Water Quality Criteria Report for Thiamethoxam

Phase III: Application of the pesticide water quality criteria methodology

Prepared for the Central Coast Regional Water Quality Control Board

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List of acronyms and abbreviations

ACR	Acute-to-Chronic Ratio
AF	Assessment factor
APHA	American Public Health Association
ASTM	American Society for Testing and Materials
BAF	Bioaccumulation Factor
BCF	Bioconcentration Factor
BMF	Biomagnification Factor
CAS	Chemical Abstract Service
CDFW	California Department of Fish and Wildlife
CSIRO	Commonwealth Scientific and Industrial Research Organization, Australia
CVRWQCB	Central Valley Regional Water Quality Control Board
CCRWQCB	Central Coast Regional Water Quality Control Board
DPR	Department of Pesticide Regulation
EC_x	Concentration that affects x% of exposed organisms
FDA	Food and Drug Administration
FT	Flow-through test
IC_x	Inhibition concentration; concentration causing *x*% inhibition
ICE	Interspecies Correlation Estimation
IUPAC	International Union of Pure and Applied Chemistry
K	Interaction Coefficient
K_H	Henry's law constant
K_{ow}	Octanol-Water partition coefficient
K_p or K_d	Solid-Water partition coefficient
LC_x	Concentration lethal to *x*% of exposed organisms
LD_x	Dose lethal to *x*% of exposed organisms
LL	Less relevant, Less reliable study
LOEC	Lowest-Observed Effect Concentration
LR	Less relevant, Reliable study
MATC	Maximum Acceptable Toxicant Concentration
MDL	Method Detection Limit
N	Not relevant or Not reliable study
n/a	Not applicable
NOEC	No-Observed Effect Concentration
NR	Not reported
OECD	Organization for Economic Co-operation and Development
pK_a	Acid dissociation constant
RL	Relevant, Less reliable study
RR	Relevant and Reliable study
S	Static test
SMACR	Species Mean Acute-to-Chronic Ratio
SMAV	Species Mean Acute Value
SR	Static renewal test

SSD	Species Sensitivity Distribution
TES	Threatened and Endangered Species
US	United States
USEPA	United States Environmental Protection Agency

Introduction

1.1 Introduction to thiamethoxam

This criteria report for thiamethoxam describes, section by section, the procedures used to derive aquatic toxicity criteria according to the UC Davis methodology (see Section 1.2). References are included to specific sections of the methodology so that the reader can refer to the report for further details.

In the environment, thiamethoxam can transform into several degradates (Figure 2). Degradates are formed primarily through hydrolysis. Aerobic soil metabolism and aqueous photolysis is very slow. The primary degradate of thiamethoxam is the neonicotinoid clothianidin, which is primarily formed via aerobic soil metabolism. Toxicity data for clothianidin is included in a separate Water Quality Criteria Report. This criteria report does not include toxicity data for other thiamethoxam degradates because none were available.

1.2 Method background

A methodology for deriving freshwater water quality criteria for the protection of aquatic life was developed by the University of California - Davis (TenBrook et al. 2009a). The need for a methodology was identified by the California Central Valley Regional Water Quality Control Board (CVRWQCB 2006) and findings from a review of existing methodologies (TenBrook & Tjeerdema 2006, TenBrook et al. 2009b). The UC Davis methodology has been used to derive aquatic life criteria for several pesticides of particular concern in the Sacramento River and San Joaquin River watersheds. It is now being used to derive aquatic life criteria for the watersheds under the jurisdiction of the Central Coast Regional Water Quality Control Board (CCRWQCB). The methodology report (TenBrook et al. 2009a) contains an introduction (Chapter 1); the rationale of the selection of specific methods (Chapter 2); detailed procedure for criteria derivation (Chapter 3); and a criteria report for a specific pesticide (Chapter 4). In 2014 a sediment methodology was developed by University of California - Davis (Fojut et al. 2014), which contains some updated parameters that are relevant for calculating freshwater water quality criteria. These include Assessment Factor and Acute-to-Chronic Ratio parameters (AF and ACR, respectively). Sections 3-3.3 (AF) and 3-4.2.3 (ACR) of the aquatic method state that these parameters can be recalculated and updated if additional relevant data become available (TenBrook et al. 2009a). Unless otherwise specified, mentions of the methodology refer to the aquatic method (TenBrook et al. 2009a). The sediment method will be specifically referenced for clarity (Fojut et al. 2014).

1.3 Interim Criteria

The toxicity data sets for the neonicotinoids thiamethoxam and clothianidin both posed challenges for deriving aquatic life criteria using the UC Davis Method. These

pesticides appear to be toxic to a narrower range of organisms compared to most other broad spectrum insecticides that have been evaluated using the UC Davis Method, as demonstrated by non-definitive or censored toxicity values for a number of key taxa from otherwise relevant and reliable studies. At a minimum, the UC Davis Method requires an acceptable definitive toxicity value from the family Daphniidae in the genus *Daphnia, Ceriodaphnia*, or *Simocephalus* to calculate an acute criterion. For thiamethoxam, acute tests were performed on *Daphnia magna* and *Ceriodaphnia dubia*, but the tests did not result in definitive toxicity values for these species. The concentrations tested in these studies were well below solubility because thiamethoxam and clothianidin are very water soluble, so it may be possible to determine definitive toxicity values for these species, but they would likely be well-above environmentally relevant concentrations. Two other key taxa used in the UC Davis Method – a warmwater fish and a species in the family Salmonidae – also were tested, but the tests did not result in definitive toxicity values because the species were so tolerant of thiamethoxam and clothianidin.

Because the thiamethoxam and clothianidin datasets were both rich in other sensitive invertebrates, and the taxa missing from the final datasets appear to be very insensitive to these pesticides, the authors derived what are termed Interim Acute and Chronic Criteria for these pesticides. The term “interim” was chosen because if definitive toxicity data became available for several key taxa, it would be possible to calculate definitive aquatic life criteria for these pesticides and to denote that the calculation of these criteria deviates from the existing UC Davis Method. Interim Acute and Chronic Criteria were derived in recognition that performing additional acute toxicity tests with the required taxa lacking definitive toxicity values aimed at resulting in definitive, rather than censored (>), toxicity values may not be a good use of resources because it has already been demonstrated that these species are not sensitive to these pesticides at environmentally relevant concentrations.

The Interim Acute Criteria were derived using the AF procedure, in which the lowest toxicity value in the final acute dataset was divided by a factor and the magnitude of the factor is based on the number of toxicity values in the dataset that fulfilled the five taxa requirements of the UC Davis Method. To derive the Interim Acute Criteria for these two pesticides, the AF was chosen based on having all five required taxa in the dataset, even though the toxicity values for three of the five required taxa are censored values; this approach deviates from the UC Davis Method guidance in two ways. The two deviations are that (1) censored toxicity values are excluded according to the UC Davis Method and (2) acute criteria are not derived without a definitive toxicity value from the family Daphniidae in the genus *Daphnia, Ceriodaphnia*, or *Simocephalus*. There are two reasons a toxicity value from the family Daphniidae in the genus *Daphnia, Ceriodaphnia*, or *Simocephalus* is required to calculate an acute criterion by the UC Davis Method: (1) testing a daphnid is always required when registering a pesticide with the US EPA, so it was expected that data for this taxon would always be available and (2) daphnids are invertebrates, which are expected to be relatively more sensitive than the other taxa required to register a pesticide (typically fish species). The goal in requiring a daphnid toxicity value is to avoid underestimating the toxicity of the pesticide to aquatic eosystems by only using data for less sensitive species. It also gave a point of reference for calculating the AFs used to calculate criteria when the five

required taxa for calculating the acute criterion using a species sensitivity distribution are not all available. In the case of thiamethoxam and clothianidin, daphnids and fish are relatively insensitive, but the acute datasets demonstrate that there are many invertebrates that are sensitive to thiamethoxam and clothianidin toxicity. Thus, deriving Interim Criteria for these pesticides without definitive daphnid data is unlikely to underestimate the toxicity of them on aquatic ecosystems. Conversely, excluding the nondefinitive data and using an AF based on only two of the five required taxa would likely result in overly coservative criteria because the missing taxa are all very insensitive to these pesticides. The UC Davis Method was developed with a goal of being able to derive water quality criteria for pestcides even when only small datasets are available but did not consider how these requirements may affect criteria calculation for pesticides that have a more narrow spectrum of toxicity. The Interim Acute and Chronic Criteria for thiamethoxam and clothianidin provide one potential procedure for deriving criteria for pesticides with limited toxicity to some of the required taxa.

The Interim Chronic Criteria for thiamethoxam and clothinidin were derived by using an ACR following the guidance of the UC Davis Method.

Statistical uncertainty cannot be directly quantified when criteria are calculated using assessment factors and ACRs. However, because these are Interim Criteria, the authors chose to present additional values to provide a lower and upper range of levels that may also be protective of aquatic ecosystems. The lower acute limits were calculated using the Assessment Factor procedure of the UC Davis Method based on only the number of definitive toxicity values in the final acute datasets, which was two of the five required taxa for both pesticides. The upper acute limits were calculated by dividing the lowest toxicity value in the acute dataset by a factor of 2, which is how US EPA Acute Aquatic Life Benchmarks are derived. The lower and upper chronic limits were calculated using the ACR procedure with the respective acute values.

These Interim Criteria were derived with the goal of providing guidance to environmental managers on protective levels of thiamethoxam and clothianidin. In addition, it is also a proposal for an alternate procedure that may be appropriate to add to the UC Davis Method for deriving criteria with a narrow spectrum of toxicity. The main aspect of this new procedure is to allow the use of censored data in deriving acute criteria when the toxicity level is above the highest concentration tested, the highest concentration is well-above concentrations detected in the environment or is approaching or exceeding solubility, and the test is otherwise relevant and reliable as scored in the UC Davis Method. Censored data are only proposed to be used with the AF procedure for deriving acute criteria because in this procedure they serve to fulfill taxa requirements, but the censored values themselves are not used for calculations. They demonstrate that sensitive taxa are not being overlooked due to a lack of testing, but that some taxa were tested and are particularly insensitive to the pesticide of interest. Censored data are not proposed to be used in species sensitivity distributions because the values themselves are not meaningful and should not be combined with uncensored data in a statistical distribution. Censored data may be off by orders of magnitude compared to the true toxic level for that species, and such different values could significantly affect the fit of the statistical distribution, thus significantly affecting the resulting criteria. The AF procedure is a more appropriate use for censored data, as

it is intended to be a method to derive criteria when insufficient information is available to fit a species sensitivity distribution, as is the case when censored data are the only data available for a given taxa.

Basic information

Thiamethoxam is a nitroguanidine-substituted neonicotinoid insecticide that is applied to agricultural crops, soils, and seeds as well as residential and institutional turf, buildings, and ornamental/landscaping plants (USEPA 2017a). It is a systemic insecticide that translocates throughout living plant tissue via xylem and phloem so that insects may come into contact with the insecticide when affected tissue is bitten, chewed, or otherwise consumed. Thimethoxam is also used in the formulation of wood preservatives.

Chemical: Thiamethoxam (Fig. 1)
Synonym: CGA-293343
CAS: 3-((2-chloro-5-thiazolyl)methyl)tetrahydro-5-methyl-N-nitro-4H-1,3,5-oxadiazin-4-imine
CAS Number: 153719-23-4
USEPA PC Code: 060109
CA DPR Chem Code: 5598
IUPAC: 3-(2-Chloro-thiazolyl-5-ylmethyl)-5-methyl-[1,3,5]oxadiazinan-4-ylidene-N-nitroamine
Chemical Formula: $C_8H_{10}ClN_5O_3S$

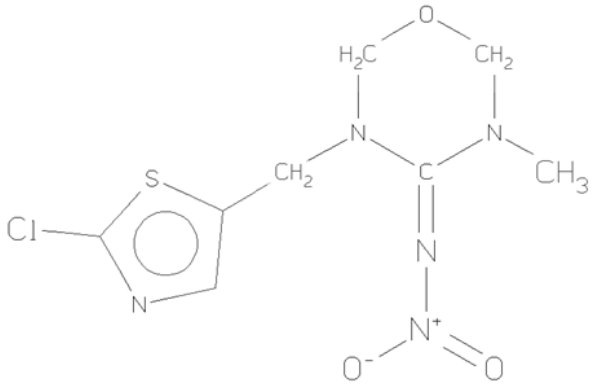

Figure 1 Structure of thiamethoxam
(BioByte 2015)

Trade names: Actara, Adage, Agita, Avicta, Caravan, Centric, Clariva, Cruiser, Cruisermaxx, Demand Duo, Durivo, Dyna-Shield, Endigo, Flagship, Four-Way Vap, Helix, Infiniguard, Meridian, Minecto, Optiguard, Platinum, Quindigo, Solvigo, Spinner, Tandem, Voliam Flexi, Warden, Xamox (USEPA 2020a, Eillis v. Bradbury 2013)

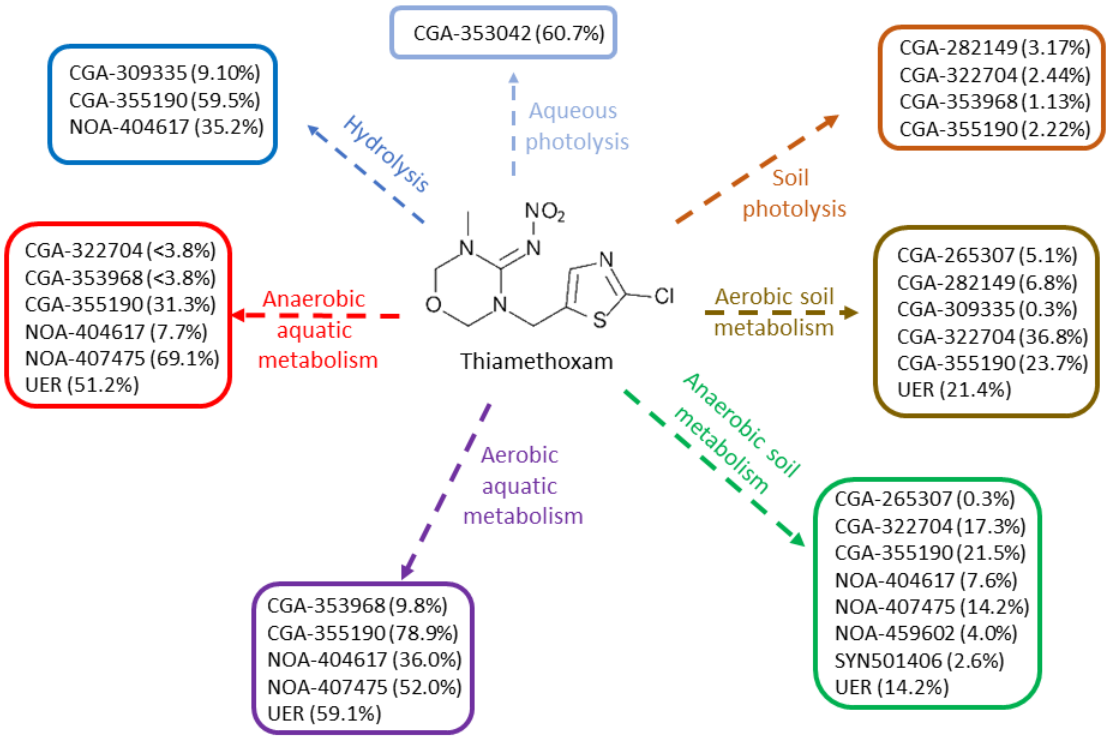

Figure 2 Degradation products of thiamethoxam
CGA-322704 is clothianidin; % maximum formation in parenteses
(Adapted from USEPA 2017a)

Physical-chemical data, Bioconcentration, and Fate

Molecular Weight
291.7 g/mole (PPDB 2016)

Density
1.57 g/mL (PPDB 2016, Lail 1998)

Water Solubility
4100 mg/L at unknown temperature (Stulz 1995)
4100 mg/L at 25ºC (Lail 1998)
4100 mg/L at unknown temperature (MacBean 2010)
4100 mg/L at unknown temperature (PPDB 2016)
Geometric mean: 4100 mg/L

Melting Point
139.1°C (Lail 1998)
163.65°C (EPI Suite, USEPA 2015)
139.1°C (PPDB 2016)

Geometric mean: 146.8°C

Vapor Pressure

$6.6x10^{-12}$ mPa at 25°C	(Lail 1998)
$6.6x10^{-13}$ mPa at unknown temperature	(Lail 1998)
$6.6x10^{-13}$ mPa at unknown temperature	(MacBean 2010)
$5.43x10^{-2}$ mPa at unknown temperature	(EPI Suite, USEPA 2015)
$5.43x10^{-2}$ mPa at 25°C, grain method	(EPI Suite, USEPA 2015)
$6.6x10^{-6}$ mPa at 20°C	(PPDB 2016)

Geometric mean: $6.2x10^{-8}$ mPa = 0.062 µPa

pKa

No dissociation	(Lail 1998)
No dissociation	(PPDB 2016)

Henry's constant (K_H)

$4.7x10^{-10}$ Pa m^3 mol^{-1} at unknown temperature	(Lail 1998)
$4.7x10^{-10}$ Pa m^3 mol^{-1} at unknown temperature	(National Library of Medicine 2019)
$6.96x10^{-10}$ Pa m^3 mol^{-1} at unknown temperature	(EPI Suite, USEPA 2015)
$4.7x10^{-10}$ Pa m^3 mol^{-1} at unknown temperature	(USEPA 2017a)

Geometric mean: $5.2x10^{-10}$ Pa m^3 mol^{-1}

Organic Carbon Sorption Partition Coefficients (log K_{oc})

2.425	(EPI Suite, USEPA 2015)
1.365	(EPI Suite, USEPA 2015)
1.85	(Concha 1998)
2.026	(Peters 2001)
1.680	(Peters 2000)

Geometric mean: 1.84
Arithmetic mean: 1.87

Log K_{ow}

-0.13	(Lail 1998)
-0.13	(PPDB 2016)
-0.10	(EPI Suite, USEPA 2015)
-0.04	(BioByte 2015)

Arithmetic mean: -0.10

Bioconcentration Factor

Table 1 Bioconcetration factors (BCF) for thiamethoxam, NR is for not reported

Species	BCF	Exposure	Reference
NR	"Low risk" no value because LogP<3	NR	PPDB 2016
NR	3.162	NR	EPI Suite, USEPA 2015 (regression method)
NR	1.159	NR	EPI Suite, USEPA 2015 (Arnot-Gobas method)
NR	3 cacluated from K_{OW}=-0.13	NR	National Library of Medicine 2019

BCF geometric mean: 2

Environmental Fate

Table 2 Thiamethoxam hydrolysis and photolysis and other degradation. NR: not reported

Reaction type	Half-life (d or y)	Water or soil	Temp (°C)	pH	Reference
Hydrolysis	1,114.0 d	Buffer solution	20	7	Clark 1998
Hydrolysis	853.6 d	Buffer solution	22	7	Clark 1998
Hydrolysis	7.3 d	Buffer solution	20	9	Clark 1998
Hydrolysis	5.8 d	Buffer solution	22	9	Clark 1998
Hydrolysis	1,253.3 d	Buffer solution	20	7	Lowery 1997
Hydrolysis	986.9 d	Buffer solution	22	7	Lowery 1997
Hydrolysis	15.6 d	Buffer solution	20	9	Lowery 1997
Hydrolysis	12.2 d	Buffer solution	22	9	Lowery 1997
Hydrolysis	595 d	Aqueous buffer solution	25	5	Sparrow 1997a
Hydrolysis	2.56 y	Aqueous buffer solution	25	5	Schwartz 1998

Reaction type	Half-life (d or y)	Water or soil	Temp (°C)	pH	Reference
Aqueous Photolysis	2.29 d	Aqueous buffer solution	25	5	Sparrow 1997a
Aqueous Photolysis	3.08 d	Aqueous buffer solution	25	5	Schwartz 1998
Biodegradation (aerobic)	193d	Sandy clay loam	25	NR	Shepler 1998
Biodegradation (aerobic)	161 d	Loam	25	NR	Shepler 1998
Biodegradation (aerobic)	289 d	Sandy loam	25	NR	Shepler 1998
Biodegradation (aerobic)	124 d	Sand	25	NR	Shepler 1998
Biodegradation (aerobic)	178	Niagara loam	25	NR	Shepler 1998
Biodegradation (aerobic)	330 d	Silty clay loam	25	NR	Shepler 1998
Biodegradation (aerobic)	47 d	Sandy loam (irradiated light conditions)	25	NR	Sparrow 1997b
Biodegradation (aerobic)	113 d	Sandy loam (non-irradiated dark conditions)	25	NR	Sparrow 1997b
Biodegradation (aerobic)	54 d	Sandy loam (irradiated light conditions)	25	NR	Sparrow 1997c
Biodegradation (aerobic)	124 d	Sandy loam (non-irradiated dark conditions)	25	NR	Sparrow 1997c

Human and wildlife dietary values

There are no FDA action levels for thiamethoxam in food (USFDA 2000) and there are no EPA pesticide tolerances set for any aquatic species (USEPA 2012).

Wildlife LC_{50} values (dietary) for animals with significant food sources in water

The US EPA Proposed Interim Registration Review Decision for Clothianidin and Thiamethoxam reports an acute oral LC_{50} value of 576 mg/kg for mallard duck (USEPA 2020b).

An acute oral study of *Anas platyrhynchos* by Johnson 1996a reported an LC_{50} value of 576 mg/kg 14 days after a single exposure. Johnson 1996b reported an acute dietary LC_{50} value of >5200 mg/kg three days following a continuous five-day exposure period. If additional highly rated measured data for mallard duck become available in the future, they should be examined to determine the potential risk to wildlife.

Wildlife dietary NOEC values for animals with significant food sources in water

The US EPA Proposed Interim Registration Review Decision for Clothianidin and Thiamethoxam reports a chronic reproduction NOEC value of 300 mg/kg for mallard duck (USEPA 2020b).

A 27-week dietary exposure study on the reproductive effects on mallard duck (*A. platyrhynchos*) resulted in a NOEC value of 300 mg/kg according to Brewer 1998. An acute dietary study of *A. platyrhynchos* by Johnson 1996b reported a NOEC for bodyweight gain of 163 mg/kg three days following a continuous five-day exposure period. No other NOEC data was available for wildlife species with significant food sources in water during the present report preparation. If additional highly rated measured data for mallard duck become available in the future, they should be examined to determine the potential risk to wildlife.

Ecotoxicity data

Approximately 50 original studies on the effects of thiamethoxam on aquatic life were identified and reviewed. In the review process, many parameters were rated for documentation and acceptability for each study, including, but not limited to: organism source and care, control description and response, chemical purity, concentrations tested, water quality conditions, and statistical methods (see Tables 3.6, 3.7, 3.8 in TenBrook et al. 2009a). Single-species effects studies that were rated as relevant (R) or less relevant (L) according to the method (Table 3.6) were summarized in data summary sheets. Information in these summaries was used to evaluate each study for reliability, using the rating systems described in the methodology (Tables 3.7 and 3.8, section 3-2.2, TenBrook et al. 2009a), to give a reliability rating of reliable (R), less reliable (L), or not reliable (N).

Studies of the effects of thiamethoxam on mallard ducks were rated for reliability using the terrestrial wildlife evaluation. Mallard studies rated as reliable (R) or less reliable (L) were used to consider bioaccumulation. Two studies for mallard duck rating R were located in the literature and are summarized in Section 4.

Copies of completed summaries for all aquatic studies are included in the Appendix of this report. All data rated as acceptable (RR) or supplemental (RL, LR, LL) for criteria derivation are summarized in Tables 3 - 10, found at the end of this report.

Acceptable studies rated as RR are used for numeric criteria derivation, while supplemental studies rated as RL, LR or LL are used for evaluation of the criteria to check that they are protective of particularly sensitive species and threatened and endangered species. These considerations are reviewed in section 10.1 and 10.3 of this report, respectively. Studies that were rated not relevant (N) or not reliable (RN or LN) were not used for criteria derivation.

Eight mesocosm studies were identified and reviewed. One study was rated L and seven studies rated R. The studies are listed in Appendices A3 and A6. They are used as supporting data in Section 10.2 to evaluate the derived criteria to ensure that they are protective of ecosystems.

Evaluation of aquatic animal data

Using the data evaluation criteria (section 3-2.2, TenBrook et al. 2009a), seven acute studies yielding 40 toxicity values from 20 taxa were judged reliable and relevant for acute criterion derivation (Tables 3-4). Twenty-eight acute toxicity animal values for 18 taxa from ten studies were rated RL, LL, or LR and were used as supplemental information for evaluation of the derived acute criteria in the Sensitive Species section 10.1 (Table 5). Ten chronic animal toxicity values from two studies were rated RR (Tables 7-8). Thirty-nine chronic toxicity animal values from 13 studies were rated RL, LL, or LR (Table 10).

Evaluation of aquatic plant data

All plant studies were considered chronic because the typical endpoints of growth or reproduction are inherently chronic. One study yielding one plant toxicity value was rated RR (Table 6).

Plant studies are more difficult to interpret than animal data because a variety of endpoints may be used, but the significance of each one is less clear. In this methodology, only endpoints of growth or reproduction (measured by biomass) and tests lasting at least 24-h had the potential to be rated highly and used for criteria calculation, which is in accordance with standard methods (ASTM 2007a, 2007b; USEPA 1996). The plant studies were rated for quality using the data evaluation criteria described in the methodology (section 3-2.2, TenBrook et al. 2009a).

Data reduction

Multiple toxicity values for thiamethoxam for the same species were reduced down to one species mean acute value (SMAV) or one species mean chronic value (SMCV) according to procedures described in the methodology (section 3-2.4, TenBrook et al. 2009a). Nineteen toxicity values from six studies were reduced from the final acute data set (Table 4). Seven toxicity values from two studies were reduced from the final chronic data set (Table 8).

Acute criterion calculation

The acute criterion is calculated with acute animal toxicity data only, because plant toxicity tests are always considered chronic (section 3-2.1.1.1, TenBrook et al. 2009a). A final acute criterion could not be calculated for thiamethoxam due to a lack of highly rated studies that meet the methodology requirements. Section 3-3.3 requires that at least one of the available, acceptable data must be from the family Daphniidae in the genus *Daphnia, Ceriodaphnia*, or *Simocephalus*, or a criterion cannot be calculated. The highly rated thiamethoxam dataset does not contain values for any daphnid species. Therefore, a final acute criterion could not be calculated.

As invertebrates, daphnids are generally a relatively sensitive species to aquatic pesticide exposures compared to vertebrates, and the USEPA requires data from this family for pesticide registration in order to ensure adequate protection of invertebrates. The UC Davis method requires a daphnid value for the same reason. However, species from the Daphnidae family and fish have been shown to be relatively insensitive to neonicotinoids, such as thiamethoxam. These species were tested as part of the USPEA registration process but resulted in non-definitive values (> or <) that are not used in the UC Davis method calculations. However, it is reasonable to calculate an interim acute criterion for thiamethoxam, despite the lack of such data because there are other sensitive species in the dataset that will ensure protection of species that are most sensitive to this pesticide. Further discussion on the rationale for deriving an interim acute criterion is given in section 1.3 of this report.

To provide information to environmental decision makers, an interim acute criterion was calculated for thiamethoxam utilizing available acute animal toxicity data. Since acceptable acute toxicity values were not available from the five required taxa for a species sensitivity distribution, an interim acute criterion was calculated using the AF procedure (section 3-3.3, TenBrook et al. 2009a). The acute dataset was missing definitive toxicity values for a daphnid, salmonind, and a warm water fish. Thiamethoxam is an organic pesticide, and the AFs given in the methodology (Table 3.13, TenBrook et al. 2009a) are the most specific AFs available for organic pesticides. The methodology points out that the AFs are limited in that they are based on organochlorine, organophosphate, and pyrethroid pesticides, which are neurotoxic insecticides. Thiamethoxam is a neurotoxic insecticide, thus, it is reasonable to use the AF procedure for thiamethoxam.

Sections 3-3.3 of the aquatic method state that AFs can be recalculated and updated if additional relevant data become available (TenBrook et al. 2009a). The AFs for the aquatic criteria calculations were updated in 2014 after additional data became available for recalculation. These updated AF values are included in the sediment method (Fojut et al. 2014). The AFs given in the methodologies will be used for clothianidin with the understanding that AFs based on measured pesticide toxicity data are likely more accurate than choosing an arbitrary AF. The methodology points out that AFs are recognized as a conservative approach for dealing with uncertainty in assessing risks posed by chemicals (section 2-3.2, TenBrook et al. 2009a). Using an AF to calculate a criterion always involves a high degree of uncertainty and there is potential for under- or over-protection, which is strongly dependent on the representation of sensitive species in the available data set. The methodology instructs that the derived criterion should be compared to all available ecotoxicity data to ensure that it will be protective of all species (section 3-6.0, TenBrook et al. 2009a).

An AF was used to derive an interim criterion, by dividing the lowest value in the acute dataset by a predetermined factor. The factors were first given in Table 3.13 of the water method and were then updated in the sediment method in Table 18. Definitive toxicity values were available for two (benthic crustacean and insect) of the five required taxa. Censored toxicity values were available for the remaining three required taxa (daphnid, warmwater fish, and Salmonidae) and each one would be an acceptable test except for the fact that the species was insensitive to the tested concentrations and thus a definitive toxicity value could not be calculated.

The interim acute value was calculated using the AF of 5.1, which is used when all five required taxa are available in the dataset, as discussed in section 1.3. The acute value calculated using the AF represents an estimate of the median 5th percentile value of the SSD, which is the recommended acute value. The recommended acute value is divided by a factor of two to calculate the acute criterion (section 3-3.3, TenBrook et al. 2009a). Because the toxicity data used to calculate the criterion reported two significant figures, the criterion is rounded to two significant figures (section 3-3.2.6, TenBrook et al. 2009a). The thiamethoxam acute criterion is termed an interim acute criterion to acknowledge that the procedure used to derive the criterion deviates from the UC Davis Method and that it may be possible to obtain definitive toxicity values for the taxa missing definitive values, at which time a final acute criterion could be derived.

An interim acute criterion was calculated using the lowest value in the data set. Raby 2018c reported an immobility EC_{50} value for *Neocoleon triangulifer* of 5.5 µg/L:

Interim acute value = lowest value in data set ÷ AF
= estimated 5th percentile
= 5.5 µg/L ÷ 5.1
= 1.078 µg/L

Interim acute criterion = acute value ÷ 2
= 1.078 µg/L ÷ 2
= 0.539 µg/L

Interim acute criterion = 0.54 µg/L

To provide some quantification of the uncertainty in the interim acute criterion, lower and upper estimates were calculated based on more or less conservative procedures for deriving aquatic life thresholds. The lower estimate was derived using the AF procedure, but using an AF based on only the definitive toxicity values in the dataset, which represent two of the five required taxa. The lower estimate is a relatively conservative value because the missing taxa are all known to be relatively insensitive, and the AF is designed to account for missing taxa that may possibly be more sensitive than the species available in the dataset.
The lower estimate was calculated using an AF of 12.

Lower estimate acute value = lowest value in data set ÷ AF
= estimated 5th percentile
= 5.5 µg/L ÷ 12
= 0.4583 µg/L

Lower estimate of the acute criterion = lower estimate acute value ÷ 2
= 0.4583 µg/L ÷ 2
= 0.2292 µg/L
= 0.23 µg/L

The upper estimate was derived in the same manner as USEPA Office of Pesticide Program's aquatic life benchmarks, in which the lowest acute toxicity value is divided by two:

Upper estimate acute value: 5.5 µg/L

Upper estimate of the acute criterion = upper estimate acute value ÷ 2
= 5.5 µg/L÷ 2
= 2.75 µg/L

Chronic criterion calculation

Acceptable chronic values were not available for five different species, so a distribution could not be fit to the available toxicity data (section 3-4.1, TenBrook et al. 2009a). The methodology instructs that in the absence of acceptable data to fit a distribution, the chronic criterion is calculated using an acute-to-chronic ratio (ACR) (section 3-4.2, TenBrook et al. 2009a). Additionally, the ACR procedure requires paired acute and chronic data from organisms in at least three different families including a fish, an invertebrate, and at least one other acutely sensitive species (section 3-4.2.1, TenBrook et al. 2009a). Highly rated paired acute and chronic studies were not available for a fish; therefore, a default ACR value was used in its place. The default value is 11.4 as updated in the sediment method for both aquatic and sediment ACR calculations (table 19, Fojut et al., 2014).

Highly rated acute and chronic studies were available for *Chironomus dilutus* to meet the invertebrate requirement. These values originated from the same laboratory using the same water in the same study. Phillips 2019 reported chronic MATC values for growth from three tests with a calculated geometric mean of 27 µg/L. The same study determined two acute LC_{50} values with a calculated geometric mean of 56.4 µg/L.

SMACR = acute toxicity value ÷ chronic toxicity value

C. dilutus SMACR = 56.4 µg/L ÷ 27 µg/L
= 2.088
= 2.1

Highly rated acute and chronic values were also available for *Chironomus riparius* to meet the requirement for a SMACR for another acutely sensitive species. Acute and chronic values were not available for this species from the same study, laboratory, or water. In this case, the only values available originated in different water. A highly rated chronic MATC value of 8.3 µg/L was determined by Saraiva 2017 in hard water medium. Mank 1998 obtained an acute EC_{50} value for immobility of 35 µg/L in

well water. It is unlikely that the differences between the dilution waters would result in a significant impact to the toxicity values given the physical and chemical properties of the thiamethoxam (i.e., high water solubility).

SMACR = acute toxicity value ÷ chronic toxicity value

C. riparius SMACR = 35 µg/L ÷ 8.3 µg/L
= 4.216
= 4.2

The method instructs that if not enough freshwater data are available to fulfill the ACR data requirements, that saltwater species may be used. These studies are included in the acute and chronic supplemental datasets. Drottar 1997 tested the toxicity of thiamethoxam to *Americamysis bahia* and reported an acute LC_{50} value of 9,300 µg/L. In a chronic test, Sayers 2015a obtained an MATC value of 780 µg/L. This allowed for calculation of a species mean acute-to-chronic ratio (SMACR) for *A. bahia:*

SMACR = acute toxicity value ÷ chronic toxicity value

A. bahia SMACR = 9,300 µg/L ÷ 780 µg/L
= 11.92
= 11.9

Final multispecies ACR = geometric mean of *C. dilutus* SMACR, *C. riparius* SMACR, *A. bahia* SMACR and one default ACR for lack of fish SMACR
Final multispecies ACR = geomean(2.1, 4.2, 11.9, 11.4)
= 5.88
= 5.9

Because the chronic criterion is calculated based on the acute value, and only an interim acute value is available for thiamethoxam, the chronic criterion will also be termed an interim value. The interim chronic criterion was calculated using the final multispecies ACR of 5.4 as follows:

Interim chronic criterion = interim acute value ÷ final multispecies ACR
= 1.078 µg/L ÷ 5.9
= 0.1827 µg/L

Interim chronic criterion = 0.18 µg/L
= 180 ng/L

Until either all the required chronic data are available for thiamethoxam to calculate a chronic criterion using a species sensitivity distribution or a final acute value is available (rather than an interim value), a definitive chronic criterion cannot be calculated. The lower and upper estimates of the chronic criterion were also calculated based on the lower and upper estimates of the acute value.

Lower estimate of the chronic criterion = lower estimate acute value ÷ final multispecies ACR
= 0.4583 μg/L ÷ 5.9
= 0.0776 μg/L
= 0.078 μg /L

Upper estimate of the chronic criterion = lowest final acute value ÷ final multispecies ACR
= 5.5 μg/L ÷ 5.9
= 0.93 μg/L

Water quality effects

1.4 Bioavailability

There were no studies found concerning the bioavailability of thiamethoxam in the water column that differentiates between tissue type. No studies were found concerning the bioavailability of thiamethoxam in the water column that differentiates when these compounds are sorbed to solids, sorbed to dissolved solids, or freely dissolved. Until there is more information that discusses the bioavailability of these three phases, it is recommended that compliance is based on the total concentration of thiamethoxam in water (section 3-5.1, TenBrook et al. 2009a).

1.5 Mixtures

The concentration addition model and the non-additive interaction model are the only predictive mixture models recommended by the methodology (section 3-5.2, TenBrook et al. 2009a), so other models found in the literature will not be considered for compliance. The concentration addition model predicts that the toxicity of a pesticide mixture will behave as directly additive, in other words the mixture toxicity is predicted by directly summing the component concentrations as toxic equivalents. Mixtures eliciting greater-than-additive effects are termed synergistic and those eliciting less-than-additive effects are termed antagonistic when compared to the toxic effect of each individual mixture component in single compound exposures. Thiamethoxam can occur in the environment with other pesticides of similar or different modes of action. Thiamethoxam is a nitroguanidine-substituted neonicotinoid insecticide that acts as a nervous system disrupter.

Two studies were available that demonstrated thiamethoxam mixtures adhering to the concentration addition model. Maloney 2018a performed in-situ wetland limnocorral studies for 28 and 56 days with single-pesticide concentrations of imidacloprid, clothianidin, or thiamethoxam as well as binary mixtures (clothianidin-imidacloprid, clothianidin-thiamethoxam, and thiamethoxam-imidacloprid). Environmental populations of aquatic invertebrates were exposed to 8.91 µg/L of thiamethoxam alone and binary mixtures of 4.46 µg/L thiamethoxam. This study demonstrated that binary mixtures were not more toxic to these invertebrate

mesocosms than single compounds under semi-controlled field settings. This is in contrast to laboratory-based experiments which have shown greater-than-additive toxicity of binary mixtures of neonicotinoid in single species exposures. At 28 days, the clothianidin-thiamethoxam exposure resulted in an approximately 44% lowered cumulative emergence of in-situ Chrinomidae compared to laboratory-based exposures. At 56 days, effects on cumulative emergence and biomass of Chironomidae were significant for the clothianidin-thiamethoxam mixture. but not for the imidacloprid-thiamethoxam mixture. However, both clothianidin-thiamethoxam and imidacloprid-thiamethoxam mixtures were shown to display concentration addition effects.

Rico 2018 also demonstrated concentration addition for thiamethoxam mixtures with other neonicotinoids. This study used outdoor constructed mesocosms inoculated with field-collected macrophytes and invertebrates to assess toxicity to an equimolar mixture of five neonicotinoids with individual nominal concentrations of 0, 0.2, 1, 5, 25, and 250 µg/L. The neonicotinoids were imidacloprid, acetamiprid, thiacloprid, thiamethoxam and clothianidin. Additive toxicity was demonstrated in this single exposure, ten-day, equimolar study

Two studies were available that demonstrated other toxicity mixture effects of clothianidin on aquatic species. Maloney et al. (2017) studied a mixture of three neonicotinoids with similar modes of action with *Chironomus dilutus*. The mixtures were composed of imidacloprid and clothianidin and/or thiamethoxam in binary or ternary combinations. It was found that all mixture toxicities were best predicted with some form of response-additive synergism. The clothianidin–thiamethoxam mixtures were predicted by concentration-additive synergism while the imidacloprid–thiamethoxam mixtures were predicted by response-additive dose-ratio–dependent synergism with a shift from antagonism to synergism as the proportion of thiamethoxam increased. The ternary mixture displayed a standard response-additive model.

A later study by Maloney (2018b) and its corrigendum publication in 2019 exposed *Chironomus dilutus* to mixtures of imidacloprid with neonicotinoids clothianidin and thiamethoxam. Thiamethoxam-clothianidin mixtures adhered to the concentration addition model in this chronic, 28-day laboratory study. It was shown that toxicities of binary mixtures of imidacloprid-clothianidin and imidacloprid-thiamethoxam were dose-ratio dependent with synergism at higher concentrations of clothianidin and thiamethoxam, respectively. However, ternary mixtures of all three neonicotinoids displayed weak antagonism at all concentration ratios and dose levels.

The literature review demonstrates that the toxicities of these neonicotinoid pesticide mixtures are generally predicted by the concentration addition model and should be considered additively. Deviations from this model are possible, indicating that toxicity of neonicotinoid mixtures are nuanced and complex. It is recommended that all neonicotinoid mixtures be considered additively. In order for mixtures to be considered in compliance, the methodology requires that each pesticide considered in an accepted mixture model must have a numeric water quality criterion for calculation of a toxic unit or a relative potency factor for a particular body of water. Water quality criteria exist for imidacloprid and interim criteria exist for clothianidin. It is up to regulators to choose which calculation is most appropriate for any given body of water (Section 3-5.2, TenBrook et al. 2009a).

1.6 Temperature, pH, and other water quality effects

Temperature, pH, and other water quality effects on the toxicity of thiamethoxam were examined to determine if any effects are described well enough in the literature to incorporate into criteria compliance (section 3-5.3, TenBrook et al. 2009a). There were no highly rated studies available designed explicitly to test the effects of temperature or pH on thiamethoxam. Thiamethoxam does not dissociate (Lail 1998, PPDB 2016), indicating that pH would not have a significant effect on the chemical structure in the range of conditions found in natural freshwater environments.

Comparison of ecotoxicity data to derived criteria

1.7 Sensitive species

The derived criteria were compared to toxicity values for the most sensitive species in both the acceptable (RR) and supplemental (RL, LR, LL) data sets to ensure that these species will be adequately protected (section 3-6.1, TenBrook et al. 2009a).

The lowest acute value in the data sets rated RR, RL, LR, or LL (Tables 3, 4, and 5) was the RR rated 96-hour EC_{50} of 5.5 µg/L based on immobility of the mayfly *Neocloeon triangulifer* (Raby 2018c). The next lowest acute value rated RR, RL, LR, or LL was the 96-hour EC_{50} of 14.0 µg/L based on immobility for the water beetle *Gyrinus* sp. (Raby 2018c). The upper estimate of the acute criterion would be protective of all acutely sensitive species in the data sets.

The chronic animal data set shows that aquatic animals are more sensitive to thiamethoxam than plants. The interim chronic criterion (180 ng/L) was calculated to be protective of animals and is several orders of magnitude lower than the single chronic MATC of 68,000 µg/L for *Anabena flos-aquae* (Staggs 2014a). The upper estimate of the chronic criterion (0.93 µg/L) is over 73,000 times lower than the *A. flos-aquae* value. The interim chronic criterion is 9 times lower than the lowest chronic animal EC_{50} of >1.60 µg/L based on days to imago emergence of *Neocloeon triangulifer* (Raby 2018b), which was considered supplemental because the methodology does not recognize EC_{50} as a chronic endpoint and the methodology requires definitive toxicity values. If water concentrations of thiamethoxam do not exceed the interim acute and interim chronic criteria values, then sensitive species should be protected.

1.8 Ecosystem and other studies

The derived criteria are compared to acceptable laboratory, field, or semi-field multispecies studies (rated R or L) to determine if the criteria will be protective of ecosystems (section 3-6.2, TenBrook et al. 2009a). These studies are summarized in Table 11.

Eight studies describing effects of thiamethoxam on mesocosm, microcosm and model ecosystems were identified and rated for reliability according to the UCDM (Table 3.9, TenBrook et al. 2009a). Seven studies were rated as reliable (R; Cavallaro 2018, Finnegan 2018, Lobson 2018, Maloney 2018, Pickford 2018, Rico 2018, and Robinson 2019) and are described below. One study was rated as less reliable (L; Basley 2018).

Cavallaro 2018 performed a nine-week in-situ wetland limnocorral experiment with exposures of 0.0, 0.05, or 0.5µg/L followed by a six-week recovery period. During the dosing period, community structure was not significantly different from controls even after the recovery period. Toxicity values for individual species or the community were not reported.

Finnegan 2018 observed aquatic organisms in varying-depth outdoor mesocosms for 93 days following a single exposure of formulated thiamethoxam at five concentrations (1, 3, 10, 30, 100 µg/L). Organisms from multiple trophic levels were exposed, including primary producers (phytoplankton), zooplankton, and macroinvertebrates such as aquatic insects. These organisms were either present in the natural sediment and water used to fill the mesocosm tanks or were added from commercially purchased sources. Statistically significant, treatment-related effects were nuanced, leading the authors to report an overall NOEC for the study of 30 µg/L. This is three orders of magnitude greater than the interim chronic criterion of 180 ng/L.

Lobson 2018 studied the effect of a single dose of thiamethoxam to aquatic zooplankton in a wetland mesocosm experiment. The concentrations tested were 0, 25, 50, 100, 250, and 500 µg/L. After eight weeks there were no statistically significant effects on abundance or diversity and there was no dose response observed.

Maloney 2018 and its corrigendum publication in 2019 reported on an in-situ wetland limnocorral exposures lasting for 28 and 56 days with single-pesticide concentrations of imidacloprid, clothianidin, or thiamethoxam as well as binary mixtures to test the effects on environmental aquatic insect communities. Total insect emergence and cumulative chironomid emergence and chironomid biomass were assessed. Community composition effects were subtle and nuanced. For example, the mean proportions of Trichoptera and Odonata emergence increased in all treatments but the cumulative abundances of these taxa were not significantly different from controls. Cumulative invertebrate emergence and biomass were not significantly different between the pesticide treatments and the controls although there was a significant effect of time, indicating that these pesticides can have extended toxic effects. Thiamethoxam exposure did not affect cumulative abundance or biomass of chironomids in a significant manner. Thiamethoxam-clothianidin mixtures adhered to the concentration addition model whereas binary mixtures of imidacloprid-clothianidin and imidacloprid-thiamethoxam were dose-ratio dependent with synergism at higher concentrations of clothianidin and thiamethoxam, respectively. However, ternary mixtures of all three neonicotinoids displayed weak antagonism at all concentration ratios and dose levels. Mixtures were not more toxic than single compounds under semi-controlled field settings in contrast to laboratory-based experiments which have shown synergism. Additionally, only minor effects to the community composition were observed. At 56 days, effects on cumulative emergence and invertebrate biomass were significant for the clothianidin-thiamethoxam mixture.

Pickford 2018 studied the effects of thiamethoxam formulations on mayfly emergence and abudnace over 35 days of exposure inside open-top steel enclosures located in an artificial outdoor pond. These mesocosms were therefore inhabited by an environmentally representative population of all trophic levels, which originated from the natural pond water and sediment layers or by aerial colonization (mayflies and other insects). Thiamethoxam exposures ranged from 0.1-10.0 g/L and reduced adult emergence and larval abundance was noted at 1.0 g/L and greater concentrations. The authors note that these observations support the chronic NOEC value of 0.3 g/L

for some mayfly species in the literature which is nearly twice the value of the interim chronic criterion (0.18 g/L).

Rico 2018 used outdoor constructed mesocosms inoculated with field-collected macrophytes and invertebrates to assess toxicity to an equimolar mixture of five neonicotinoids with individual nominal concentrations of 0, 0.2, 1, 5, 25, and 250 µg/L. The neonicotinoids were imidacloprid, acetamiprid, thiacloprid, clothianidin, and thiamethoxam. NOEC values for most taxa in the mesocosm were determined to be >250 µg/L. There was not a uniform dose-response relationship for the entire population.

Robinson 2019 dosed artificial pond mesocosms with 2.5 and 250 µg/L of a commercial formulation of thiamethoxam to observe effect on amphibian larval development through metamorphosis. No differences were measured between the pesticide exposures and the controls.

The mesocosm data for thiamethoxam indicate that the interim chronic criterion of 180 ng/L would be protective of all trophic levels tested in these studies. The upper estimate of the chronic criterion of 0.93 µg/L may be adequately protective of the mayfly species tested in Pickford 2018 mesocosms.

1.9 Threatened and endangered species

The derived criteria are compared to measured toxicity values for threatened and endangered species (TES), as well as to predicted toxicity values for TES, to ensure that they will be protective of these species (section 3-6.3, TenBrook et al. 2009a). Current lists of state and federally listed threatened and endangered plant and animal species in California were obtained from the California Department of Fish and Wildlife (CDFW) (formerly the California Department of Fish and Game) website (CDFW 2015). One listed animal species is represented in the dataset with two toxicity values. Five Evolutionarily Significant Units of *Oncorhynchus mykiss* are listed as federally threatened or endangered throughout California. The acute dataset contains one *O. mykiss* study rated as supplemental due to a non-definitive LC50 of >100,000 µg/L (Rufli 1997). This value indicates that the upper estimate of the acute criterion of 2.75 µg/L would be protective of this species.

The USEPA interspecies correlation estimation (Web-ICE v. 3.2.1; Raimondo et al. 2013) software was used to estimate toxicity values for the listed animals or plants represented in the acute data set by members of the same family or genus. Table 13 summarizes the results of the ICE analyses. The estimated toxicity values in Table 13 range from 158,956.62 µg/L for Apache trout, 71,353.48 µg/L for Cutthroat trout, 97,331.23 µg/L for Chinook salmon, 130,239.59µg/L for Coho salmon, and 44,658.37µg/L for Sockeye salmon.

No plant studies used in the criteria derivation were of state or federal endangered, threatened or rare species. There are no aquatic plants listed as state or federal endangered, threatened or rare species so they could not be considered in this section.

Based on the available data and estimated values for animals, there is no evidence that the derived acute or chronic criteria will be underprotective of threatened and endangered species.

Harmonization with other environmental media

1.10 Bioaccumulation

Bioaccumulation was assessed to ensure that the derived criteria will not lead to unacceptable levels of thiamethoxam in food items (section 3-7.1, TenBrook et al. 2009a). Thiamethoxam has a log K_{ow} of -0.10 (Section 3), a K_d of 2.01-1.97.53 depending on soil type (Shepler 1998), and a molecular weight of 291.7 g/mole, which does not indicate a strong bioaccumulative potential. There are no FDA action levels for thiamethoxam in food (USFDA 2000), however, the EPA has established pesticide tolerances for residues of thiamethoxam but not in any aquatic animal species (USEPA 2012). The only product that is grown in water for which a pesticide toleranace exists is rice at 6 ppm or mg/kg (USEPA 2019). Bioconcentration of thiamethoxam has been measured by only a few researchers (Table 1).

To check that these criteria are protective of humans that may consume aquatic organisms, a bioaccumulation factor (BAF) was used to estimate the water concentration that would roughly equate to a reported tolerance for residues in food of aquatic origin for humans (pesticide tolerance, $_{human}$), in this case for rice. These calculations are further described in section 3-7.1 of the methodology (TenBrook et al. 2009a). The BAF of a given chemical is the product of the BCF and a biomagnification factor (BMF), such that BAF=BCF*BMF. No BMF value was found for thiamethoxam. A BCF of 2 L/kg (Table 1) was used as an example estimation of bioaccumulation in the environment. No BMF value was available in the literature so it was estimated two ways according to the methodology (a value of 1 both when as approximated from log K_{ow} and as approximated from BCF as in section 3-7.1 and Table 3.15 in TenBrook et al. 2009a).

$$NOEC_{water} = \frac{Pesticide\ tolerance_{human}}{BCF_{food\_item} \cdot BMF_{food\_item}}$$

Human:

$$NOEC_{water} = \frac{6\ ^{mg}/_{kg}}{2\ ^{L}/_{kg} * 1} = 3\ ^{mg}/_{L} = 3{,}000\ ^{\mu g}/_{L}$$

In this example, the interim chronic criterion (180 ng/L) is four orders of magnitude below the estimated $NOEC_{water}$ value for humans. The upper estimate of the chronic criterion (0.93 μg/L) is three orders of magnitude below the estimated $NOEC_{water}$ value for humans. In both cases, the interim chronic criterion and upper estimate are not expected to cause adverse effects due to bioaccumulation.

To check that these criteria are protective of terrestrial wildlife that may consume aquatic organisms, a bioaccumulation factor (BAF) was used to estimate the water concentration that would roughly equate to a reported toxicity value for such terrestrial wildlife ($NOEC_{, oral\ predator}$). These calculations are further described in section 3-7.1 of the methodology (TenBrook et al. 2009a). The BAF of a given chemical is the product of the BCF and a biomagnification factor (BMF), such that BAF=BCF*BMF. No BMF value

was found for thiamethoxam. Chronic dietary toxicity values are preferred for this calculation. There were two highly rated studies available for *Anas platyrhynchos* that reported NOEC values. A 27-week dietary exposure study on the reproductive effects on mallard duck (*Anus platyrhynchos*) resulted in a NOEC value of 300 mg/kg according to Brewer 1998. An acute dietary study of *A. platyrhynchos* by Johnson 1996b reported aNOEC for bodyweight gain of 163 mg/kg three days following a continuous five-day exposure period. The geometric mean of these NOEC values was 221 mg/kg. A BCF of 2 L/kg (Table 1) was used as an example estimation of bioaccumulation in the environment. No BMF value was available in the literature so it was estimated two ways according to the methodology (a value of 1 both when as approximated from log K_{ow} and as approximated from BCF as in section 3-7.1 and Table 3.15 in TenBrook et al. 2009a).

$$NOEC_{water} = \frac{NOEC_{oral\ predator}}{BCF_{food\ item} \cdot BMF_{food\ item}}$$

Mallard:

$$NOEC_{water} = \frac{221\ ^{mg}/_{kg}}{2\ ^{L}/_{kg} * 1} = 111\ ^{mg}/_{L} = 111{,}000\ ^{\mu g}/_{L}$$

In this example, the interim chronic criterion (180 ng/L) is six orders of magnitude below the estimated $NOEC_{water}$ value for wildlife. The upper estimate of the chronic criterion (0.93 μg/L) is five orders of magnitude below the estimated $NOEC_{water}$ value for wildlife. In both cases, the interim chronic criterion and the upper estimate are not expected to cause adverse effects due to bioaccumulation.

1.11 Harmonization with air and sediment criteria

This section addresses how the maximum allowable concentration of thiamethoxam might impact life in other environmental compartments through partitioning (section 3-7.2, TenBrook et al. 2009a). Thiamethoxam is not listed as a hazardous air pollutant or toxic air contaminant by the California Air Resources Board (CCR 2016). There are no other federal or state sediment or air quality standards for thiamethoxam (CARB 2008; CDWR 1995), nor is thiamethoxam mentioned in the NOAA sediment quality guidelines (NOAA 1999). For biota, the limited data on bioconcentration or biomagnification of thiamethoxam is addressed in section 15.

Thiamethoxam criteria summary

1.12 Limitations, assumptions, and uncertainties

The assumptions, limitations and uncertainties involved in criteria generation are available to inform environmental managers of the accuracy and confidence in criteria (section 3-8.0, TenBrook et al. 2009a). Chapter 2 of the methodology (TenBrook et al.

2009a) discusses these points for each section as different procedures were chosen, such as the list of assumptions associated with using an SSD (section 2-3.1.5.1), and reviews them in section 2-7.0. This section summarizes any data limitations that affected the procedure used to determine the final thiamethoxam criteria.

Overall, there was a lack of highly rated aquatic plant and animal toxicity data for thiamethoxam. Both the acute and chronic data sets lacked the full complement of five required taxa to fit a distribution for criteria derivation. The acute data set was missing definitive data for a Daphnid, warm water fish, and Salmonidae because these species are relatively tolerant of thiamethoxam. The chronic data set was missing values for Salmonidae, benthic crustacean, insect, and a warm water fish. Final acute and chronic criteria could not be calculated due to these limitations in the datasets. Instead, interim criteria were derived using a proposed procedure that would be an update to the existing UC Davis Method (see Section 1.3 for further discussion). One limitation of the proposed procedure of using censored data when pesticides have a narrow spectrum of toxicity is that it has not undergone peer review as part of the original UC Davis Method, and may warrant revisions following additional peer review.

The AF procedure was used to calculate an interim acute criterion using the lowest definitive value in the acute dataset and an AF representing toxicity values being available for all five required taxa, even though the toxicity values for three of these taxa are censored values, which would not typically be used. This procedure is proposed because all three taxa were tested and were so insensitive to thiamethoxam that definitive toxicity values could not be determined, and concentrations were tested that are well above those found in the environment. The goal in proposing this new procedure and deriving an interim acute criterion was to continue building on the concepts developed in the UC Davis Method for deriving criteria for pesticides when limited toxicity data are available. This procedure is proposed to avoid deriving overly conservative criteria by not using data for taxa that are very insensitive to thiamethoxam. Because this is a new procedure, lower and upper estimates of acute criteria are also presented based on more and less conservative calculations to provide some range of uncertainty around the interim acute criterion.

ACR calculations were used to determine an interim chronic criterion. The interim chronic criterion was derived with a minimum amount of data according to the methodology (section 3-4.2.3, TenBrook et al. 2009a) using three highly rated SMACRs and one default ACR value. The chronic criterion is also termed an interim value because it is calculated based on an interim acute value, but the procedure for calculing the interim chronic criterion does not otherwise deviate from the UC Davis Method. Plant studies are always considered chronic (Section 3-2.1.1.1, TenBrook et al. 2009a) and therefore could not be used in the ACR calculations because there was no associated acute data. As a result, the interim chronic criterion does not incorporate plant toxicity.

Other limitations include the lack of sediment, bioavailability, and wildlife studies. There were no sediment or bioavailability studies available although thiamethoxam has a moderately high solubility and therefore retention on sediment surfaces is not expected to be significant. Additional high-quality mallard duck studies could be useful

although the demonstrated lack of definitive toxicity values indicates that this species is not particularly sensitive to thiamethoxam.

1.13 Comparison to national standard methods

This section is provided as a comparison between the UC Davis methodology for criteria calculation (TenBrook et al. 2009a) and the current USEPA (1985) national standard. The following example thiamethoxam criteria were generated using the USEPA (1985) methodology with the data set generated in this thiamethoxam criteria report.

The acute dataset is missing three of the five taxa requirements of the UC Davis methodolgy. The UC Davis methodology does not utilize non-definitive values (> or < values), however the USEPA method allows for these values (section IV.E.5., USEPA 1985). The first missing taxa is for a planktonic crustacean, of which one must be in the family Daphniidae in the genus *Ceriodaphnia, Daphnia*, or *Simocephalus*. However, this requirement could be met with with the supplemental value of >80,000 µg/L for *Ceriodaphnia dubia* in the Daphnidae family. The second missing taxa requirement is for a salmonidae and the supplemental value for *Oncorhynchus mykiss* of >100,000 µg/L can be used for this requirement. The third missing taxa requirement is for a warm water fish. The supplemental value of >114,000 µg/L for *Lepomis macrochirus* meets this taxa requirement.

The USEPA acute methods have three additional taxa requirements beyond the five required by the SSD procedure of the UC Davis methodology (section 3-3.1, TenBrook et al. 2009a). They are:

1. A third family in the phylum Chordata (e.g., fish, amphibian);
2. A family in a phylum other than Arthropoda or Chordata (e.g., Rotifera, Annelida, Mollusca);
3. A family in any order of insect or any phylum not already represented.

The first additional requirement could not be met with RR rated or supplemental data because the USEPA method requires freshwater species only. The second additional requirement could be met by *Lumbriculus variegatus* in the Annelida phylum. *Trichocorixa* in the Corixidae family could satisfy the third additional requirement. However, it is reasonable to calculate an interim USEPA criterion for thiamethoxam, despite the lack data for a third freshwater family in the phylum Chordata because there are other more sensitive species in the dataset that will ensure protection of species that are most sensitive to this pesticide. The California Department of Fish and Game has derived criteria using the USEPA (1985) SSD method with fewer than the eight required families, using professional judgment to determine that species in the missing categories were relatively insensitive and their addition would not lower the criteria (Menconi & Beckman 1996; Siepmann & Jones 1998).

The acute dataset contains 20 values which were combined with the three supplemental values above as well as three additional supplemental values that meet the USEPA requirements to calculate a USEPA acute criterion. The values were ranked and a Final Acute Value was determined using the four lowest values. Because the

lowest number of significant figures reported for a definitive value in the toxicity dataset used to calculate the criterion was two, the criterion is rounded to two significant figures. For thiamethoxam the Final Acute Value (estimate of the 5th percentile) was determined to be 9.2 µg/L according to USEPA 1985 calculation, and the Final Acute Criterion 5 µg/L. This Final Acute Criterion is an order of magnitude greater than the UC Davis methodology interim acute criterion of 0.54 µg/L and is 2.25 µg/L greater than the UC Davis methodology upper estimate of the acute criterion of 2.75 µg/L. Details of the calculations can be found in Appendix B.

USEPA Final Acute Value = 9.2 µg/L (see Appendix B)
USEPA Final Acute Criterion = Final Acute Value ÷ 2
= 9.2 µg/L ÷ 2
= 4.6 µg/L
= 5 µg/L

According to the USEPA (1985) methodology, the chronic criterion is equal to the lowest of the Final Chronic Value, the Final Plant Value, and the Final Residue Value.

To calculate the Final Chronic Value, animal data are used and the same taxa requirements must be met as in the calculation of the acute criterion (section III B USEPA 1985). Only one of the eight taxa requirements is available in the RR chronic animal data set with *Chironomus riparius* and *Chironomus dilutus* (Table 7). The missing taxa are as follows:

1. A warm water fish
2. A Salmonidae
3. A daphnid
4. A benthic crustacean
5. An insect
6. A third family in the phylum Chordata (e.g., fish, amphibian)
7. A family in a phylum other than Arthropoda or Chordata (e.g., Rotifera, Annelida, Mollusca)

The CDFW has derived criteria using the USEPA (1985) SSD method with fewer than the eight required families, using professional judgment to determine that species in the missing categories were relatively insensitive and their addition would not lower the criteria (Menconi & Beckman 1996; Siepmann & Jones 1998). However, in this case, there are too many missing taxa values to derive a Final Chronic Value in this way.

The Final Plant Value is calculated as the lowest result from a 96-hour test conducted with an important plant species in which the concentrations of test material were measured and the endpoint was biologically important. The final chronic plant dataset for thiamethoxam contains a single value for *Anabena flos-aquae* that meets these requirements with an MATC of 68,000 g/L to serve as the Final Plant Value for thiamethoxam (Table 6).

The Final Plant Value is calculated as the lowest result from a 96-hour test conducted with an important plant species in which the concentrations of test material

were measured and the endpoint was biologically important. The final chronic plant dataset for thiamethoxam contains a value from a 96-hour test as required by the USEPA 1985 method, for *Anabena flos-aquae* with an MATC of 68,000 µg/L (Table 6). Therefore, the Final Plant Value for thiamethoxam would be 68,000 µg/L.

The Final Residue Value is calculated by dividing the maximum permissible tissue concentration by an appropriate bioconcentration or bioaccumulation factor. A maximum allowable tissue concentration is either (a) a FDA action level for fish oil or for the edible portion of fish or shellfish, or (b) a maximum acceptable dietary intake based on observations on survival, growth, or reproduction in a chronic wildlife feeding study or long-term wildlife field study. There are no FDA action levels for thiamethoxam in food (USFDA 2000), however, the EPA has established pesticide tolerances for residues of thiamethoxam but not in any aquatic animal species (USEPA 2012). The only product that is grown in water for which a pesticide toleranace exists is rice at 6 ppm or mg/kg (USEPA 2019). There were two highly rated studies that report NOEC values available for wildlife that result in a geometric mean of 221 mg/kg. A BCF of 2 (Table 1) was used to calculate the Final Residue Value.

$$\text{Final Residue Value}_{\text{human}} = \text{maximum acceptable dietary intake} \div \text{BCF}$$
$$= 6 \text{ mg/kg} \div 2 \text{ L/kg}$$
$$= 3 \text{ mg/L}$$
$$= 3{,}000 \quad \text{g/L}$$

$$\text{Final Residue Value}_{\text{wildlife}} = \text{maximum acceptable dietary intake} \div \text{BCF}$$
$$= 221 \text{ mg/kg} \div 2 \text{ L/kg}$$
$$= 111 \text{ mg/L}$$
$$= 111{,}000 \quad \text{g/L}$$

A Final Chronic Value cannot be calculated. A Final Plant Value cannot be calculated. The Final Residue Value for humans is the lowest value and therefore the chronic criterion by the USEPA (1985) methodology for thiamethoxam would be 3,000 g/L. The example chronic criterion is four orders of magnitude higher than the one recommended by the UC Davis methodology.

1.14 Environmental Monitoring Data

A review of the available data from the Surface Water Database (SURF 2019) indicates that thiamethoxam and some of its metabolities have been present in some freshwater systems within the Central Coast Regional Water Quality Control Board (CCRWQCB) jurisdiction. Its geographic area encompasses some or all of nine counties. The data for the following counties was included in the SURF data anaylsis for this report because they fully reside within this waterboard's jurisdiction: Santa Cruz, San Benito, Monterey, San Luis Obispo, and Santa Barbara. Data was available for 2011-2018.

Thiamethoxam concentrations were detected in 65 of the 115 reported samples between 2011-2018. The values ranged from 0.0068 to 9 parts per billion (ppb, equivalent to µg/L) in Monterey and San Benito Counties, respectively. Twenty detections were greater than the interim acute criterion of 0.54 µg/L, ranging from 0.053 to 8.46 µg/L greater. There were five detections greater than the upper estimate of the interim acute

criterion of 2.75 µg/L and there were seven detections lower than the lower estimate of the interim acute criterion of 0.23 µg/L by 0.88 to 6.25 µg/L and 0.009 to 0.22 µg/L, respectively. There were thirty-six detections greater than the interim chronic criterion of 0.18 µg/L, raning from 0.01 to 8.82 µg/L greater. Seventeen detections were greater than the upper estimate of the interim chronic criterion and thirteen were lower than the lower estimate of the interim chronti criterion, by 0.92 to 8 µg/L and by 0.007 to 0.064 µg/L, respectively. Average detection concentations by county are Monterey: 0.82, San Luis Obispo: 0.53, Santa Barbara: 0.24, Santa Cruz: 0.034, and San Benito: 3.9 ppb.

The reported method detection limits (MDL) for these thiamethoxam have varied over time from 0.0002 to 0.2 ppb, which have always been below both the interim acute and chronic criteria.

1.15 Final criteria statement

Interim criteria for thiamethoxam:

- Interim acute criterion: 0.54 µg/L
- Interim chronic criterion: 0.18 µg/L

Aquatic life in the watersheds of the CCRWQCB should not be affected unacceptably if the four-day average concentration of thiamethoxam does not exceed 0.18 µg/L more than once every three years on the average and if the one-hour average concentration does not exceed 0.54 µg/L more than once every three years on the average.

Application:

Although the intention of this report is to report thiamethoxam water quality criteria to be protective of aquatic life in the watersheds of the CCRWQCB, these interim criteria would be appropriate for any freshwater ecosystem in North America, unless species more sensitive than the species examined in this report are likely to occur in those ecosystems.

Comparisons to other aquatic criteria:

There are no established water quality criteria for thiamethoxam with which to compare the criteria derived in this report. However, the interim acute criterion in this report can be compared to the acute criterion derived according to the USEPA (1985) method. The USEPA acute criterion of 5.0 ug/L is greater than the interim acute criterion by a factor of 9.

The USEPA has several aquatic life benchmarks established for thiamethoxam, shown in Table 12, to which the derived criteria in this report can be compared with caution (USEPA 2017b. According to the USEPA (2017b), aquatic life benchmarks are not calculated following the same methodology used to calculate water quality criteria. Water quality criteria can be used to set water quality standards under the Clean Water Act, but aquatic life benchmarks may not be used for this purpose (USEPA 2017b).

The derived interim acute criterion (0.54 µg/L) is below the acute fish benchmark by five orders of magnitude and is below the acute invertebrate benchmark by two

orders of magnitude. The upper estimate of the acute criterion was calculated using the same procedure as acute benchmarks, and the upper estimate (2.75 µg/L) is below the acute fish benchmark by four orders of magnitude and is below the acute invertebrate benchmark by one order of magnitude (Table 12). The interim chronic criterion of this report (0.18 µg/L) is several orders of magnitude below both the chronic benchmarks for fish and non-vascular plants. The interim chronic criterion (0.18 µg/L) is below the chronic invertebrate benchmark of 0.74 µg/L.

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