential indirect effects to the CTS based on risks to mammalian prey exposed to methyl bromide via soil fumigation.			
Crop, App. Rate (lbs. a.i./A), and Montreal Protocol Designations	**Application Scenario**	**Upper 90th Percentile Peak PERFUM EEC ($\mu g/m^3$)**	**Acute Risk Quotient**
Tomatoes (264) (CUE)	Shallow Shank Broadcast Tarp	5,828	< 0.01
	Shallow Shank Bedded Tarp	10,490	0.01
	Hot Gas Tarped Chemigation	11,267	0.01
Golf Courses and Athletic Fields (400) (SP)	Shallow Shank Broadcast Tarp	8,936	0.01
	Shallow Shank Bedded Tarp	15,929	0.02
	Hot Gas Tarped Chemigation	16,706	0.02

[1] Montreal Protocol Designation Codes: CUE – Critical Use Exemption; QPS – Quarantine and Pre-Shipment Exemption; SP – Stockpile

[2.] Mammal endangered species RQ calculated by the PERFUM EEC divided by the LC_{50} = 730,009 $\mu g/m^3$ (MRID 425041-01).

Chronic exposure is not expected for soil fumigant applications. Only one application per season occurs at treated sites. Therefore, chronic RQs are not presented for methyl bromide soil fumigant applications.

Structural Uses

Acute RQs used to evaluate the potential for indirect effects to the terrestrial-phase CTS resulting from direct effects to mammals from the structural uses of methyl bromide are presented in **Table 5-6.** For the tile, timber and space fumigation uses (maximum application rate = 15 lbs./1,000 $ft.^3$ ft.) acute RQs exceeded the acute endangered species LOC for all mechanical and active fumigation scenarios except for railcars and cargo. Acute RQs calculated for all seven modeled tile, timber and space fumigation uses ranged from **<0.01 to 0.32**. For all seven food and commodity exposure scenarios (application rate of 9 lb/1000ft^3), acute RQs range **from <0.01 to 0.19** for food and commodity uses, and exceed for both active (mechanical) aeration scenarios. **Table 5-6** also presents the downwind distance from the structure needed for the RQ to fall below the endangered species LOC, which for the tile, timber, and space treatment is 70 m (230 ft.) for the 6 -hour horizontal mechanical aeration from 250,000 $ft.^3$ building scenario, 12-hour vertical mechanical aeration from 10,000,000 $ft.^3$ building scenario, and the 12-hour passive aeration scenario from 10,000,000 $ft.^3$ building scenario. For food and commodity treatments, the distance to reach the LOC is 50 m (164 ft.) for both the 12-hour passive aeration scenario from 10,000,000$ft.^3$ building scenario and 6-hour active (mechanical) aeration scenario from 250,000 $ft.^3$ building scenario. The EECs corresponding to these acute RQ values are presented in **Table 3-13**.

Table 5-6. Acute risk quotients (dimensionless) used to define potential indirect effects to the CTS based on risks to mammalian prey exposed to methyl bromide via structural fumigation and downwind distances to the LOC (m).

Use Types and Montreal Protocol Designation	Application Rate (lbs./1,000 ft.^{3})	Structure Volume (ft.^{3}) and Release Period (hrs.)	Building Aeration Emission Scenarios			Railcars and Cargo Aeration Emissions [4]
			Scenario 1 Exponential Emissions Decay, Single Source, AXR = 0.1, Passive Aeration, No Stack	Scenario 2 Exponential Emissions Decay, Single Source, AXR = 1.0, Active Aeration, 10 ft. Vertical Stack	Scenario 3 Exponential Emissions Decay, Single Source, AXR = 1.0, Active Aeration, 3 ft. Horizontal Portable Stack	Scenario 4 Exponential Emissions Decay, Multiple Source, AXR = 0.05, Passive Aeration, No Stack
• Post Harvest Indoor Food Fumigation (QPS) • Commodity Indoor Fumigation (QPS)	9	10,000 ft^3 for 6 hrs.	ND	ND	ND	<0.01
		250,000 ft^3 for 6 hrs.	<0.01 / 0m	< 0.01 / 0 m	**0.19/ 50 m**	N/A
		10,000,000 ft.^{3} for 12 hrs.	0.06 / 0m	**0.19 / 50 m**	0.04/ 0 m	N/A
• Timber and Tile Indoor Fumigation (QPS) • Space Fumigation (SP)	15	5,000 ft.^{3} for 6 hrs.	ND	ND	ND	<0.01
		250,000 ft^3 for 6 hrs.	<0.01 / 0m	< 0.01 / 0m	**0.32 / 70 m**	N/ A
		10,000,000 ft.^{3} for 12 hrs.	**0.11 / 70m**	**0.32 / 70 m**	0.07 / 0 m	N/ A

[1] Montreal Protocol Designation Codes: CUE – Critical Use Exemption; QPS – Quarantine and Pre-Shipment Exemption; SP – Stockpile

[2.] RQs exceeding mammal endangered species LOC = 0.1 calculated by the PERFUM EEC divided by the LC_{50} = 730,009 μg/m^3 (MRID No. 48515601) shown in bold face.

[3] N/A means not applicable. ND means not modeled.

[4] Modeling at 5,000 ft.3 and 10,000 ft.3 representative of railcar and cargo hold structure sizes per CSX website (http://www.csx.com/index.cfm/customers/equipment/railroad-equipment/).

5 Distance from the edge of the building based on the distribution of PERFUM upper 90th percentile peak(hourly) air concentrations along each receptor ring for the worst time of day (hourly average).

To assess chronic risk, a reproductive chronic rat study for methyl bromide (MRID No. 00160477) is used to evaluate the indirect effects due to reduction of prey for the CTS. Therefore, RQs are computed integrating this data with upper 90th percentile peak (hourly) PERFUM EEC in air, in the absence of a tool to calculate chronic EECs. These upper-bound RQs are presented in **Table 5-7**. **Upper-bound chronic RQs range between 0.13 – 20.4.** RQs exceed the chronic LOC for mammals = 1.0 by wide margins for all passive and active (mechanical) 12-hour release scenarios from a 10,000,000 ft.^{3} as well as the horizontal mechanical 6-hour release scenario from a 250,000 ft.^{3} for all uses included food, commodity, tile, timber, and space structural fumigation treatments.

In addition, the chronic reproductive rat study is integrated with maximum ambient air concentration values measured in California to calculate lower-bound chronic RQs. The 11-week NOAEL endpoint value derived from this study was a concentration was 3 ppm (11,649 $\mu g/m^3$ based on the ideal gas law). The maximum 24-hour average ambient monitoring concentration in California air sheds targeted with high methyl bromide use was measured at 30.8 ppb (119.6 $\mu g/m^3$). **Therefore, the lower-bound chronic RQ delineating indirect effects due to reduction of mammalian prey is calculated at 119.6 $\mu g/m^3$ ÷ 11,649 $\mu g/m^3$ = 0.01.** This is two orders of magnitude lower than the chronic LOC for mammals = 1.0.

Table 5-7. Risk quotients used to define potential indirect effects to the CTS based on chronic risks to mammalian prey exposed to methyl bromide via structural fumigation.

Use Types and Montreal Protocol Designation	Application Rate (lbs./1,000 ft.^{3})	Structure Volume (ft.^{3}) and Release Period (hrs.)	Building Aeration Emission Scenarios			Railcars and Cargo Aeration Emissions [5]
			Scenario 1 Exponential Emissions Decay, Single Source, AXR = 0.1, Passive Aeration, No Stack	Scenario 2 Exponential Emissions Decay, Single Source, AXR = 1.0, Active Aeration, 10 ft. Vertical Stack	Scenario 3 Exponential Emissions Decay, Single Source, AXR = 1.0, Active Aeration, 3 ft. Horizontal Portable Stack	Scenario 4 Exponential Emissions Decay, Multiple Source, AXR = 0.05, Passive Aeration, No Stack
• Post Harvest Indoor Food Fumigation (QPS) • Commodity Indoor Fumigation (QPS)	9	10,000 ft^3 for 6 hrs.	ND	ND	ND	0.13
		250,000 ft^3 for 6 hrs.	0.13	0.13	**12.13**	N/A
		10,000,000 ft.^{3} for 12 hrs.	**4.07**	**11.81**	**2.73**	N/A
• Timber and Tile Indoor Fumigation (QPS) • Space Fumigation (SP)	15	5,000 ft.^{3} for 6 hrs.	ND	ND	ND	0.13
		250,000 ft^3 for 6 hrs.	0.13	0.13	**20.40**	N/A
		10,000,000 ft.^{3} for 12 hrs.	**6.74**	**19.81**	**4.73**	N/A

[1] Montreal Protocol Designation Codes: CUE – Critical Use Exemption; QPS – Quarantine and Pre-Shipment Exemption; SP – Stockpile
[2.] RQs exceeding mammal chronic LOC = 1.0, calculated by the PERFUM EEC divided by the rat NOAEL = 11,649 μg/m^3 (MRID No. 00160477), shown in bold-face.
[3] N/A means not applicable.
[4] ND means not modeled.
[5] Modeling at 5,000 ft.3 and 10,000 ft.3 representative of railcar and cargo hold structure sizes per CSX website (http://www.csx.com/index.cfm/customers/equipment/railroad-equipment/).
[6] Distance from the edge of the building based on the distribution of PERFUM upper 90th percentile peak(hourly) air concentrations along each receptor ring for the worst time of day (hourly average).

5.1.1.d. Indirect Effects to CTS: Terrestrial Invertebrates

The potential for indirect effects to the terrestrial-phase CTS from direct acute effects to terrestrial invertebrates used as prey was evaluated qualitatively. Typically, risks to terrestrial invertebrates (in this case, those that are used as prey) are determined using toxicity data for the honey bee, since registrant-submitted data for honey bee are typically available for outdoor uses.

For methyl bromide, no toxicity data for the honey bee was available and no acceptable toxicity data for other terrestrial invertebrates were identified. Previously, a waiver request for the acute contact honey bee study was received on August 26, 2010 and supported on November 2010. The basis for granting the waiver for the honey bee toxicity study related to presumed lack of exposure of honey bees when considering methyl bromide's soil fumigation uses. Specifically, methyl bromide is applied on bare ground when no plants are available to attract bees. Furthermore, methyl bromide is applied as a gas and likely does not result in any measurable residues in plants on treated fields which might attract bees. In addition, no uptake of methyl bromide by plants on treated fields is anticipated given the plant back interval of 10 days specified on the label. Therefore, no residues are expected on plants. However, methyl bromide is used to control nematodes, beetles, weevils, moths, termites and mites, indicating potential exposure to soil dwelling invertebrates which may be used as food by the CTS. Risk to terrestrial invertebrates will therefore be evaluated qualitatively using various lines of evidence presented in the Risk Description (**Section 5.2.2)**.

5.1.1.e. Indirect Effects to CTS (Terrestrial Plants)

Potential indirect effects of methyl bromide on the CTS due to effects on terrestrial plants were evaluated because terrestrial plants are known to be used as habitat by the CTS. Generally, risks to terrestrial plants are based on two types of toxicity studies: vegetative vigor and seedling emergence. Risk quotients are determined based on the ratio of the pesticide application rate (lb ai/A) to the EC_{25} values from these studies.

For the seedling emergence study, EFED recently accepted a waiver request for this study based on lack of expected exposure to planted seeds. Specifically, methyl bromide is applied to bare soil prior to planting with little or no residues remaining after the10 day plant back period specified on the label due to its high volatility and degradation in soil). For the vegetative vigor toxicity study, the submitted waiver request was denied because exposure of terrestrial plants to volatilized methyl bromide in areas adjacent to treated fields could not be discounted. Methyl bromide is also known to have herbicidal properties based on its use to control weeds. However, a vegetative vigor plant study has not been submitted to the Agency as of the date of this assessment. Therefore, the risk to CTS via indirect effects on terrestrial plants is evaluated qualitatively further assessed in **Section 5.2** (Risk Description).

5.1.2. Primary Constituent Elements of Designated Critical Habitat

For methyl bromide uses, the assessment endpoints for designated critical habitat PCEs of the CTS involve the same endpoints as those being assessed relative to the potential for direct and indirect effects to the CTS. Therefore, the effects determinations for direct and indirect effects are used as the basis of the effects determination for potential modification to designated critical habitat.

5.2. Risk Description

The risk description synthesizes overall conclusions regarding the likelihood of adverse impacts leading to a preliminary effects determination (*i.e.*, "no effect," "may affect, but not likely to adversely affect," or "likely to adversely affect") for the assessed species and the potential for modification of their designated critical habitat based on analysis of risk quotients and a comparison to the Level of Concern. The final No Effect/May Affect determination is made after the spatial analysis is completed at the end of the risk description in **Section 5.3.2**. In **Section 5.2.4.a**, a discussion of any potential overlap between areas where potential usage may result in LAA effects and areas where species are expected to occur (including any designated critical habitat) is presented. If there is no overlap of the species habitat and occurrence sections with the Potential Area of LAA Effects a "No Effect," determination is made.

If the RQs presented in the Risk Estimation (**Section 5.2**) show no direct or indirect effects for the assessed species, and no modification to PCEs of the designated critical habitat, a preliminary "no effect" determination is made, based on methyl bromide's use within the action area. However, if LOCs for direct or indirect effect are exceeded or effects may modify the PCEs of the critical habitat, the Agency concludes a preliminary "may affect" determination for the FIFRA regulatory action regarding methyl bromide. A summary of the risk estimation results are provided in **Table 5-8** for direct and indirect effects to the listed species assessed here and for the PCEs of their designated critical habitat.

Table 5-8. Risk estimation summary for methyl bromide direct and indirect effects and critical habitat effects to the California Tiger Salamander.

Taxa	LOC Exceedances (Yes/No)	Description of Results of Risk Estimation	Assessed Species Potentially Affected
Birds, and Terrestrial-Phase Amphibians (Bird as surrogate)	Listed Species (Yes: structural tile, timber and space application methods) Non-listed LOC (No: All uses)	Methyl bromide acute inhalation RQs (0.10 and 0.11) for birds equaled or exceeded the endangered species LOC of 0.1 for two of the seven structural timber, tile and space exposure scenarios evaluated.	Direct and Indirect: CTS (all 3 DPSs) and its amphibian prey
	Non-listed and Listed Species (No: Structural food and commodity uses and soil fumigant uses)	Avian acute inhalation RQs for post harvest indoor food and commodity indoor structural applications using the PERFUM model EECs ranged from <0.01 to 0.06. Avian acute inhalation RQs (< 0.01 – 0.02) for soil fumigants (orchard replant peppers, forestry nursery, nursery and ornamentals, sweet potatoes, golf courses, and athletic fields) did not exceed the LOC of 0.1 using EECs from the SCREEN3 and PERFUM model.	

Table 5-8. Risk estimation summary for methyl bromide direct and indirect effects and critical habitat effects to the California Tiger Salamander.

Taxa	LOC Exceedances (Yes/No)	Description of Results of Risk Estimation	Assessed Species Potentially Affected
	Non-listed and Listed Species (No: Structural food and commodity uses and soil fumigant uses)	Avian acute inhalation RQs for soil fumigants using SCREEN3 EECs for orchard replant, eggplant, cucurbits, strawberries, other berries and tomatoes ranged from 0.03 to 0.09.	
Mammals	Listed Species (Yes: Structural Applications)	Mammalian acute inhalation RQS for two of the food and commodity scenarios for application rated of 9 lbs/1000ft^3 and three of the tile, timber and space scenarios for application rates of 15 lbs/1000 ft^3 exceed the LOC of 0.1. RQs ranged from <0.01 to 0.32 (using PERFUM).	Direct and Indirect: CTS (all 3 DPSs) (prey) and shelter/cover from mammal burrows
	Listed Species (No: Soil fumigants)	Mammalian acute inhalation RQs did not exceed the endangered species LOC of 0.1 for any use patterns for soil fumigant applications using PERFUM to refine the risk. Screening level acute RQs for mammals ranged from 0.5 to 0.27. Soil fumigant RQs using the refined modeling resulted in RQs ranging from 0.01 to 0.02.	
Terrestrial Invertebrates	Nonlisted and Listed Species (Undetermined)	Risk for both structural and soil fumigant applications could not be calculated as there are no acceptable toxicity endpoints available from which to calculate RQs for terrestrial invertebrates. Risk are further evaluated in the Risk Description (**Section 5.2.2)** using other lines of evidence.	Indirect: CTS (all 3 DPSs) (prey)
Terrestrial Plants – Monocots	Non-listed Species (Undetermined)	Risk for both structural and soil fumigant applications could not be calculated as there are no acceptable toxicity endpoints from which to calculate RQs. Risk are further evaluated in the Risk Description **(Section 5.2.2)** using other lines of evidence.	Indirect: CTS (all 3 DPSs) (prey)
Terrestrial Plants – Dicots			

Critical habitat has been defined for the CTS and the PCEs are described in **Table 2-8**. The PCEs for the terrestrial-phase CTs include general requirements that provide essential life cycle needs such as space, food, water and cover and shelter. Critical habitat includes areas with small mammal burrows and areas that allow dispersal. Therefore, the effect of methyl bromide applications are also evaluated with endpoints used to evaluate direct and indirect effects in **Table 5-8.**

Following a preliminary "may affect" determination, additional information is considered to refine the potential for exposure at the predicted levels based on the life history characteristics (*i.e*., habitat range, feeding preferences, *etc*.) of the assessed species. Based on the best available information, the Agency uses the refined evaluation to distinguish those actions that "may affect, but are not likely to adversely affect" from those actions that are "likely to adversely affect" the assessed species and its designated critical habitat.

The criteria used to make determinations that the effects of an action are "not likely to adversely affect" the assessed species or modify its designated critical habitat include the following:

- Significance of Effect: Insignificant effects are those that cannot be meaningfully measured, detected, or evaluated in the context of a level of effect where "take" occurs for even a single individual. "Take" in this context means to harass or harm, defined as the following:
    - Harm includes significant habitat modification or degradation that results in death or injury to listed species by significantly impairing behavioral patterns such as breeding, feeding, or sheltering.
    - Harass is defined as actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding, or sheltering.
- Likelihood of the Effect Occurring: Discountable effects are those that are extremely unlikely to occur.
- Adverse Nature of Effect: Effects that are wholly beneficial without any adverse effects are not considered adverse.

A description of the risk and effects determination for each of the established assessment endpoints for the assessed species and their designated critical habitat is provided in **Sections 5.2.1 and 5.2.2.** Each will start with a discussion of the potential for direct effects, followed by a discussion of the potential for indirect effects. A summary of the chance of an individual effect will also be provided for direct and indirect effects. These discussions do not consider the spatial analysis. For those listed species that have designated critical habitat, the section will end with a discussion on the potential for modification to the critical habitat from the use of methyl bromide. Finally, in **Section 5.2.4.a** a discussion of any potential overlap between areas of concern and the species (including any designated critical habitat) is presented. If there is no overlap of the species habitat and occurrence sections with the Potential Area of LAA Effects a "No Effect," determination is made.

5.2.1. Direct Effects to the Terrestrial-Phase CTS

Acute Inhalation Exposure

In the absence of amphibian inhalation data, avian inhalation toxicity data are used to represent the effect of methyl bromide on the terrestrial-phase CTS. There are several physiological differences between amphibians and birds that are the cause for uncertainty in this assessment. There is uncertainty due to the lower inhalation rate for amphibians versus birds. Differences in lung physiology also increase the uncertainty. Amphibian lungs are tidal systems as opposed to bird lungs which are unidirectional. The skin of the terrestrial-phase CTS also acts as an inhalation membrane. The available avian inhalation toxicity data does not account for simple diffusion across the skin. Nonetheless, given these uncertainties, the acute avian inhalation data is used since it most represents the physiology of the CTS given the information available for methyl bromide.

With an acute bird inhalation LC_{50} of 561 ppm (2,178,378 μg/m^3), the highest RQ based on PERFUM structural fumigant modeling is **0.11** (237,686 μg/ m^3/2,178,378 μg/ m^3), **thus exceeding the 0.1 endangered species LOC**. The modeling is based on a 15 lb a.i./1,000ft^3 maximum application rate for tile, timber (QPS) uses and general space fumigation (stockpile) uses. Therefore, only the space fumigation uses require past stocks which are certain to diminish over time with labeled application rates of 15 lbs./1,000 ft.^{3} The particular scenario with the highest RQ is the horizontal release aeration scenario from a 250,000 ft.^{3} building, 6-hour release. However, the vertical 12- hour release aeration scenario from a 10,000,000 ft.^{3} building, had a slightly lower RQ, but still exceeded the 0.1 endangered species LOC. It appears that episodes of multiple releases throughout the day and night from various applications within the building increase the probability that peak emission rates may occur at nighttime hours when conditions are often conducive to stagnate air and lead to very high pollutant concentrations as compared to a 12-hour release to a larger building. The increase in probability of nighttime emissions can be due to a repetitive cyclical nature of treatments such as that included in the model parameterization of flux rates (**see Table 3-11**). This result is reflective of one of many release scenarios which can influence air EECs. There are no specific release parameters specified on the label; therefore, the potential for this multiple release scenario to result in direct inhalation risks to the CTS cannot be ruled out based on existing labels.

Other methyl bromide structural application scenarios did not exceed the LOC of 0.1. RQs for post harvest indoor food and commodity indoor structural applications using the PERFUM model EECs ranged from <0.01 to 0.06 with lower maximum application rates of 9 lbs./1,000 ft.^{3}

Soil fumigant uses were first evaluated using the SCREEN3 modeled peak EECs. No risk quotients exceeded the acute listed species LOC (RQs $\leq$0.09). However, the PERFUM model was used to address RQs exceeding the LOC of 0.1 for indirect effects due to reduction in prey concerns for broadcast tarped shank injection applications, bedded shank injection applications, and hot gas chemigation tarped applications (see indirect effects section below). However, when a refined exposure analysis was conducted using the PERFUM model, the RQ values for all evaluate uses were well below the acute risk LOC of 0.1 (RQ = < 0.01 for all cases).

Sub-lethal endpoints from a northern Bobwhite Quail acute inhalation study (MRID No. 48515801) can also compared to the modeled EECs. No twitching was reported at the NOAEL concentration of 505 ppm during the exposure duration. However, immediately following the 4-hour exposure period, hypoactivity and tremors were reported. Therefore, 505 ppm is the NOAEL which is used to compare to the air EECs. Given the similar magnitude of this endpoint value to the avian acute inhalation survival endpoint of 561 ppm, sublethal adverse effects are not anticipated from the soil fumigants. However, it is important to note that the dose response relationship was not clearly established for all sublethal effects reported.

One reason for no exceedances resulting from the soil uses is that the exposure determined by flux in the field volatility studies for methyl bromide reflect the field management practices specified on the labels. Moreover, inhalation toxicity values suggest low toxicity of methyl bromide as the avian inhalation LC_{50} of 561 ppm (converted to 2,178,378 μg/ m^3) has been measured. However, it is important to note that there are uncertainties with the field management practices applied in the field volatility studies which served as the basis for air EECs (**see Section 6.1.2** for details).

RQs based on exposure modeling EECs can be qualified further by using the available air monitoring dataset for methyl bromide to compute RQs representative of observed typical conditions in the environment. This comparison is shown in **Table 5-9** for the least and greatest soil fumigant EECs and **Table 5-10** for structural EECs. In all cases, the RQs based on modeled EECs are higher than those based on monitored soil fumigant application data. The highest monitoring value of 3.35 ppm (converted to 13,008μg/m^3) used for all comparisons in the table was at most, about half the maximum modeled EECs of all soil fumigant application scenarios (hot gas tarped chemigation using PERFUM). In addition, the PERFUM modeling EECs for the hot gas tarped chemigation uses at 390 lb a.i./A and 400 lbs. a.i./A uses are lower than all of the SCREEN3 peak EECs for all uses Therefore, as expected, the PERFUM model most closely represents typical conditions observed in monitoring data. The 3.35 ppm value was reported as a peak value, which most resembles the modeled values than values with higher multiple-hour averaging periods. Therefore, the most likely reason for the discrepancy between the modeled and monitoring results is due to the fact that modeling provides a robust representation accounting for a wide variation of meteorological conditions, where these variations can be limited during monitoring observing periods.

In general, there is even less of a discrepancy between the monitoring RQs and modeling RQs for the structural RQs. **Table 5-10** and comparison of EECs to monitored values in **Table 3-17** show that the maximum modeled EEC (or RQ) is higher than the maximum monitored concentration (or monitored-based RQ) by a factor of only 2, suggesting that the high end structural exposure scenarios produce air EECs that are reasonable results. For the structural fumigants, the minimum modeled EECs were as much as two orders of magnitude lower than the maximum monitored concentration. There are numerous reasons explaining the lower modeling value for the least impacting scenarios than monitoring value. First, the highest monitored concentration of 27 ppm (converted to 104,841.7 μg/m^3) used in this evaluation was measured as a 5-minute average as compared to an hourly average value calculated in the modeling. Secondly, comparison of the least impacted modeling scenarios to this monitoring value are not appropriate, given differences in the release specifications between modeling and monitoring scenarios. However, despite the higher monitored concentration value versus the lowest EEC modeled, the RQ based on the maximum monitored value was lower than the LOC of 0.1 for endangered species, whereas the RQ based on the maximum modeled concentration did exceed the LOC of 0.1.

Table 5-9. Comparison of RQs for direct effects to CTS to monitoring data-based RQ for evaluation of soil fumigant EECs.

Crop and Montreal Protocol Designations	Application Rate and Method Scenario	Acute Risk Quotient with Modeled EEC	Acute Risk Quotient with Maximum Monitored Data Value[2]
Evaluation of RQs Based on SCREEN3 Maximum EEC = 268,822 μg/m[3] or 69.23 ppm			
Forestry Nursery (CUE)	400 lbs. a.i./A Hot Gas Tarped Chemigation	0.09	< 0.01
Nursery and Ornamentals (CUE)	400 lbs. a.i./A Hot Gas Tarped Chemigation	0.09	< 0.01
Sweet Potatoes (CUE)	400 lbs. a.i./A Hot Gas Tarped Chemigation	0.09	< 0.01
Golf Courses and Athletic Fields (SP)	400 lbs. a.i./A Hot Gas Tarped Chemigation	0.09	< 0.01
Evaluation of RQs Based on SCREEN3 Minimum EEC = 40,367 μg/m[3] or 10.39 ppm			
Orchard Replant (CUE)	400 lbs. a.i./A Deep Shank Injection Untarped	0.02	< 0.01
Evaluation of RQs Based on PERFUM EEC = 30,692 μg/m[3] or 7.9 ppm			
Forestry Nursery (CUE)	400 lbs. a.i./A Hot Gas Tarped Chemigation	< 0.01	< 0.01
Nursery and Ornamentals (CUE)	400 lbs. a.i./A Hot Gas Tarped Chemigation	< 0.01	< 0.01
Sweet Potatoes (CUE)	400 lbs. a.i./A Hot Gas Tarped Chemigation	< 0.01	< 0.01
Golf Courses and Athletic Fields (SP)	400 lbs. a.i./A Hot Gas Tarped Chemigation	< 0.01	< 0.01

[1] Montreal Protocol Designation Codes: CUE – Critical Use Exemption; QPS – Quarantine and Pre-Shipment Exemption; SP – Stockpile

[2] Highest observed value in application monitoring data of 3.35 ppm (converted to 13,008μg/m[3] using the ideal gas law) used for comparison in all evaluations shown.

[3.] Avian endangered species RQ calculated by the PERFUM EEC divided by the LC_{50} = 2,178,390 μg/m[3] (MRID No. 48515601).

Table 5-10. Comparison of RQs for direct effects to CTS to monitoring data-based RQ for evaluation of structural use EECs.			
Crop and Montreal Protocol Designations	**Application Rate and Method Scenario**	**Acute Risk Quotient with Modeled EEC**	**Acute Risk Quotient with Maximum Monitored Data Value**
Evaluation of RQs Based on PERFUM Maximum EEC = 237,686 μg/m³ or 61.21 ppm			
• **Timber and Tile Indoor Fumigation (QPS)** • **Space Fumigation (SP)**	15 lbs. a.i./1,000 ft.³ 3 ft. Horizontal Portable Stack, 250,000 ft.³ building, 6-hour release	0.11	0.05
Evaluation of RQs Based on PERFUM Minimum EEC = 1,554 μg/m³ or 0.4 ppm			
• **Timber and Tile Indoor Fumigation (QPS)** • **Space Fumigation (SP)** • **Post-Harvest Food Uses (QPS)** • **Post-Harvest Commodity Uses (QPS)**	15 lbs. a.i./1,000 ft.³ and 9 lbs. a.i./1,000 ft.³ for: • Railcars/Cargo 6-hour release scenario, • Passive Release scenario, 250,000 ft.³ building, 6-hour release • Active Vertical Release scenario, 250,000 ft.³ building, 6-hour release	< 0.01	0.05

[1] Montreal Protocol Designation Codes: CUE – Critical Use Exemption; QPS – Quarantine and Pre-Shipment Exemption; SP – Stockpile

[2] Highest observed value in structural fumigant outdoor monitoring data of 27 ppm (converted to 104,841.7 μg/m³ using the ideal gas law) used for comparison in all evaluations shown.

[3.] Avian endangered species RQ calculated by the PERFUM EEC divided by the LC_{50} = 2,178,390 μg/m³ (MRID No. 48515601).

Despite the favorable comparison on the risk determination outcomes influenced between monitored and modeled values for soil fumigant applications, uncertainties exist with both the exposure and effects aspects of the risk determinations. These include the incorporation of flux profiles from a limited amount of study sites and using the bird as a surrogate for the CTS in the absence of an inhalation endpoint value available for the CTS. However, RQs are much less than the endangered species LOC. Therefore, this wide margin suggests that uncertainties would not preclude the NE or NLAA determinations for direct risks of concern to the CTS related to soil fumigant applications.

Risk quotients for several structural uses are either just below or just above the endangered species LOC of 0.1. In general, there are several factors accounted for in this risk assessment that can be discussed to further qualify the potential adverse effects to CTS populations as suggested by this assessment. These include the following factors and corresponding qualification regarding the reality of the RQs calculated:

- There is uncertainty relating avian inhalation toxicity data to the terrestrial-phase CTS due to differences in lung function and due to the active gas phase transfer across the skin. Further discussion of differences is discussed in **Section 6.2.2**.

- RQs were calculated comparing the inhalation LC_{50} from the 4-hour avian inhalation studies to an hourly peak EEC in air. Therefore, since peak EECs in air are always greater over shorter periods due to turbulence over treated fields or in the wake of treated buildings, the RQs calculated in this assessment are conservative with respect to the comparison between EECs and inhalation toxicological endpoints.

- Structural monitoring exposure data generally reflect concentrations close to the upper-bound EECs determined in the high impact scenarios which resulted in LOC exceedances in this assessment. Therefore, this would suggest that the RQs calculated in this assessment can reflect some realism.

- Uncertainties related to the varying magnitudes of methyl bromide flux from treated fields or varying emission rates from treated structures may lead to equal chances of under or over-prediction of EECs and the resulting quantification of RQs. These uncertainties are discussed in **Section 6.1.2 and 6.1.3**.

- Air dispersion models do not account for meandering of highly concentrated plumes over short time period from treated fields or structures which may lead to amplified levels of exposure. These conditions are common during temperature inversions. Therefore, RQ values would be under-quantified under these conditions. This is further discussed in **Section 6.1.4.**

Overall, direct adverse effects to CTS populations from structural fumigation treatments should not be discounted given these uncertainties and other considerations. Although risk quotients for structural fumigants suggest that endangered species LOC excedances are marginal, there are several considerations which suggest that this risk concern accompanying methyl bromide structural fumigation treatments is not discountable. First, the risk quotients are developed using PERFUM upper 90^{th} percentile peak (hourly) EECs in air. Therefore, it is possible that there may be cases where air concentrations may actually exceed these levels, although this scenario is not anticipated to occur frequently. Such a scenario may include temperature inversion conditions which are often associated with air stagnation events. In addition, application air monitoring data suggests that maximum air concentrations are within an order of magnitude of the acute EEC in air for the release scenario modeled resulting in the highest EECs in PERFUM. Therefore, this magnitude departure from monitoring values suggests that the PERFUM EEC likely depicts some realism. Furthermore, it is entirely possible that there would be horizontal releases close to the ground, such as the scenario which resulted in the maximum upper-bound

PERFUM air EEC. In addition, for releases from the tops of buildings, phenomenon such as building downwash and convective downdrafts in the wake of buildings may contribute to ground-level exposures of methyl bromide. Similar RQ magnitudes of 0.11 were calculated from a scenario with a mechanical release from a 10 foot stack from the top of a 10,000,000 $ft.^3$ building corresponding to the 15 lb./1,000 $ft.^3$ application rate. However, it is important to note the bird is the surrogate species for the CTS in the absence of an inhalation endpoint value available for the CTS. Please refer to **Section 6.2.2** for a description of the uncertainties and justification for the selection of bird species as a surrogate to the CTS.

Chronic Inhalation Exposure

Chronic exposure(s) of the CTS to airborne methyl bromide gas could conceivably occur due to repeated exposures from multiple treated fields where methyl bromide is used in large quantities and multiple treatments in structures due to commodity and food treatments. However, chronic exposure from single soil applications of methyl bromide is not expected due to the highly transient nature of methyl bromide concentrations in the atmosphere and restrictive application practices that involve tarps and deep shank injections. For structural fumigation treatments, chronic exposure may be a concern given that label requirements do not restrict the amount of methyl bromide treatments and subsequent releases for buildings. However, given the highest monitoring value of 30.8 ppb (119.6 $\mu g/m^3$) in California in targeted ambient air where building treatments occur and that the majority of methyl bromide use is seasonal for post-harvested food and commodities treatments, the risk of chronic exposure to the CTS from treated structures is unlikely.

While fumigant applications methyl bromide are not expected to result in ecologically significant chronic exposures near treated application sites due to its high dispersion rate, methyl bromide is recognized as being persistent in the atmosphere at trace levels (the atmosphere with a tropospheric half-life of 210 days). Therefore, long range transport is investigated using the OECD Screening P_{ov} (Overall Persistence) and LRTP (Long Range Transport Potential) Screening Tool for quantifying long range atmospheric transport potential of methyl bromide. The OECD tool indicates a CTD (Characteristic Travel Distance) value of 89,972.86 km and Overall Persistence of 278.93 days (Scheringer, M., 2008)[7]. The overall persistence value of 278.93 days is logical given the measured tropospheric half-life of 210 days (Atkinson, 1989) and is similar in value to 255 measured atmospheric residence time (WMO, 2002). Despite the long range transport potential of methyl bromide, this process is not expected to contribute towards chronic exposure. Accumulation of methyl bromide environmental mass in biota is not probable given its likelihood to remain as a gas in the air. In addition, the decline of levels of global mean methyl bromide atmospheric concentrations suggests that the importance of methyl bromide long range transport will diminish over time given the phase-out of methyl bromide. Composite mean monitoring data of atmospheric methyl bromide is shown in **Figure 3-1.**

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[7] Characteristic travel distance defined as the distance to which 38 percent of the chemical has degradaded in the system.
Overall persistence is defined as the residence time of the chemical in the system.
OECD Pov and LRTP Screening Tool methyl bromide inputs: molecular weight = 94.94 g/mol; Log K_{aw} = -0.523; Log K_{ow} = 1.18; Half Life in Air = 5,040 hours; Half Life in Water = 0.05 hours; Half-Life in Soil = 528 hours

Soil Exposure

As mentioned in **Section 2.9.2**, there is the potential for soil borne methyl bromide dermal and inhalation exposure to burrowing terrestrial-phase CTS on fields treated with methyl bromide. A qualitative analysis is presented here which demonstrates the potential direct effect on the terrestrial-phase CTS exposed to methyl bromide gas in the soil via direct incorporation. Acute avian inhalation data are used to represent direct effects to the CTS. Since there are no dermal toxicity data available for methyl bromide, this analysis is limited to the assessment of inhalation exposure. Please refer to **Section 6.2.1** for details.

Peak EECs in soil are calculated within the treated field using the minimum incorporation depth and maximum application rate for each methyl bromide soil fumigation application method including bedded tarped shank injection, broadcast tarped shank injection, deep shank untarped shank injection, and hot gas tarped chemigation applications specified on labels. A soil bulk density of 1.5 g/cm^3 and soil particle density of 3.0 g/cm^3 are assumed to be representative values in California and thus are used in the calculation of soil EECs. The equation calculating the soil EECs is provided in **Section 3.1.3**. These EECs represent the peak upper-bound air concentrations in burrows where CTS inhabit. These EECs were calculated assuming an instantaneous concentration after application and that all methyl bromide mass within the depth of injection resides in the pore space between soil particles homogenously throughout the field. Importantly, no volatility is assumed, although it is assumed that methyl bromide is mixed homogeneously in the soil column due to diffusion processes, with no methyl bromide escaping into the atmosphere. This is a highly conservative assumption designed to support a bounding analysis of exposure within burrows. The EECs and their departures from the acute avian inhalation LC_{50} value for each application method are shown in **Table 5-11.**

As expected, soil pore space EECs were high ranging from between 49,031,066 – 882,559,185 $\mu g/m^3$. These EECs exceeded the avian inhalation LC_{50} values by wide margins with magnitudes of 22.5 for deep shank injection applications, 50.6 for broadcast tarped shank injection applications, 405.1 for hot gas tarped chemigation applications, and 202.6 for bedded tarped shank injection applications. Application rates and incorporation depths accounted for the differences in estimated EECs. For example, the highest EEC value for hot gas tarped chemigation applications is based on an application rate of 400 lb a.i./A and 1 inch incorporation depth. Specific crop pre-plant treatments for the different application methods are listed in **Table 2-5.**

Table 5-11. Departures of soil EECs indicating potential effects to CTS populations residing in burrows.						
Soil Fumigation Application Method	**Treated Field Application Rate (lbs. a.i./A)**	**Incorporation Depth of Methyl Bromide in Soil (inches)**	**Soil Bulk Density (g/cm^3)**	**Soil Particle Density (g/cm^3)**	**Soil Pore Space EEC ($\mu g/m^3$)**	**EEC Magnitude Departure from Acute Avian Inhalation LC_{50} ($\mu g/m^3$)**
Deep Shank Injection Untarped Applications	400	18[2]	1.5	3.0	49,031,066	22.5
Broadcast Tarped Shank Injection Applications	400	8[2]			110,319,898	50.6
Hot Gas Tarped Chemigation Applications	400	1[3]			882,559,185	405.1
Bedded Tarped Shank Injection Applications	200[3]	1[2]			441,279,593	202.6

[1] Magnitude departure from EEC = $\dfrac{\text{Soil EEC } (\mu g/m^3)}{\text{Acute Avian Inhalation } LC_{50} \ (\mu g/m^3)}$

[2] Acute Avian LC_{50} = 2,178,390 $\mu g/m^3$ (MRID No. 48515601).

[3.]Maximum application rate adjusted for percent treated area of 0.5 assumed for bedded tarped applications.

Although the exposure magnitude is very high especially for bedded tarped and hot gas tarped chemigation applications, the exposure scenario resulting from incorporation of methyl bromide onto treated fields is not very probable. This is mainly due to the likely scenario that CTS populations on the treated field would likely relocate due to cultivation practices required on the label before methyl bromide is applied. Cultivation practices would likely destabilize the landscape on the field. In addition, after treatment, CTS populations would not likely inhabit a field with a broadcast tarp covering. However, it is plausible that CTS populations may inhabit a field without full tarp coverage in bedded shank injection applications. Even so, the majority of methyl bromide gas is expected to remain in the bed under the tarps or escape through the tarps into the air. In addition, the CTS may be exposed in soil from methyl bromide treatments in deep burrows below the cultivated zone off-of the treated fields given the possibility for lateral movement of methyl bromide gas. However, these exposure scenarios are not very plausible given that methyl bromide gas would mostly move upwards towards the cultivated top soil.

Use of Probit Slope Response Relationship to Provide Information on the Endangered Species Levels of Concern

Table 5-12 conveys information relevant to the chance of an individual effect on the terrestrial-phase CTS for direct effects. The probit is first estimated at the LOC of 0.1 . The slope of 1.09, as well as the boundaries for the 95% confidence interval (1.04 and 1.14) from the avian inhalation study (MRID 485156-01) are used to estimate the probability of an individual effect. The probability of an individual effect using the slope of 1.09 at the LOC level was calculated to be ~ 1 in 7.25. The slope using the 95% confidence interval was also estimated at the LOC. The probability of an individual effect at the RQ of 0.1 at the lower bound slope of 1.04 was calculated to be ~ 1 in 6.70. The upper bound slope of 1.14 at the LOC is ~1 in 7.87.

The probability of an individual effect using the slope of 1.09 at the RQ of 0.11was calculated to be ~ 1 in 6.75. The slope using the 95% confidence intervals were also estimated at the RQ of 0.11. The probability of an individual effect at the lower bound slope of 1.04 was calculated to be ~ 1 in 6.27. The upper bound using the slope of 1.14 at the LOC is ~1 in 7.29. Given the high probability of an individual mortality occurrence based on acute exposure and because acute RQs do exceed LOCs for the bird as a surrogate, methyl bromide is likely to cause direct adverse effects to the terrestrial-phase CTS (all 3 DPSs) for structural tile, timber, and space applications.

Table 5-12. Estimate of the chance of individual effect for direct effects on the terrestrial-phase CTS using birds as a surrogate.

Uses (Application Method)	**Chance of Individual Effect At LOC**	**Chance of Individual Effect At RQ.**	**Chance of Individual Effect At RQ.**
Tile, timber and space	Slope	Slope =1.09:~ 1 in 7.25	Slope =1.09:~ 1 in 6.75
	95% Confidence Interval	Slope=1.04:~ 1 in 6.70	Slope=1.04: ~1 in 6.27
		Slope=1.14: ~1 in 7.87	Slope= 1.14: ~1 in 7.29

A description of the probit slope analysis method is discussed in **Section 4.5.** In summary, given the lines of evidence supporting the LOCs exceedances for listed species and given the high probability of individual mortality, there is a potential for methyl bromide to cause direct effects to the terrestrial-phase CTS (all 3 DPSs). These exposure occurrences supporting the risks to terrestrial species can be attributed to the high application rate and high mobility of methyl bromide.

5.2.2. Indirect Effects

The potential for indirect effects to the CTS based on reduction in amphibian prey was evaluated using the same exposure estimates and toxicity information described previously in **Section 5.2.1** for direct effects to the CTS. For all soil fumigant uses modeled, acute avian inhalation RQs did not exceed the listed species LOC (0.1) based on the sequential application of the SCREEN3 and PERFUM models. For structural methyl bromide applications, only one use (tile, timber and space fumigation) exceeded the listed species LOC, with an RQ value of 0.11. The similarity of maximum modeled and monitored concentrations for structural uses suggests that the structural EECs are environmentally realistic. Additional characterization of risks and a summary of factors addressing the uncertainty in the assessment of effects to amphibians based on the modeled EECs and monitored concentrations associated with methyl bromide fumigant applications, as well as species differences in species' physiology is provided in **Section 5.2.1.**

Amphibians

In this risk assessment, indirect effects to the terrestrial-phase CTS that consume amphibians as prey are evaluated analogously with the analysis presented for direct effects. Indirect effects to the terrestrial-phase CTS via reduction in prey are possible based on structural use patterns of methyl bromide. Therefore, the risk characterization provided in **Section 5.2.1** is relevant in full to this effects determination.

Mammals

Acute Inhalation

An acute mammalian inhalation 6-hour LC_{50} value of 730,000 $\mu g/m^3$ derived from the mouse study (MRID 425041-01) was used to estimate the effect of air concentrations of methyl bromide calculated using the SCREEN3 exposure model (for soil fumigant uses) and the refined PERFUM model (for soil fumigant and structural uses). The screening level RQs for soil fumigants ranged from 0.05 to 0.27 based on SCREEN3 modeling. Therefore broadcast tarped shank injection, bedded tarped shank injection, and hot gas chemigation pre-plant applications on forestry, nursery, sweet potato, pepper and golf courses were further refined using the PERFUM model. Acute inhalation RQs resulting from these uses for mammals were **<0.01** for soil fumigant uses based on PERFUM modeling.

Acute inhalation RQs for mammals range from **0.01-0.32** for structural fumigant uses based on refined PERFUM modeling. The structural use RQs exceed the acute LOC of 0.1 for endangered mammals. The analysis above relies on the acute inhalation toxicity value for an adult mouse. **However, due to size limitations, terrestrial-phase CTS are only able to prey on very small mammals such as mice and rat pups**. An additional developmental toxicity study on rats indicated that methyl bromide is toxic to juvenile rats, which supports the LAA determination.

Chronic Inhalation

Chronic exposure(s) of the CTS to airborne methyl bromide gas could conceivably occur due to repeated exposures from fields and structures that are repeatedly treated with methyl bromide. Chronic inhalation exposure is not expected to occur with methyl bromide soil fumigation, given the specified one seasonal application occurring on treated fields on labels. However, for methyl bromide structural fumigation treatments, chronic exposure may occur due to a potentially high amount of releases which may occur from treated structures. Upper and lower-bound chronic RQs are also calculated using a reproductive mammalian toxicological study available for rats

(MRID No. 00160477) compared to PERFUM peak acute EECs in air and maximum ambient air monitoring concentrations, respectively. This analysis is shown in **Section 5.1.1.c.** Indirect Effects to CTS (Mammalian Prey) The ambient monitoring data used to derive the lower-bound chronic RQ were measured in a targeted California air shed with a high volume of methyl bromide use. Upper-bound chronic RQs are very high ranging between 0.13 – 20.40, and the lower-bound chronic RQs is 0.01. Although the upper-bound RQs exceeds the LOC by a wide margin, the departure of ambient air monitoring concentration are two orders of magnitude below the LOC concentration. The ambient air monitoring data represents a 24-hour average concentration for monitoring data in a targeted air shed. This averaging period is more relevant of chronic exposure in air than the hourly upper-bound peak PERFUM modeled EECs. In addition, the upper-bound RQ is highly conservative, based on the one-hour estimated air concentration in PERFUM from structural releases. Furthermore, the reproductive rat study may represent a conservative endpoint value considering the repetitive 6-hour exposure duration over 11 weeks in the study. It is not anticipated that the CTS mammalian prey would be exposed to this level of continuous exposure considering that structural methyl bromide treatments mainly encompass post-harvesting seasons. Therefore, risk to mammals associated with chronic exposure from releases occurring after structural treatments are assumed to be unlikely, given the relevant methyl bromide targeted ambient air monitoring concentrations as well as the mostly seasonal use for methyl bromide structural fumigations.

Terrestrial Invertebrates

The terrestrial-phase CTS feeds on terrestrial invertebrates such as insects and worms. Acute toxicity data for the honey bee is typically used as a surrogate for terrestrial invertebrates since such data are often required to be submitted by registrants. As discussed in **Section 5.1.1**, no toxicity data are available on the effects of methyl bromide to the honey bee. Furthermore, no toxicity studies of other terrestrial invertebrates were identified in the open literature that were considered acceptable for quantitative use.

Therefore, since a honeybee study is not available, a qualitative analysis comparing maximum PERFUM upper 90th percentile peak air EECs to a survival endpoint using insect toxicity data from the open literature is used for evaluating risks to the CTS via reduction in terrestrial invertebrate prey abundance (Rajendran, 1992). **Maximum EECs of 237,686 μg/m^3 calculated for structural fumigation treatments are above the LOC of 0.05 for insects[8].** Results from a toxicity study on the rust red flour beetle resulting in an LD_{50} of 0.81 mg/L or 810,000 μg/m^3 (Rajendran 1992) are available in the open literature. There are no toxicity studies available for other fumigants that provide an indication of the risk to terrestrial invertebrates.

Lastly, the incident databases (EIIS, AIMS) were searched for any indication of adverse effects to terrestrial invertebrates associated with methyl bromide. There were no wildlife incidents to terrestrial invertebrates reported in the databases that were associated with methyl bromide uses. However, lack of reported ecological incidents does not indicate ecological incidents have not occurred, rather they may have occurred but not been identified and/or reported. Thus, lack of

[8] Toxicological endpoint magnitude departure from EEC = $\frac{237{,}686\ \mu g/m^3}{810{,}000\ \mu g/m^3}$ = 0.29 > LOC = 0.05.

ecological incidences does not necessarily refute the likelihood that methyl bromide would be toxic to at least some soil invertebrates at labeled application rates. Therefore, the lines of evidence support an LAA determination from the use of methyl bromide on terrestrial insects.

Potential Modification of Habitat as an Indirect Effect

Mammal Burrows Providing Shelter

The terrestrial-phase CTS uses California ground squirrel (*Spermophilus beecheyi*) or Botta' pocket gopher (*Thomonys bottae*) (Barry and Shaffer 1994) burrows for refuge. Indirect effects from alteration in habitat may result from a reduction in mammals digging burrows. For structural food and commodity uses, RQs (<0.01 to 0.19) derived using air EECs from the PERFUM model and toxicity data for the mouse exceeded the acute listed species LOC of 0.1 Similarly, acute inhalation RQs determined for structural tile, timber and space fumigant uses exceeded the acute listed species LOC (RQs ranged from <0.01-0.32). Therefore, there is an "LAA" determination for structural applications of food and commodity and tile, timber and space.

It is important to note that other factors may modify the exposure of methyl bromide within mammalian burrows. The exposure from use may be reduced based on the dimensions of the burrow which is below the site of soil application. The burrows can be five to 30 feet or more in length and extend two to four feet below the surface. The burrows may have multiple openings, which may allow the mammals to move away from the application site during application periods. Although the terrestrial-phase CTS uses mammal burrows, it will occasionally use man-made structures (Stebbins 1972, Shaffer *et al*. 1993).

Soil fumigant use RQs resulting from SCREEN3 modeling resulted in RQs ranging from 0.05 to 0.27. The refined PERFUM modeling for forestry, nursery, peppers, sweet potatoes, golf courses, strawberries, tomatoes, eggplant, cucurbits and berries resulted in RQs ranging from 0.01 to 0.02. The highest of these RQs is below the LOC of 0.1, thus indicating no indirect effects due to reduction in mammalian burrows used for habitat based on toxicity data for the mouse. After reviewing the lines of evidence for indirect effects to the terrestrial-phase CTS for reduced availability of mammal burrows, there is a "NLAA determination for all soil fumigant uses, except orchard replant. Orchard replant application resulted in a "No Effect" determination based on screening level modeling.

Terrestrial Plants Providing Cover

Risk quotients for terrestrial plants were not calculated due to the absence of plant toxicity values. However, methyl bromide is known to have herbicidal properties based on label information. There is no proven mechanism for the phytotoxic effects of methyl bromide, although it has been proposed that excessive accumulation of the bromide ion by plants produces toxic effects (WHO 1995). In carnation plants exposed to methyl bromide by soil fumigation, plant survival and flower yield were inversely proportional to inorganic bromide concentration in the soil (Kempton and Maw 1974). However, it is also possible that some of the phytotoxic

effects of methyl bromide are due to indirect actions, such as the elimination of beneficial microorganisms from soil (MRID 00118842, Lambert et al. 1979).
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An additional line of evidence is based on a review of incident reports from EIIS, IDS, AIMS, and the aggregate incident database. The only plant incident located in the databases was a minor plant incident from the aggregate database. The report did not indicate whether the incident involved aquatic or terrestrial plants. The aggregate incident database, unlike EIIS, provides only the raw counts of reported incidents and the taxa involved rather than location of incident, certainty of the incident, whether the incident resulted from a registered use, etc.

In summary, there is uncertainty in the terrestrial plant determinations due to the absence of toxicity data. However, based on the known herbicidal properties of methyl bromide, existence of at least one reported incident involving plants, risk is presumed for upland and riparian vegetation in close proximity to treated areas. Given that both upland and riparian areas are comprised of a mixture of both non-sensitive woody (trees and shrubs) and sensitive grassy herbaceous vegetation, CTS may be indirectly affected by adverse effects to herbaceous vegetation which provides habitat and cover for the CTS and its prey. Therefore, methyl bromide structural and soil fumigant uses have the potential to indirectly affect the CTS (all 3 DPSs).

Exposure to UV Radiation

As mentioned in **Section 2.3.1**, indirect toxicological effects of cancer-causing UV radiation penetrating to the ground, partially caused by methyl bromide emissions into the stratosphere, may lead to disruptions of growth and survival for amphibians such as the CTS (UNEP, 2010). At this time, this risk cannot be quantified. However, it is anticipated that as current usage of methyl bromide continues to decline, any risk associated with increased exposure to UV radiation due to methyl bromide releases would also decline.

5.2.3. Modification of Designated Critical Habitat

There is a potential for the modification of designated critical habitat for terrestrial-phase CTS based on terrestrial-phase amphibian and terrestrial invertebrate prey loss due to changes in the composition of food supply. Alteration of the environment is based on potential reduction in the availability of mammal burrows for shelter and from the potential effects to terrestrial plants. Risk to terrestrial plants is based on the absence of toxicity data for estimating effects, the reported phytotoxic properties of methyl bromide, and the minor incident reported in the aggregate database.

5.2.4. Spatial Extent of Potential Effects

Since the acute listed species LOC is exceeded for structural fumigant uses of methyl bromide, analysis of the spatial extent of potential LAA effects is needed to determine where effects may occur in relation to the treated site. In addition, this risk assessment indicates the potential of CTS habitat to be altered due to a potential reduction in available mammal burrows for shelter and presumed risks to terrestrial plants nearby structural and soil fumigation treatment sites. If the potential area of usage and subsequent Potential Area of LAA Effects overlaps with CTS habitat or areas of occurrence and/or critical habitat, a "likely to adversely affect," determination is made. If the Potential Area of LAA Effects and the CTS habitat and areas of occurrence and/or critical habitat do not overlap, a "no effect"determination is made.

To determine this area, the footprint of methyl bromide's soil fumigant use pattern is identified, using corresponding land cover data. For methyl bromide structural uses, open/developed low/developed medium/ developed high land use classes are included. Actual usage is expected to occur in a smaller area as the chemical is only expected to be used on a portion of the identified area. The footprint for methyl bromide soil and structural uses are presented in **Figure 2-8** and **Figure 2-9.**

5.2.4.a. Overlap of Potential Areas of LAA Effect and Habitat and Occurrence of CTS

PERFUM spatial distributions of upper 90th percentile peak (hourly) estimated air exposure concentrations indicate that **a distance of 70 meters (230 feet) from the treated structure to the critical habitat is a sufficient to protect CTS populations from adverse direct and effects from methyl bromide structural treatments for tile, timber and space treatments.** Similarly**, a distance of 50 meters (164 ft.) from the treated structure to the critical habitat is sufficient to protect CTS populations from adverse indirect effects (only) from methyl bromide for food and commodity structural treatments.** No distance can be estimated accounting for indirect effects to the CTS from methyl bromide structural and soil treatments causing habitat modification due to related loss of terrestrial plants in this risk assessment. This is the case given the absence of a definitive terrestrial plant toxicological endpoint which is normally used to determine the distance from treatment sites necessary for the RQ to fall below the LOC.

When the distances described above are added to the footprint of the Initial Area of Concern (which represents potential methyl bromide use sites) and compared to CTS habitat, there are several areas of overlap. **Figure 5-1** and **Figure 5-2** show the overlap (in black shaded areas) between the areas of LAA effect and CTS habitat, including designated critical habitat, coupled with soil and structural use sites, respectively. Both figures indicate that methyl bromide use in California has the potential to affect the terrestrial-phase CTS (all 3 DPSs).

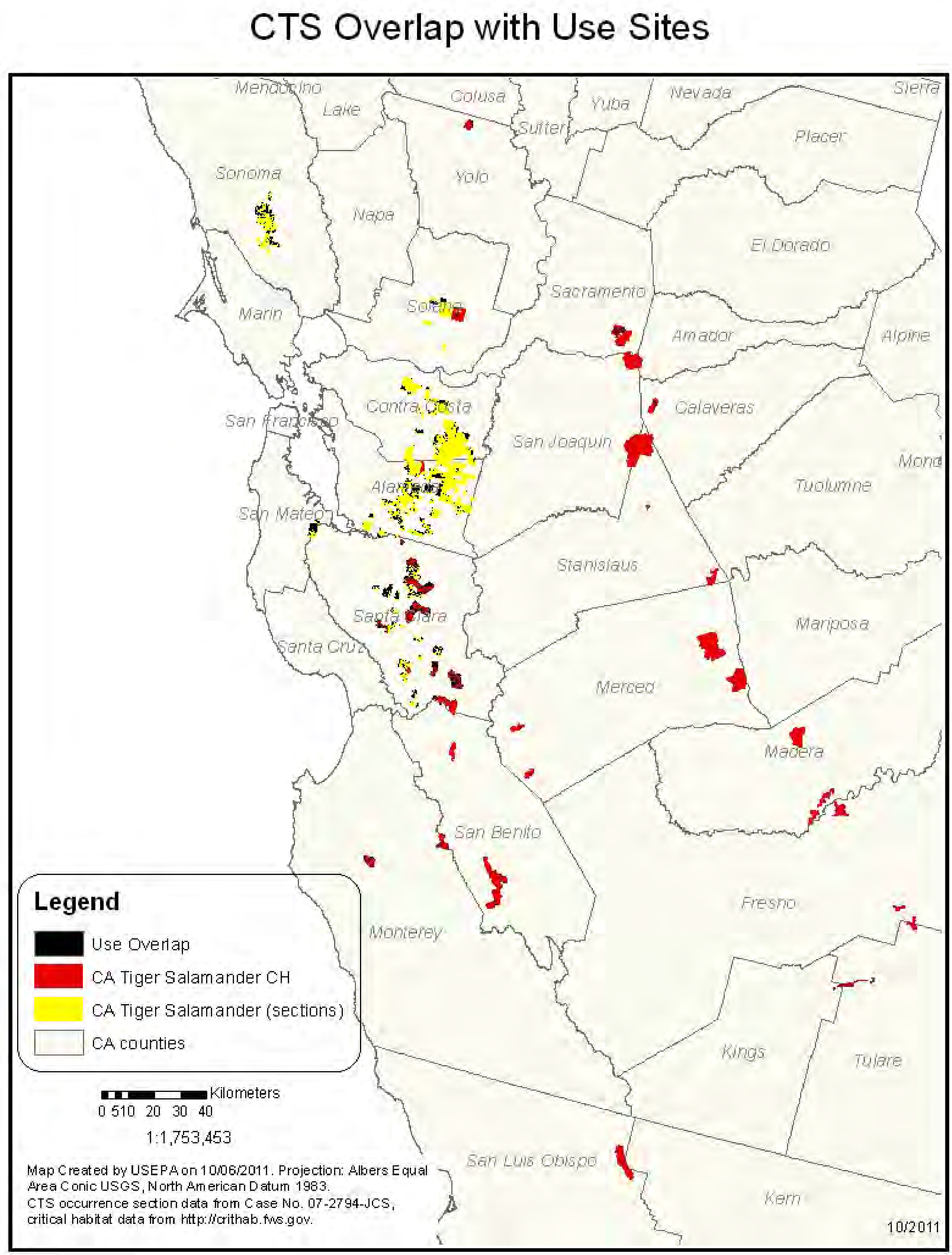

Figure 5-1. Map showing the methyl bromide soil fumigant use overlap with the CTS critical habitat and occurrence sections identified by Case No. 07-2794-JCS.

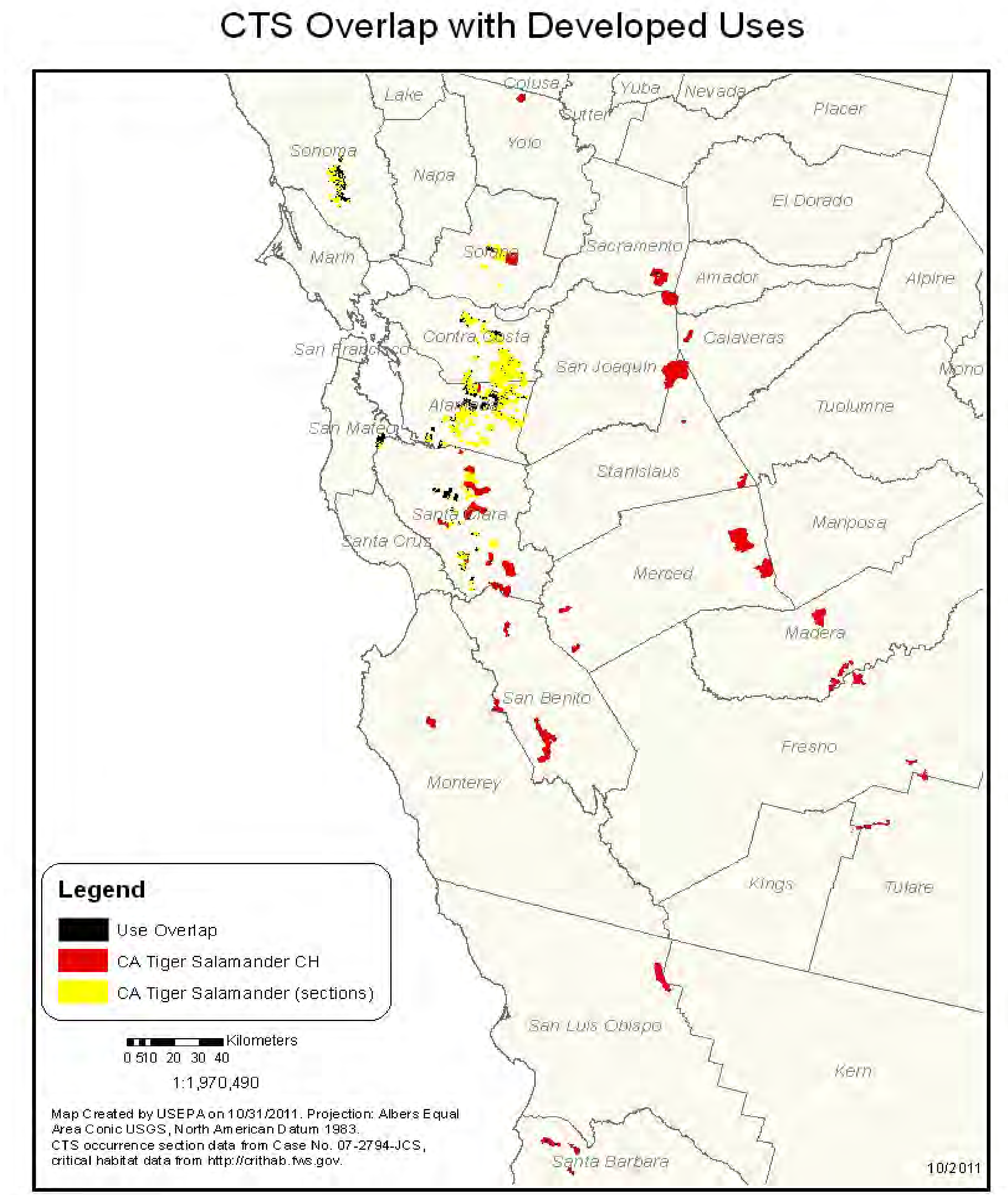

Figure 5-2. Map showing the methyl bromide structural use overlap with the CTS critical habitat and occurrence sections identified by Case No. 07-2794-JCS.

5.3. Effects Determinations

5.3.1 CTS

Direct effects to the terrestrial-phase CTS are likely due to adverse effects from inhalation using birds as a surrogate for terrestrial-phase amphibians. Indirect effects to the CTS are possible due to adverse effects on terrestrial prey (i.e., amphibians, invertebrates, small mammals) which may provide food as well as to alterations in the environment including reduced availability of mammal burrows for shelter and terrestrial plants which provide habitat for the species. Therefore, the Agency makes a **may affect, and likely to adversely affect** determination for the CTS (all 3 DPSs) and a **habitat modification determination** for their designated critical habitat based on the potential for direct and indirect effects to the terrestrial-phase CTS and effects to the PCEs of critical habitat.

5.3.2 Addressing the Risk Hypotheses

In order to conclude this risk assessment, it is necessary to address the risk hypotheses defined in **Section 2.9.1** . Based on the conclusions of this assessment, the hypotheses listed below cannot be rejected:

- Methyl bromide may directly affect the terrestrial-phase CTS (all 3 DPSs).
- Methyl bromide may indirectly affect the terrestrial-phase CTS (all 3 DPSs) and/or affect their designated critical habitat by reducing or changing the composition of the available prey in the species' current range.
- The evaluation of mammal risk is also used to evaluate risk from reduction in mammal burrows used for shelter. There is a potential indirect effect from alteration in the environment as reduction in shelter based on the refined PERFUM modeling indicating LOC exceedance.
- Methyl bromide may indirectly affect their designated critical habitat by altering the environment through effects to terrestrial plants.

6. Uncertainties

Uncertainties that apply to most assessments completed for the San Francisco Bay species litigation are discussed in **Attachment 1**. This section describes additional uncertainties specific to this assessment.

6.1. Exposure Assessment Uncertainties

For soil fumigants, the uncertainties inherent in the exposure assessment tend to result in over-estimation of exposures. This is apparent when comparing modeling results with monitoring data. Air monitoring data are over an order of magnitude less than the upper-bound air concentrations predicted by SCREEN3 and PERFUM in many cases for soil. In general, the monitoring data should be considered a lower bound on exposure, while modeling represents an upper bound.

There is more uncertainty with upper-bound exposure estimates for structural fumigants. First, directions for use prescribing aeration procedures on relevant methyl bromide labels are very general, often only defining the application rate, duration of treatment, and statement recommending a minimum aeration period. However, the labels do not provide specific instructions related to aeration practices. Therefore, the air exposure assessment for structural uses was based on a sampling of scenarios accounting for a few combinations of a few building sizes, aeration rates, and release periods that may occur under this use pattern. These parameters are critical parameters for emissions and resulting EECs from treated structures. However, scenarios were developed in an attempt to determine the upper-bound exposure considering the largest building sizes (corresponding roughly to the volumetric size of four football stadiums) and resulting probable release durations from those buildings. Second, there is some uncertainty with outdoor monitoring conducted concurrent with structural treatments and aeration operations as the factors impacting emissions described above are not included in monitoring reports in many cases. Therefore, definitive comparisons between the monitoring data and modeling EECs from structural uses are difficult. However, indoor air monitoring data consistently demonstrate the exponential decline observed overtime in indoor air concentrations which qualifies the trend in emissions originating from structures. Due to the nature of the various uncertainties in the use and labels of methyl bromide, initial air concentrations originating from the buildings are the most uncertain variable.

6.1.1. Usage Uncertainties

County-level usage data were obtained from California's Department of Pesticide Regulation Pesticide Use Reporting (CDPR-PUR) database. Nine years of data (1999 – 2008) were included in this analysis because statistical methodology for identifying outliers, in terms of area treated and pounds applied, was provided by CDPR for these years only. No methodology for removing outliers was provided by CDPR for 2001 and earlier pesticide data; therefore, this information was not included in the analysis because it may misrepresent actual usage patterns. CDPR PUR documentation indicates that errors in the data may include the following: a misplaced decimal; incorrect measures, area treated, or units; and reports of diluted pesticide concentrations. In addition, it is possible that the data may contain reports for pesticide uses that have been cancelled. The CPDR PUR data does not include home owner applied pesticides; therefore, residential uses are not likely to be reported. As with all pesticide usage data, there may be instances of misuse and misreporting. The Agency made use of the most current, verifiable information; in cases where there were discrepancies, the most conservative information was used.

In addition, there are many uncertainties in the usage of methyl bromide on buildings. As mentioned in the preceding paragraph, there is a lack of information related to the building sizes that are often fumigated which is important to consider since building size is one factor which directly influences emission rates at a specific air exchange rate and related impacts on outdoor air concentrations. In addition, there is a lack of information related to the design of buildings fumigated, including the dimensions of buildings, different tiers of buildings, as well as the number and relative locations of stack and vents that serve as the release points during methyl bromide aeration operations. These variables all impact the magnitude of downwash often occurring downwind from treated structures. As mentioned above, scenarios were developed in an attempt to determine the upper-bound exposure in air resulting from releases of methyl bromide from structures.

6.1.2. Uncertainties in Environmental Fate Database

There are a wide variety of environmental fate and transport studies in water, soil, and air in the open literature for methyl bromide, which by in large this assessment relies upon. However, many of the studies utilized in the literature do not completely comply with the OCSPP guidelines which are specifically designed for results to be applied for a wide range of pesticides treatment uses. These studies provide valuable information for this risk assessment, but are considered supplemental information in order to develop the fate profile for methyl bromide in the environment in this risk assessment.

Furthermore, there are numerous noteworthy deficiencies in the Wasco, CA field volatility study (MRID No. 48006001) used to assess exposure from methyl bromide soil fumigant use in air that render this study being classified supplemental. First, application rates in the study were not conducted to the maximum application rate on labels for the soil fumigant uses. Secondly, air monitoring started 12 – 47 minutes after the applications started for all fields monitored in the study. Third, laboratory spikes, which may provide information related to the stability of methyl bromide in mixtures with the other active ingredient chloropicrin used in this study as compared to stabilities evident in other studies with methyl bromide as the only active ingredient were not provided. Fourth, monitored air concentrations are not easily verifiable as raw data was only provided by hard copy. Nonetheless, the results of the study provided valuable information and were used in this risk assessment.

6.1.3. Uncertainty Associated with Exposure Scenarios

As mentioned above, perhaps the largest uncertainty with estimating risk from methyl bromide use lies within the scenarios developed to assess exposure from the structural uses. Labels for the structural uses do not specify allowable emission rates from treated structures, nor do they specify any parameters such as gas stream exit flow rates or specific time periods for releases as these parameters would influence the temporal emission profiles as well as the resulting outdoor air concentrations. Furthermore, there is a dearth of information related to typical building sizes affecting the amount emitted from buildings as well as building layouts affecting resulting outdoor concentrations. Scenarios consisting of a combination of release durations with appropriately large building sizes were considered in an attempt to calculate upper-bound EECs in air from this use pattern. However, since use information is only limited to the amount of methyl bromide used for structural fumigations in California, it is unclear the margin by which the upper-bound EECs overestimate air concentrations actually contributed from this use.

There are also some uncertainties related to the scenarios used to calculate EECs for the soil uses. The scenarios encompassed measurement of volatility loss of methyl bromide from soil measured in field volatility studies. However, the vast majority of the soil volatile flux used for the basis of air EECs for the methyl bromide soil uses was developed from composited data by application method from many individual studies. The details of the compositing method used to develop the flux rates are provided in **Appendix E**. Single temporal flux profiles for each application method were incorporated into the PERFUM model for the basis of the air exposure modeling. Therefore, different flux rates may exist as conditions such as temperature, soil moisture, organic matter, and tarps used which all influence emission rates of methyl bromide from soil, can impact air EECs within and adjacent to treated fields. However, in general, the composite flux profiles were developed from many studies which showed moderate variability of volatile flux measurements within each application method at most. In addition, some conservatism was considered in the development of these profiles. Therefore, actual air EECs for soil fumigant uses are not expected to underpredict actual air concentrations which is demonstrated in the comparison between modeled EECs and actual application monitoring data air concentration measurements shown in **Section 3.1.2**.

Furthermore, actual dosages that the CTS and obligate species would be exposed to are likely to be lower than conveyed in this risk assessment for all methyl bromide uses. This risk assessment assumes that the receptor is constantly exposed to the methyl bromide at one location. Under practical conditions, the organism's time at any single location is transient and will therefore not contain the dose indicated by the EEC.

6.1.4. Terrestrial Exposure Models Limitations

For the terrestrial exposure analysis of this risk assessment, a generic bird or mammal was assumed to occupy either the treated field or adjacent areas receiving a treatment rate on the field. Actual habitat requirements of any particular terrestrial species were not considered, and it was assumed that species occupy, exclusively and permanently, the modeled treatment area.

In addition, there are several uncertainties associated with SCREEN3 and PERFUM models. These include the following elements:

- There are various uncertainties related to the initial conditions of emission rates used in these models. As discussed in **Section 6.1.2** above, there are uncertainties associated with the consideration of one composite flux profile for each soil fumigant application method. Furthermore, there are uncertainties related to the various emission rates parameterized in PERFUM for the structural uses given the lack of release parameters and building characteristics. However, as explained in **Section 6.1.3**, modeling approaches for both scenarios are expected to result in upper-bound EECs for methyl bromide.

- SCREEN3 and PERFUM do not address exposure durations that are less than one hour. Peak EECs predicted by SCREEN3 may actually be higher on these time scales especially during periods with temperature inversions. Such conditions are often associated with light and variable wind speeds and highly stagnant air with poor mixing within plume elements and may exist over only portions of one hour. Therefore, peak air concentrations may be underestimated by SCREEN3 and PERFUM since plume elements on and off the treated field may be more concentrated at sub-hourly time scales rather than at hourly time scales. However, it is not expected that these conditions would significantly impact the expected frequency of exposure events since these conditions may only occur within a few hours of some days after fumigant applications.

- In addition, the lowest receptor height available in PERFUM is at 1.5 meters above ground level. Ground-level representations of air concentrations may be higher considering the ground release from soil fumigation treatments or lower considering the elevated release of structures. However, this difference is not anticipated to throughout this height.

6.1.5. Terrestrial Air Monitoring Limitations

The air monitoring database for methyl bromide is very robust. However, there are a few limitations worth noting. First, many air samples reflect hourly average air concentrations greater than one hour. For this risk assessment, a one-hour average air concentration is considered to be the appropriate acute exposure duration for the CTS and obligate species. Secondly, monitoring concentrations are only representative of the meteorological conditions during the time of sampling, where a range of meteorological conditions are accounted for in this assessment. Third, methyl bromide ambient monitoring is not just representative of the concentration as a result of pesticide use, it also represents the contributions from natural sources. Therefore, it is difficult to determine how pesticide use contributes to the continual and chronic exposure for CTS and obligate species. Fourth, historical monitoring data concurrent and nearby soil applications may not reflect the current combination of field management practices and application methods required on today's labels. Fifth, large uncertainty with aeration source parameters such as application rates, building sizes, and release durations render difficulties with comparing monitoring data with the appropriate modeling results given the scenarios depicted.

6.2. Effects Assessment Uncertainties

6.2.1. Data Gaps and Uncertainties

There is uncertainty due to potential dermal exposure. However, no dermal toxicity data is available. Toxicity data for primary skin irritation (Alexeef and Kilgore 1983; and Hezemans-Boer et al 1988) indicate severe irritation following accidental exposure to humans.

There is also uncertainty due to the absence of terrestrial plant data to evaluate the indirect effect of methyl bromide on the terrestrial-phase CTS mediated by direct effects to terrestrial plants. Methyl bromide is used to kill weeds, indicating phytotoxic effects. Therefore, a vegetative vigor study has been requested to assess the effect of methyl bromide to terrestrial plants.

6.2.2. Use of Surrogate Species Effects Data

Efforts are made to select the organisms most likely to be affected by the type of compound and usage pattern; however, there is an inherent uncertainty in extrapolating across phyla. In addition, the Agency's LOCs are intentionally set very low, and conservative estimates are made in the screening level risk assessment to account for these uncertainties.

This assessment used available avian inhalation toxicity data to evaluate the effect of methyl bromide on the terrestrial-phase CTS due to the absence of amphibian toxicity data. There are several physiological differences between amphibians and birds that lead to uncertainty in the assessment. There is uncertainty due to the lower inhalation rate for amphibians versus birds. Differences in lung physiology also increase the uncertainty. Amphibian lungs are tidal systems as opposed to bird lungs which are unidirectional. The skin of the terrestrial-phase CTS also acts as an inhalation membrane. The available avian inhalation toxicity data does not account for simple diffusion across the skin.

6.2.3. Age Class and Sensitivity of Effects Thresholds

It is generally recognized that test organism age may have a significant impact on the observed sensitivity to a toxicant. Testing of juveniles may overestimate toxicity at older age classes for pesticide active ingredients that act directly without metabolic transformation because younger age classes may not have the enzymatic systems associated with detoxifying xenobiotics. In so far as the available toxicity data may provide ranges of sensitivity information with respect to age class, this assessment uses the most sensitive life-stage information available as measures of effect for fish and aquatic invertebrates.

The available acute bird toxicity data provides information on the direct effects from methyl bromide to the adult life stage of development. This toxicity data is used to represent the terrestrial-phase CTS. This data is also used to assess the indirect effects as reduction in amphibian prey.

The terrestrial-phase CTS consumes rat and mice pups, so available adult mouse toxicity data is used to assess the indirect acute effects as reduction in prey. There is also a rat reproductive study providing a NOAEL for reproduction and juvenile survival to assess the chronic effects of methyl bromide use.

6.2.4. Sublethal Effects

When assessing acute risk, the screening risk assessment relies on the acute mortality endpoint as well as a suite of sublethal responses to the pesticide, as determined by the testing of species response to chronic exposure conditions and subsequent chronic risk assessment. Consideration of additional sublethal data in the effects determination is exercised on a case-by-case basis and only after careful consideration of the nature of the sublethal effect measured and the extent and quality of available data to support establishing a plausible relationship between the measure of effect (sublethal endpoint) and the assessment endpoints. However, the full suite of sublethal effects from valid open literature studies is considered for the characterization purposes. To the extent to which sublethal effects are not considered in this assessment, the potential direct and indirect effects of methyl bromide on listed species may be underestimated.

Sub-lethal endpoints are available from a northern Bobwhite Quail acute inhalation study (MRID No. 48515801). No twitching was reported at the NOAEL concentration of 505 ppm during the exposure duration. However, immediately following the 4-hour exposure period, hypoactivity and tremors were reported. In addition, the dose response relationship was not clearly established for all sublethal effects reported.

6.2.5. Acute LOC Assumptions

The risk characterization section of this assessment includes an evaluation of the potential for individual effects. The individual effects probability associated with the acute RQ is based on the assumption that the dose-response curve fits a probit model. It uses the mean estimate of the slope and the LC_{50} to estimate the probability of individual effects.

6.2.6. Mixtures

The California tiger salamander and various components of their ecosystem may be exposed to multiple pesticides, introduced into its environment either via a multiple active ingredient formulated product, a tank mixture, or transport from independently applied active ingredients. Multiple pesticides may act in an additive, synergistic, or antagonistic fashion. Quantifying reasonable environmental exposures and establishing reasonable corresponding toxicological endpoints for the myriad of possible situations is beyond the scope of this document, and in some cases, beyond the current state of ecotoxicological practice. Mixtures could affect the CTS in ways not addressed in this assessment. Exposure to multiple contaminants could make organisms more or less sensitive to the effects of methyl bromide, thus the directional bias associated with environmental mixtures is unknown, and may vary on a case-by-case basis.

7. Risk Conclusions

In fulfilling its obligations under Section 7(a)(2) of the Endangered Species Act, the information presented in this endangered species risk assessment represents the best data currently available to assess the potential risks of methyl bromide to CTS and their designated critical habitat.

Based on the best available information, the Agency makes a May Affect, and Likely to Adversely Affect determination for CTS (all 3 DPSs) from the use of methyl bromide. Additionally, the Agency has determined that there is the potential for modification of designated critical habitat for CTS (all 3 DPSs) from the use methyl bromide.

Direct and indirect effects were evaluated using lines of evidence, including use, potential exposure and toxicity endpoints. Direct, indirect effects and habitat modification determinations for the aquatic-phase CTS were evaluated using lines of evidence based on fate and transport properties resulting in a "No Effect" determination. No RQs for the aquatic-phase CTS were calculated.

Based on the best available information, the Agency makes a May Affect, and Likely to Adversely Affect determination for CTS (all 3 DPSs) from the use of methyl bromide. Additionally, the Agency has determined that there is the potential for modification of designated critical habitat for CTS (all 3 DPSs) from the use methyl bromide.

Direct and indirect effects were evaluated using lines of evidence, including use, potential exposure and toxicity endpoints. **Direct, indirect effects, and habitat modification determinations for the aquatic-phase CTS were evaluated using lines of evidence based on fate and transport properties resulting in a "No Effect" determination. No RQs for the aquatic-phase CTS were calculated.**

Direct Effects

Direct acute effects to the terrestrial-phase CTS due to inhalation were evaluated using the bird as a surrogate. **An "LAA" determination resulted from LOC exceedance for structural tile, timber and space applications of methyl bromide. RQs exceed the endangered species LOCs for horizontal and vertical mechanical release scenarios only at the application rate of 15 lbs./1,000 $ft.^3$ corresponding to tile, timber, and space structural fumigant treatments.** Labeled uses at this application rate include tile, timber, and space fumigation which is a QPS-exempted use and space fumigation where only stockpiles are allowed. The highest **RQ of 0.11** exceeds the endangered species LOC of 0.1. **The refined approach using the PERFUM model indicates that an upper-bound downwind distance for concentrations to fall below the LOC is 70 meters (230 feet) from the treated building.** This risk determination was further refined using the probit analysis to estimate the chance of an individual effect. Based on this analysis, the chance of an individual effect at the RQ is ~ 1 in 6.75. Although RQs for structural fumigants suggest that endangered species LOC excedences are marginal, there are several considerations which suggest that this risk concern is not discountable. First, estimates of exposure are developed using PERFUM upper 90^{th} percentile peak (hourly) EECs in air. Therefore, it is possible that there may be cases where air concentrations may actually exceed these levels, although this scenario is not anticipated to occur frequently. Such a scenario may include temperature inversion conditions which are often associated with air stagnation events. In addition, application air monitoring data suggests that maximum air concentrations are within an order of magnitude of the acute EEC in air for the release scenario modeled resulting in the highest EECs in PERFUM. Therefore, this low magnitude departure of modeled values from monitoring values suggests that PERFUM EEC likely depicts some realism. Furthermore, it is entirely possible that there would be horizontal releases close to the ground as depicted from the scenario modeled which result in the maximum upper-bound PERFUM air EEC. In addition, for releases from the tops of buildings, phenomena such as building downwash and convective downdrafts in the wake of buildings may contribute to ground-level exposures of methyl bromide. Similar RQ magnitudes of 0.11 were calculated in PERFUM from a scenario depicting a mechanical release from a 10 foot stack from the top of a 10,000,000 $ft.^3$ building corresponding to the 15 lb./1,000 $ft.^3$ application rate. However, it is important to note that the bird is used as a surrogate species for the CTS in the absence of an inhalation endpoint value available for the CTS. **There is a "NLAA" determination for food and commodity structural applications (maximum application rate = 9 lbs./1,000 $ft.^3$) of methyl bromide**. The acute RQs using EECs from the refined approach using PERFUM ranged from <0.01 to 0.03.

A "NLAA" determination was also made for pre-plant soil fumigant broadcast applications including broadcast, bedded, and hot gas chemigation tarped applications for peppers, forestry nursery, nursery and ornamentals, sweet potatoes and golf courses and athletic fields. Based on EECs from the refined approach using the PERFUM model, no LOCs were exceeded. The soil fumigant uses resulted in RQs ranging from between 0.02 – 0.09 based on SCREEN3 peak EECs. Although no exceedances occurred at the endangered species LOC using the SCREEN3 model, the PERFUM model was used to further refine this analysis since the upper range of the RQs approached the endangered species LOC, and to address indirect effects risk concerns (see below) for all pre-plant broadcast tarped shank injection, bedded tarped shank injection, and hot gas tarped chemigation applications. RQs developed using the peak upper 90^{th} percentile peak (hourly) EECs from the PERFUM model equaled < 0.01 for all of the evaluated soil fumigation uses.

The "No Effect" determination for pre-plant deep shank untarped applications for orchard replant crops resulted from lack of LOC exceedance based on SCREEN3 peak EECs. The resulting RQ of 0.02 does not indicate a risk of concern directly to the CTS for these applications.

There are also uncertainties with both the exposure and effects aspects of the risk determinations associated with soil fumigant applications. These include the incorporation of field volatility flux profiles from a limited amount of study sites and using the bird as a surrogate for the CTS in the absence of an inhalation endpoint value available for the CTS. However, RQs are much less than the endangered species LOC. Therefore, this wide margin suggests that uncertainties would not preclude the NE or NLAA determinations for direct risks of concern to the CTS related to soil fumigant applications.

Chronic inhalation exposure is not expected to occur with methyl bromide soil fumigation given the one seasonal application occurring on treated fields. For methyl bromide structural fumigation treatments, chronic exposure may occur due to a potentially high frequency of releases which may occur from treated structures. . Upper-bound chronic RQs are presented for indirect effect to mammalian prey based on the comparison of the upper 90th percentile peak (hourly) PERFUM air EECs to the same toxicological endpoint. Lower-bound chronic RQs calculated for indirect effects to mammalian prey, based on the comparison of the maximum value from ambient air monitoring concentrations in California to a reproductive mammalian chronic toxicological study, indicate that long-term air concentrations are far below the LOC concentration by at least two orders of magnitude. Although RQs exceed the LOC by a wide margin, the significant departure of the ambient air monitoring value below the LOC concentration suggests that the upper bound RQ based on peak air EECs is discountable. Please refer to the indirect effects section below for further details. It should be noted that this discussion is relevant for indirect effects to mammalian prey. There is a degree of uncertainty that exists between the extrapolation of this information and its relevance to the direct effects on CTS populations. However, in the absence of other chronic toxicological data, the mammalian data are being used in this characterization discounting direct effects due to chronic exposure to the CTS resulting from structural fumigant applications.

Indirect Effects

Indirect acute effects for the terrestrial-phase CTS are indicated by the potential for reduction in mammal, amphibian, and terrestrial invertebrate prey as well as loss of habitat associated with reduction of mammal burrows. **A LAA determination is made for reduction in prey of mammals using the mouse as a surrogate based on tile, timber, and space structural methyl bromide applications.** The acute inhalation RQ was estimated using the PERFUM model for tile, timber and space applications at the application rate of 15 lb/1000ft^3. The resulting **RQ of 0.32** exceeds the endangered species LOC of 0.1 from timber, tile, and space structural treatments. **The PERFUM model indicates that an upper-bound downwind distance for concentrations to fall below the LOC is also 70 meters (230 feet) from the treated building for indirect effects occurring due to reduction in mammalian prey and loss of habitat from timber, tile, and space treatments (maximum application rate = 15 lbs./1,000 ft.^{3}). For food and commodity uses, an LAA determination is also made** using PERFUM EECs. The resulting **RQ of 0.19** exceeds the endangered species LOC of 0.1 from food and commodity structural uses. **The PERFUM model indicates that an upper-bound downwind distance for concentrations to fall below the LOC is also < 50 meters from the treated building for indirect effects occurring due to the reduction in mammalian prey and loss of habitat from food and commodity uses (maximum application rate of 9 lbs./1,000 ft.^{3}).**

A "NLAA" determination was made for pre-plant soil fumigant broadcast applications including bedded, broadcast, and hot gas tarped chemigation applications for peppers, forestry nursery, nursery and ornamentals, sweet potatoes and golf courses and athletic fields. No LOC exceedances resulted from the refined approach using PERFUM modeled air EECs. The soil fumigant uses resulted in acute RQs ranging from between 0.05 – 0.27 based on SCREEN3 peak EECs. Since there were some exceedances which occurred at the endangered species LOC using the SCREEN3 model, the PERFUM model was used to further refine this analysis since the upper range of the RQs approached the endangered species LOC. RQs developed using the upper 90th percentile peak (hourly) EECs from the PERFUM model ranged between < 0.01 – 0.02 for all of these uses.

The "No Effect" determination for deep shank untarped pre-plant application for orchard replant crops resulted from lack of LOC exceedance based on SCREEN3 peak EECs. The resulting acute RQ of 0.05 does not indicate a risk of concern directly to the CTS for these applications.

The diet of the terrestrial-phase CTS also includes other amphibians. Therefore, indirect acute effects for the terrestrial CTS are indicated by the potential for reduction in amphibian, and terrestrial invertebrate prey. A LAA determination is made for reduction in prey of frogs using the bird as a surrogate based on tile, timber, and space structural methyl bromide applications. The acute inhalation RQ was estimated using the PERFUM model for tile, timber and space applications at the application rate of 15 lb/1000ft^3. The resulting **RQ of 0.11** exceeds the endangered species LOC of 0.1.

Chronic inhalation exposure is not expected to occur with methyl bromide soil fumigation given the one seasonal application occurring on treated fields. For methyl bromide structural fumigation treatments, chronic exposure may occur due to a potentially high amount of releases which may occur from treated structures. Upper-bound chronic RQs are presented for indirect effect to mammalian prey based on the comparison of the upper 90th percentile peak (hourly) PERFUM air EECs to a reproductive mammalian chronic toxicological study (MRID 00160477). Lower-bound chronic RQs calculated for indirect effects to mammalian prey based on the comparison of the maximum value from ambient air monitoring concentrations in California to the same toxicological endpoint as calculated from upper-bound RQs. Upper-bound chronic RQs are very high ranging between 0.13 – 20.40, and the lower-bound chronic RQs is 0.01. Although the upper-bound RQs exceed the LOC by a wide margin, the significant departure of the ambient air monitoring value two orders of magnitude below the LOC concentration suggests that the upper bound RQs based on peak air EECs are discountable. The calculation of the upper-bound RQ reflects very high conservatism as it is based on a one-hour estimated concentration. The ambient air monitoring data at a 24-hour average concentration for monitoring data in a targeted air shed reflects a more relevant if not conservative chronic exposure concentration in air. Furthermore, the reproductive rat study may represent a conservative endpoint value considering the repetitive 6-hour exposure duration over 11 weeks in the study. It is not anticipated that the CTS mammalian prey would be exposed to this level of continuous exposure considering that structural methyl bromide treatments mainly encompass post-harvesting seasons. Therefore, chronic exposure from releases occurring after structural treatments is discounted considering the high level of conservativeness inherent in the upper-bound RQs, and more realistic but still conservative lower-bound RQs.

Risk is also evaluated for terrestrial invertebrates from both soil and structural applications of methyl bromide. Acceptable toxicity data for terrestrial invertebrates were not available to estimate RQs for terrestrial invertebrate prey of the CTS. Labeled uses of methyl bromide include terrestrial invertebrates as target pests and efficacy data support the presumed toxicity of methyl bromide to soil invertebrates. Therefore, based on these lines of evidence, risk to terrestrial invertebrates is presumed.

In addition to indirect reduction in prey risk determinations, the results from the mammal assessment are also used to evaluate changes in availability of mammal burrows for shelter for the CTS. Based on LOC exceedances for structural uses, adverse effects on the availability of mammal burrows is expected. However, no adverse effects are expected resulting from soil uses as there are no LOC exceedances noted.

Indirect effects to the terrestrial CTS also include effects to terrestrial plants that may contribute to the alteration of habitat. There is the potential for indirect effects based on the uncertainty due to absence of data. Methyl bromide also has a phytotoxic mode of actions leading to a presumption of risk for terrestrial plants for uses of methyl bromide applied as soil and structural fumigants.

Effects to Endpoints used to Assess Critical Habitat

The CTS has designated critical habitat and the results from the indirect effects assessment are used to evaluate the effect of methyl bromide on critical habitat. A "Habitat Modification" determination is made for reduction in prey as well as alteration of the habitat as described above for the indirect effects determination.

Table 7-1. Effects Determination Summary for Effects of methyl bromide on the CTS

Species	Effects Determination	Basis for Determination
California Tiger Salamander (*Ambystoma californiense*)	**May Affect and Likely to Adversely Affect (LAA)**	**Potential for Direct Effects** *Terrestrial phase:* Using birds as a surrogate for the terrestrial-phase CTS, the potential for direct effects to the CTS is expected labeled methyl bromide uses. Specifically, the avian acute inhalation RQ for structural tile, timber, and space fumigant applications (**0.11) marginally exceed the acute listed species** LOC of 0.1. A probit analysis at this RQ resulted in an estimated chance of individual effect of ~1 in 6.75. A spatial analysis indicates overlap between potential methyl bromide application sites and CTS occurrence locations. **Potential for Indirect Effects** ***Terrestrial prey items, riparian habitat*** The diet of the terrestrial CTS includes frogs, small mammals, and terrestrial invertebrates. As described under direct effects to the CTS, the RQ of 0.11 calculated for birds (used as a surrogate for terrestrial phase CTS) exceeded the acute listed species LOC of 0.1 for structural tile, timber, and space fumigant applications. A probit analysis at this RQ resulted in an estimated chance of an individual effect of ~1 in 6.75. Risk to the terrestrial-phase CTS based on reduction in prey resulted in RQs exceeding the LOC of 0.1 for structural food and commodity uses, as well as tile, timber and space uses. RQs for food and commodity uses based on refined PERFUM modeling ranged from <0.01 to 0.19. RQs for structural

Table 7-1. Effects Determination Summary for Effects of methyl bromide on the CTS		
Species	**Effects Determination**	**Basis for Determination**
		tile, timber and space uses based on refined PERFUM modeling ranged from <0.01 to 0.32. The evaluation of mammal risk is also used to evaluate risk from reduction in mammal burrows used for shelter. There is a potential indirect effect from alteration in the environment as reduction in shelter based on the refined PERFUM modeling indicating LOC exceedance. Risk to terrestrial invertebrates from soil and structural applications could not be determined quantitatively using RQs because acute toxicity endpoints were not available for terrestrial invertebrates. Given that methyl bromide is used as a nematicide, it is reasonable to presume risk to terrestrial invertebrate species residing in or near application sites. Risks to terrestrial plants from soil and structural applications of methyl bromide could not be determined quantitatively using RQs because toxicity endpoints for terrestrial plants were not available. However, based on the known herbicidal properties of methyl bromide and one reported incident involving plants, risk to terrestrial plants is presumed. A spatial analysis indicates overlap between potential methyl bromide application sites and the occurrence of CTS prey species.

Table 7-2. Effects Determination Summary for the Critical Habitat Impact Analysis.		
Designated Critical Habitat for:	**Effects Determination**	**Basis for Determination**
CTS (all 3 DPSs)	Habitat Modification	Habitat modification mediated by reduction in prey is described under indirect effects for amphibians and terrestrial invertebrates. Habitat modification is indicated based on potential reduction in prey species for the CTS (amphibians and terrestrial invertebrates). The potential for alteration in upland habitat is indicated due to presumed impacts on terrestrial plants between the pond and the mammal burrows. Based on the absence of data and mode of action, methyl bromide may indirectly affect the CTS (all 3 DPSs) and/or affect their designated critical habitat by changing the composition of the terrestrial plant community.

Table 7-3. Use specific summary of the potential for adverse effects to terrestrial taxa.						
Potential for Effects to Identified Taxa Found in the Terrestrial Environment						
Uses and Montreal Protocol Designation	**Application Method**	**Small Mammals[2]**	**Small Birds**	**Invertebrates[3]**	**Dicots[4]**	**Monocots[4]**
Orchard Replant (CUE)	Deep Shank	No	No	Yes	Yes	Yes
Peppers (CUE)	Shallow Shank (Broadcast and Bedded) and Hot Gas Tarped Chemigation	No	No	Yes	Yes	Yes
Eggplant (CUE)	Shallow Shank (Broadcast and Bedded) and Hot Gas Tarped Chemigation					
Cucurbits (CUE)	Shallow Shank (Broadcast and Bedded) and Hot Gas Tarped Chemigation					
Forestry Nursery (CUE)	Shallow Shank (Broadcast and Bedded) and Hot Gas Tarped Chemigation					

Table 7-3. Use specific summary of the potential for adverse effects to terrestrial taxa.						
Potential for Effects to Identified Taxa Found in the Terrestrial Environment						
Uses and Montreal Protocol Designation	**Application Method**	**Small Mammals[2]**	**Small Birds**	**Invertebrates[3]**	**Dicots[4]**	**Monocots[4]**
Nursey and Ornamentals (CUE)	Shallow Shank (Broadcast and Bedded) and Hot Gas Tarped Chemigation	No	No	Yes	Yes	Yes
Strawberries (CUE)	Shallow Shank (Broadcast and Bedded) and Hot Gas Tarped Chemigation					
Berries (SP)	Shallow Shank (Broadcast and Bedded) and Hot Gas Tarped Chemigation					
Sweet Potatoes (CUE)	Shallow Shank (Broadcast and Bedded) and Hot Gas Tarped Chemigation					
Tomatoes (CUE)	Shallow Shank (Broadcast and Bedded) and Hot Gas Tarped Chemigation					
Golf Courses and Athletic Fields (SP)	Shallow Shank (Broadcast and Bedded) and Hot Gas Tarped Chemigation					
Post Harvest Indoor Food Fumigation (QPS)	Structural	Yes	No	Yes	Yes	Yes
Commodity Indoor Fumigation (QPS)	Structural	Yes	No	Yes	Yes	Yes
Timber and Tile Indoor Fumigation (CUE)	Structural	Yes	Yes	Yes	Yes	Yes
Space Fumigation (SP)	Structural	Yes	Yes	Yes	Yes	Yes

[1]Montreal Protocol Designation Codes: CUE – Critical Use Exemption; QPS – Quarantine and Pre-Shipment Exemption; SP – Stockpile

[2,]A yes in this column indicates a potential for direct and indirect effects to CTS-CC, CTS-SC, and CTS-SB

[3]A yes in this column indicates a potential for indirect effects to CTS-CC, CTS-SC, and CTS-SB
[4]A yes in this column indicates a potential for indirect effects to CTS-CC, CTS-SC, CTS-SB. Risk is evaluated based on the absence of data for and known phytotoxic properties

Based on the conclusions of this assessment, a formal consultation with the U. S. Fish and Wildlife Service under Section 7 of the Endangered Species Act should be initiated.

When evaluating the significance of this risk assessment's direct/indirect and adverse habitat modification effects determinations, it is important to note that pesticide exposures and predicted risks to the listed species and its resources (*i.e*., food and habitat) are not expected to be uniform across the action area. In fact, given the assumptions of downstream transport (*i.e*., attenuation with distance), pesticide exposure and associated risks to the species and its resources are expected to decrease with increasing distance away from the treated field or site of application. Evaluation of the implication of this non-uniform distribution of risk to the species would require information and assessment techniques that are not currently available.

When evaluating the significance of this risk assessment's direct/indirect and adverse habitat modification effects determinations, it is important to note that pesticide exposures and predicted risks to the species and its resources (*i.e*., food and habitat) are not expected to be uniform across the action area. In fact, given the assumptions of drift and downstream transport (*i.e*., attenuation with distance), pesticide exposure and associated risks to the species and its resources are expected to decrease with increasing distance away from the treated field or site of application. Evaluation of the implication of this non-uniform distribution of risk to the species would require information and assessment techniques that are not currently available. Examples of such information and methodology required for this type of analysis would include the following:

- Enhanced information on the density and distribution of CTS life stages within the action area and/or applicable designated critical habitat. This information would allow for quantitative extrapolation of the present risk assessment's predictions of individual effects to the proportion of the population extant within geographical areas where those effects are predicted. Furthermore, such population information would allow for a more comprehensive evaluation of the significance of potential resource impairment to individuals of the assessed species.
- Quantitative information on prey base requirements for the assessed species. While existing information provides a preliminary picture of the types of food sources utilized by the assessed species, it does not establish minimal requirements to sustain healthy individuals at varying life stages. Such information could be used to establish biologically relevant thresholds of effects on the prey base, and ultimately establish geographical limits to those effects. This information could be used together with the density data discussed above to characterize the likelihood of adverse effects to individuals.
- Information on population responses of prey base organisms to the pesticide. Currently, methodologies are limited to predicting exposures and likely levels of direct mortality, growth or reproductive impairment immediately following exposure to the pesticide. The degree to which repeated exposure events and the inherent demographic characteristics of the prey population play into the extent to

which prey resources may recover is not predictable. An enhanced understanding of long-term prey responses to pesticide exposure would allow for a more refined determination of the magnitude and duration of resource impairment, and together with the information described above, a more complete prediction of effects to individual species and potential modification to critical habitat.

8. References

A bibliography of ECOTOX references, identified by the letter E followed by a number, is located in **Appendix H**.

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DataBases and Models

The California Department of Pesticide Regulation's Pesticide Use Reporting database provides a census of pesticide applications in the state. See http://www.cdpr.ca.gov/docs/pur/purmain.htm.

Pesticides in Groundwater DataBase (PGWDB)

http://www.epa.gov/oppefed1/models/water

http://www.epa.gov/scram001/tt22htm#isc

Doane (www.doane.com; the full dataset is not provided due to its proprietary nature)

United States Depart of Agriculture (USDA), National Agricultural Statistics Service (NASS) Chemical Use Reports provide summary pesticide usage statistics for select agricultural use sites by chemical, crop and state. See http://www.usda.gov/nass/pubs/estindx1.htm#agchem.

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Habitat Maps

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