OFFICE OF CHEMICAL SAFETY AND POLLUTION PREVENTION

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October 16, 2024

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MEMORANDUM

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SUBJECT: **Glufosinate-P and Glufosinate-P Ammonium:** Final Environmental Fate and Ecological Risk Assessment (ERA) for the FIFRA Section 3 Registration and Biological Evaluation (BE) with Associated Effects Determinations for Federally Listed Endangered and Threatened Species and Designated Critical Habitat

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The Environmental Fate and Effects Division (EFED) has completed the final environmental fate and ecological risk assessment (ERA) in support of the FIFRA Section 3 registration for the new herbicide glufosinate-P. Two forms of glufosinate-P are being registered: glufosinate-P ((*2S*)-2-amino-4-[hydroxy(methyl)phosphoryl]butanoic acid; PC Code 128812) and glufosinate-P ammonium (azanium (*2S*)-2-amino-4-[hydroxy(methyl)phosphoryl]butanoate; PC Code 128300). For both compounds, glufosinate-P is considered the active ingredient since in solution at environmentally relevant pH values (pH 5-9), glufosinate-P ammonium and

glufosinate-P will exist in the same form as glufosinate-P; therefore, the assessment is for both forms of glufosinate.

Both compounds included for registration are enantiomerically[1] enriched forms of the currently registered racemic glufosinate, which is a 50:50 mixture of D and L enantiomers (PC Code 128850). This assessment focuses on the enantiomerically enriched L-glufosinate. In this assessment, the term "L-glufosinate" refers to both glufosinate-P ammonium and glufosinate-P, while "L-glufosinate ammonium" refers to only glufosinate-P ammonium. The terms "racemic glufosinate" or "racemic glufosinate ammonium" are also used in this document and refer to the racemic mixture. Any subsequent reference to "glufosinate" only (not containing "L" or "P") applies more generically to both racemic glufosinate and L-glufosinate active ingredient (ai) unless otherwise specified. Thus, the Agency considers glufosinate-P ammonium and glufosinate-P as functionally equivalent and glufosinate-P to be the active ingredient for both forms under typical environmental conditions.

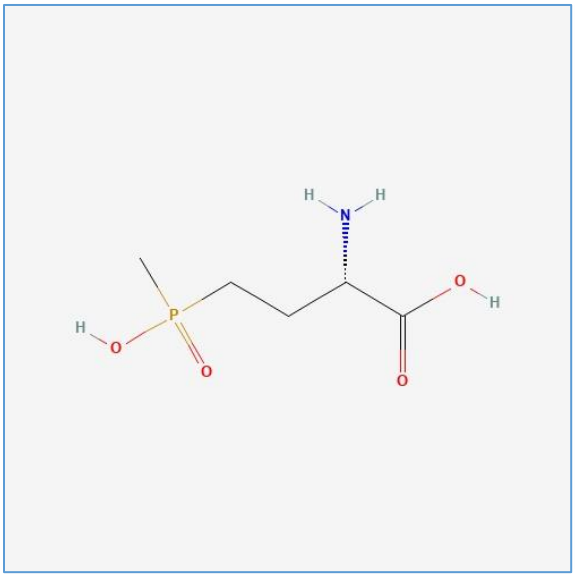
EFED has also completed final effects determinations that are included in a biological evaluation (BE) for Federally listed threatened and endangered ("listed") species for the labeled uses of L-glufosinate. For those species where EFED determined that L-glufosinate is Likely to Adversely Affect (LAA) a listed species or designated critical habitat from labeled uses of the compound, EFED included predictions of the potential likelihood for listed species to be jeopardized or for designated critical habitats to be adversely modified in the future. EPA predicted a potential likelihood of future jeopardy (J) from labeled uses for 60 listed species. EPA also predicted a potential likelihood of future adverse modification (AM) of 38 CHs from labeled uses. These predictions are intended to help inform any necessary consultation with U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) (collectively referred to as "the Services"). The Services will make the final determination as to any jeopardy to listed species and any adverse modification to designated critical habitats in any biological opinion that issue at the end of any necessary formal consultation. EFED has finalized this assessment after considering comments received during the public comment period. If the EPA determines that the uses meet the FIFRA standard, then the EPA will consult with the Services because the final effects determinations include May Affect determinations.

EPA developed the conclusions conveyed in this assessment in full compliance with *EPA Scientific Integrity Policy for Transparent and Objective Science* and EPA Scientific Integrity Program's *Approaches for Expressing and Resolving Differing Scientific Opinions.* The full text of *EPA Scientific Integrity Policy for Transparent and Objective Science*, as updated and approved by the Scientific Integrity Committee and EPA Science Advisor can be found at: https://www.epa.gov/sites/default/files/2014-02/documents/scientific_integrity_policy_2012.pdf. The full text of the EPA Scientific Integrity Program's *Approaches for Expressing and Resolving*

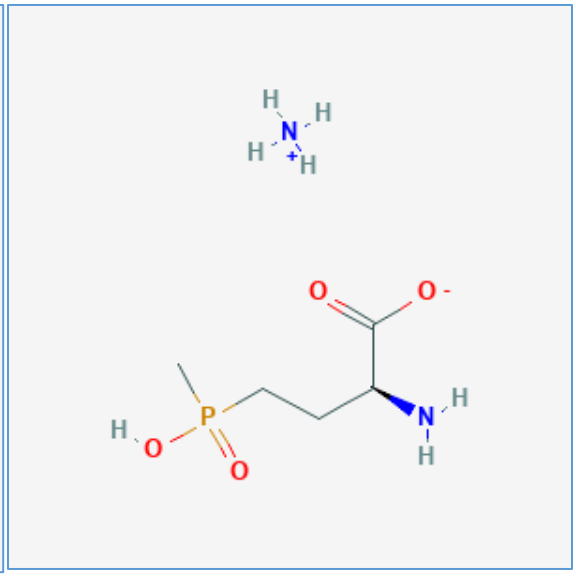
[1] Enantiomerically enriched compounds are chiral compounds whose enantiomeric ratio is greater than 50:50 but less than 100:0 (IUPAC Compendium of Technology, 2006).

Differing Scientific Opinions can be found at: https://www.epa.gov/scientific-integrity/approaches-expressing-and-resolving-differing-scientific-opinions.

Final Environmental Fate and Ecological Risk Assessment and Biological Evaluation Including Effects Determinations for Federally Listed Endangered and Threatened Species and Designated Critical Habitat for the Section 3 Registrations of Glufosinate-P and Glufosinate-P Ammonium



Glufosinate-P (PC Code 128812)



Glufosinate-P Ammonium (PC Code 128300)

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Table of Contents

1 Executive Summary

This assessment examines the environmental fate and potential ecological risks to non-target organisms under FIFRA (*i.e.*, a screening-level taxa-based ecological risk assessment (ERA)) and a biological evaluation (BE) that includes effects determinations for federally listed threatened and endangered (listed) species under the Endangered Species Act (ESA) associated with the labeled uses of glufosinate-P ((*2S*)-2-amino-4-[hydroxy(methyl)phosphoryl]butanoic acid; PC Code 128812) and glufosinate-P ammonium (azanium (*2S*)-2-amino-4-[hydroxy(methyl)phosphoryl]butanoate; PC Code 128300). For both compounds, glufosinate-P is considered the active ingredient since in solution at environmentally relevant pH values (pH 5-9), glufosinate-P ammonium and glufosinate-P will exist in the same form as glufosinate-P; therefore, the assessment is for both forms of glufosinate. EPA prepared a BE that includes an evaluation of the potential effects of an agency's action (here, registering glufosinate-P and glufosinate-P ammonium uses) on listed species and designated critical habitat.

Both compounds included for registration are enantiomerically[2] enriched forms of the currently registered racemic glufosinate, which is a 50:50 mixture of D and L enantiomers (PC Code 128850). This assessment focuses on the enantiomerically enriched L-glufosinate. In this assessment, the term "L-glufosinate" refers to both glufosinate-P ammonium and glufosinate-P, while "L-glufosinate ammonium" refers to only glufosinate-P ammonium. The terms "racemic glufosinate" or "racemic glufosinate ammonium" are also used in this document and refer to the racemic mixture. Any subsequent reference to "glufosinate" only (not containing "L" or "P") applies more generically to both racemic glufosinate and L-glufosinate active ingredient (ai) unless otherwise specified.

Identical to racemic glufosinate, L-glufosinate mode of action is by inhibiting glutamine synthetase needed for the ammonification of glutamate to the amino acid glutamine; inhibition of the enzyme leads to cell membrane disruption, buildup of excess ammonia, and cell death (Takano *et al.*, 2020). Although glufosinate degrades to MPP (3-methylphosphinico-propionic acid), MPA (2-methylphosphinico-acetic acid), and NAG (2-acetamido-4-(methylphosphinico)butanoic acid) to varying extents, this assessment only considers the parent compound as a residue of concern (ROC) for ecological exposure since the degradates are generally less toxic than the parent compound. In solution at environmentally relevant pH levels (*i.e.*, pH range 5 – 9), L-glufosinate ammonium is expected to exist primarily as its deprotonated acid form (*i.e.*, glufosinate-P) with no fixed counterion rather than as the ammonium salt; therefore, throughout this assessment, application rates are expressed in terms of acid equivalents (ae).

[2] Enantiomerically enriched compounds are chiral compounds whose enantiomeric ratio is greater than 50:50 but less than 100:0 (IUPAC Compendium of Technology, 2006).

1.1 Use Overview

L-glufosinate is labeled for use as a foliar herbicide for post-emergence control of annual and perennial grass and broadleaf weeds in non-tolerant and glufosinate-resistant (aka, genetically modified organism; GMO) corn, sweet corn, soybean, cotton, and canola.

1.2 FIFRA ERA Risk Conclusions Summary

The uses of L-glufosinate products in accordance with the submitted labels are expected to result in potential risks of concern to several taxa in the environment) including estuarine/marine invertebrates, terrestrial and aquatic plants, mammals, and terrestrial invertebrates, summarized in **Table 1**. Because risk quotient (RQ) values are below the acute and chronic risk levels of concerns (LOCs) for birds, reptiles, terrestrial- and aquatic-phase amphibians, freshwater invertebrates, and freshwater and estuarine/marine fish, there are no risks of concern for species within these taxa. There are also no acute risks of concern for bees and estuarine/marine invertebrates based on the RQ values falling below the acute risk LOCs. For more information on risk to non-target organisms, refer to **Appendices E** and **F.**

Potential chronic risk to estuarine/marine invertebrates from the labeled uses varied with the size of the waterbody. The RQs for estuarine/marine invertebrates that inhabit low volume (*e.g.,* vernal pools) waterbodies (RQ range: 0.58 to 2.01) exceed the Agency's chronic risk LOC of 1.0 for labeled uses on cotton and corn. The labeled uses do not pose a chronic risk to estuarine/marine invertebrates in medium volume (*e.g.*, ponds) or larger waterbodies.

Like estuarine/marine invertebrates, risk to aquatic plants is dependent on the size of the waterbody. In medium to larger volume waterbodies, non-vascular aquatic plant RQs (RQ range = 0.25-1.09) exceed the Agency's LOC for risk to aquatic plants (LOC = 1.0) for the uses on glufosinate-resistant corn uses only. In medium to larger volume waterbodies, non-vascular aquatic plant RQs range from 0.25-1.09.. Within this range there is an exceedance of the Agency's LOC for risk to aquatic plants (LOC = 1.0) for the labeled uses on glufosinate-resistant corn uses only. In low-volume waterbodies and wetlands, RQs range from 0.07-6.42. Within this range there are exceedances for all uses above the Agency's LOC for risk to non-vascular aquatic plants.

The risk assessment for mammals utilizes upper-bound residue levels and a chemical-specific foliar dissipation half-life ($t_{½}$ = 13.73 days). While the assessment indicates that RQ values are below the acute risk LOC of 0.5 for mammals across all labeled uses, there are chronic risks of concern (RQ range: 0.04-12.1; LOC = 1.0) for small, medium, and large-sized mammals that feed primarily on grasses, broadleaf plants, or arthropods. For all uses, upper-bound exposure estimates exceed the lowest-observed adverse effect level (LOAEL), where there was an 11% reduction in the number of viable offspring for small-sized mammals that forage primarily on grasses and broadleaf plants; medium-sized mammals that forage primarily on short grasses and broadleaf plants; large-sized mammals that forage primarily on short grasses. Chronic RQs

based on mean rather than upper-bound residue levels, likewise, exceed the chronic risk LOC for small- and medium sized mammals foraging primarily on short grasses, broadleaf plants, and arthropods; large-sized mammals foraging primarily on short grasses. Residues (based on upper-bound estimates) on the treated field are expected to exceed the chronic risk LOC for up to 90 days. Mammals may also be exposed to residues on food items off-site from spray drift during application to the treated field. The RQs exceed the chronic risk LOC for mammals up to 76 feet from the treated field when L-glufosinate is applied aerially and between 3 and 7 feet from the treated field when applied via ground equipment depending on the boom height. These spray drift estimates assume a droplet size distribution (DSD; aerial = medium to coarse; ground-boom = fine to medium/coarse) and boom height [both high (50 inches from the ground) and low (20 inches from the ground) boom height are modeled] consistent with final label recommendations.

There are potential chronic risks of concern for bees based on model-generated exposure values. The chronic RQs for adult (RQ range: 20.0 - 40.8) and larval bees (RQ range: 0.94 - 1.90) for all uses exceed the Agency's chronic risk LOC of 1.0 for bees. The chronic RQs for adult (RQ range: 20.0 - 40.8) and larval bees (RQ range: 0.94 - 1.90) for all labeled uses exceed the Agency's chronic risk LOC of 1.0 for bees. The chronic LOAEL for larval bees is based on a 19% reduction in adult bee emergence and is two times above the NOAEL used to calculate the RQs. The chronic LOAEL for adult bees is based on a 30% reduction in food consumption at the lowest dose tested. Chronic risks of concern for adult bees extend up to 203 feet and 13 to 23 feet from the treated field when L-glufosinate is applied via aerial equipment and ground equipment, respectively, based on the same spray DSD and boom height assumptions considered in the mammal spray drift assessment.

Potential risks of concern are identified for terrestrial invertebrates other than bees based on a screening-level assessment with upper-bound residue values for both contact and dietary exposure. Chronic dietary RQs for all labeled uses exceed the Agency's chronic risk LOC (1.0) for adult (RQ range: 0.30-6.49) and larval (RQ range: 0.08-2.38) terrestrial invertebrates other than bees. There are no acute dietary-based risks of concern for these terrestrial invertebrates; however, contact exposure from all labeled uses poses an acute risk of concern. The identified risks are based on effects in individuals; however, semi-field studies further suggest that adverse effects resulting from exposure due to labeled L-glufosinate uses may manifest in non-bee terrestrial invertebrate populations and communities. Given the herbicidal activity of glufosinate, indirect effects on terrestrial invertebrates due to loss of forage are possible.

All the labeled uses for L-glufosinate pose a potential risk to upland terrestrial (LOC = 1.0; RQ range: 0.53-5.66) and semi-aquatic (LOC = 1.0; RQ range: 0.80-10.4) dicotyledonous (dicot) and monocotyledonous (monocot) plants. Exposure from spray drift alone exceeds the Agency's LOC for risk to terrestrial plants up to 89 and 10 feet from the field for aerial and ground applications, respectively, from the field edge when considering spray drift requirements on the final label.

1.3 Environmental Fate and Exposure Summary

Since the physical chemical properties of different enantiomers of a compound are identical outside of a chiral environment, except for the direction of rotation of plane polarized light, the physical chemical properties of the racemic mixture and the enriched isomer of glufosinate are expected to the be the same. L-glufosinate is classified as highly water soluble and as mobile to highly mobile in soil based on the FAO classification system (FAO, 2000). Glufosinate is not likely to volatilize from soil or water, based on low measured vapor pressure. Based on measured bioconcentration factor (BCF) values, the compound is not expected to bioconcentrate significantly in aquatic organisms (USEPA, 2010a).[3] Based on the high mobility and solubility of the compound, glufosinate may be transported to surface water via spray drift and runoff or to groundwater via leaching.

The compound is considered non-persistent to slightly persistent to aerobic soil systems (time to 50% dissipation (DT_{50} = 1.71 to 23 days) and degrades more rapidly in aerobic aquatic systems (DT_{50} = 1 to 87 days) than in anaerobic aquatic systems (DT_{50} = 415 days) (Goring *et al.*, 1975). The compound is stable to hydrolysis at environmentally relevant pH values and to aqueous photolysis at pH 5 and 7. L-Glufosinate did not convert to D-glufosinate in any of the aerobic soil metabolism, aqueous hydrolysis, or aqueous photolysis studies conducted on the enriched isomer. While unextracted residues were present in >10% of the applied in several studies, the extraction protocols in the recently submitted studies used polar and non-polar extraction solvents that extracted <1% additional material. Therefore, the unextracted residues are considered bound and are not anticipated to contribute to dissolved residues in water.

In terrestrial field dissipation studies, glufosinate dissipated with DT_{50} values ranging from 1.1-23 days, which is consistent with the measured aerobic soil metabolism DT_{50} values. The degradates MPP (3-methylphosphinico-propionic acid) and MPA (2-methylphosphinico-acetic acid) were detected in multiple field dissipation studies. While the compound is classified as mobile-to-highly mobile in soil, glufosinate residues were not detected below 6-inch soil depth in loam or clay soils, or below 24-inch soil depth in sandy soil. However, this may be due to the relatively high percentage of organic matter (2%-3%) in the test soils. Glufosinate has been detected at a maximum concentration of 3.2 µg/L in surface water and 4.5 µg/L in groundwater in non-targeted monitoring studies. These detections reflect usage of racemic glufosinate, as there are no currently registered enantiomerically enriched glufosinate formulations.

[3] Compounds with a bioconcentration factor (BCF) greater than 1,000 (log BCF >3) are considered to have to the potential to bioaccumulate in organisms.

1.4 Ecological Effects Summary

EFED combined new and previously available toxicity data for the three glufosinate active ingredients (*i.e*., racemic glufosinate ammonium, L-glufosinate ammonium, and L-glufosinate acid) into a single toxicity database to support ecotoxicity characterization and risk evaluation for all glufosinate ais. These data indicate that L-glufosinate technical grade active ingredient (TGAI) is practically non-toxic to freshwater fish, estuarine/marine fish, and freshwater invertebrates on an acute exposure basis, and is moderately toxic to estuarine/marine invertebrates on an acute exposure basis. Chronic toxicity is comparable between freshwater fish and invertebrates; however, the most sensitive chronic toxicity measurement endpoint in freshwater fish is survival (*i.e.,* 12% decrease in post-hatch survival); whereas impaired reproduction (*i.e.,* 47% decrease in the number of offspring per female) is the most sensitive measurement endpoint in freshwater invertebrates. Estuarine/marine invertebrates are three orders of magnitude more sensitive than both freshwater fish and freshwater invertebrates on a chronic exposure basis and the most sensitive measurement endpoints in this taxon are 9-30% reductions in reproduction and growth. In lieu of data on aquatic-phase amphibians, toxicity data for freshwater fish are used as a surrogate to evaluate risk to aquatic stages of this taxon.

Of the non-vascular aquatic plant species tested, cyanobacteria (*e.g*., *Anabaena flos-aquae*) are the most sensitive to glufosinate exposure. The available data indicate though that vascular aquatic plants (*e.g*., *Lemna gibba*) are ~23 times less sensitive to glufosinate exposure compared to the most sensitive non-vascular aquatic plant. Final biomass and yield are the most sensitive measurement endpoints in both non-vascular and vascular plants, respectively.

Glufosinate is characterized as slightly toxic to birds on an acute oral and subacute dietary exposure basis. No adverse effects were observed up to the highest dietary concentration tested (364 mg ae/kg-diet) in the 22-week reproductive toxicity study on the Mallard Duck (*Anas platyrhynchus*). In the 20-week reproductive study with the Bobwhite Quail (*Colinus virginianus*), a 7% reduction in the ratio of live-to-viable embryos relative to controls was observed at a dietary dose 2.4 times above the highest dose tested in the Mallard Duck. In lieu of data on reptiles and terrestrial-phase amphibians, toxicity data for birds are used as a surrogate to evaluate risk to these taxa.

Glufosinate is characterized as slightly toxic to mammals on an acute oral exposure basis. Chronic dietary exposure in mammals at doses $\geq$16.5 mg ae/kg/day results in an 11-37% decrease in the number of viable pups per litter across two generations.

Glufosinate is practically non-toxic to young adult honey bees (*Apis mellifera*) on both an acute contact and oral exposure basis and the compound is practically non-toxic to larval honey bees on an acute oral exposure basis. Chronic oral exposure in adult honey bees for 10 days resulted in decreased food consumption at all doses tested and increased mortality at higher doses. Adult bee emergence was the most sensitive endpoint following chronic oral exposure of honey bee larvae with evidence of pupal and larval mortality at higher dose levels. Since honey bees

serve as a surrogate for other *Apis* and non-*Apis* bees, the toxicity data and subsequent risk estimates for honey bees applies to these other bee species as well.

Toxicity data for non-bee terrestrial invertebrates are available for contact exposure to parasitic wasps (*Aphidius rhopalosiphi* and *Aphidius colemani*), the predatory mite (*Phytoseiulus persimilis*), and the predacious flower bug (*Orius strigicolli*s). In one study, a significant increase in mortality was observed in parasitic wasps after 48-hours of contact exposure to residues on a petri dish resulting from spray applications at a rate of $\geq$0.041 lbs ae/A. In other studies, mortality rates of 20-100% were observed in parasitic wasps, predatory mites, and flower bugs after 48 hours of contact exposure to the only concentration tested (20.5 µg ae/cm^2) with the parasitic wasps and predatory mites exhibiting the greatest sensitivity. Toxicity data for soil-dwelling invertebrates is limited to findings from an open literature study on earthworms (*Eisenia fetida*). Based on the findings from this study, glufosinate is moderately toxic to earthworms on an acute contact basis. Further, the authors report a 14-day LC_{50} of 148 mg ae/kg-soil (reported as 162.2 mg ai/kg-soil) from exposure to artificial soil.

Terrestrial plant toxicity data are available for both L-glufosinate ammonium salt and L-glufosinate acid typical end-use products (TEP). Dry weight is the most sensitive measurement endpoint for both monocot and dicot seedlings following foliar exposure. Survival is the most sensitive measurement endpoint for dicot seeds exposed prior to plant emergence, whereas the most sensitive measurement endpoint could not be determined for monocot seeds. Dicots tend to be more sensitive than monocots, and both monocots and dicots appear to be more susceptible to foliar exposure after emergence compared to exposure in the soil pre-emergence. There is also some variability in response among terrestrial plants to the two L-glufosinate ai TEPs. The L-glufosinate acid TEP exhibits greater toxicity to dicot plants; whereas, L-glufosinate ammonium TEP is more toxic to monocots based on the concentrations resulting in 25% inhibition (IC_{25}) values.

Both technical registrants completed reviews of U.S. Patents for any claims of greater-than-additive (GTA) effects associated with L-glufosinate. Based on these reviews, there are no data at this time to support claims of GTA or synergistic interactions of L-glufosinate with other active ingredients.

Table 1. Summary of Risk Quotients (RQs) for Taxonomic Groups from the Labeled Uses of L-glufosinate on Conventional and Glufosinate-resistant Corn, Sweet corn, Soybean, Cotton, and Canola.

Taxa	Exposure Duration	Risk Quotient (RQ) Range[1]	RQ Exceeding the LOC	Additional Information/ Lines of Evidence
Freshwater Fish	Acute	Not calculated	No	RQs are not calculated due to non-definitive endpoint – no mortality in study. Daily mean EECs are over three orders of magnitude below the highest concentration tested in the study where no mortality was observed.
	Chronic	<0.01	No	The RQs are based on a NOAEC, there was a 12% reduction in post-hatch survival at the LOAEC.
Estuarine/ Marine Fish	Acute	Not calculated	No	RQs are not calculated due to non-definitive endpoint – no mortality in study. Daily mean EECs are over three orders of magnitude below the highest concentration tested in the study.
	Chronic	No data	No data	Estimated that estuarine/marine fish would have to be over an order of magnitude more sensitive than freshwater fish to exceed the Agency's chronic risk LOC.
Freshwater Invertebrates (Water-Column Exposure)	Acute	Not calculated	No	Daily mean EECs are over three orders of magnitude below the highest concentration tested in the acute toxicity study where no mortality was observed.
	Chronic	<0.01	No	The RQs are based on a NOAEC, there was a 47% reduction in number of offspring per female at the LOAEC.
Estuarine/ Marine Invertebrates	Acute	<0.01	No	--
	Chronic	FP: <0.01-0.42 EOF: 0.58-**2.01**	Yes, EOF only	RQ is based on a NOAEC, there is a 30% reduction in offspring/female, 9% decrease in length, and 22% decrease in dry weight at the LOAEC. LOC exceedances based on edge-of-field EECs only.
Freshwater and Estuarine/Marine Invertebrates (Sediment Exposure)	Acute and Chronic	No data	No data	Based on the chemical/physical characteristics of L-glufosinate, benthic invertebrate toxicity data are not triggered. Exposure in the sediment pore water/overlying water is expected to be similar or lower than the water column; therefore, water column-based risk estimates are considered protective for benthic invertebrates.

Taxa	Exposure Duration	Risk Quotient (RQ) Range[1]	RQ Exceeding the LOC	Additional Information/ Lines of Evidence
Mammals	Acute	Dose-based: <0.01–0.07	No	RQs based on upper-bound exposure estimates fall below the LOC for acute risk to mammals for all uses. The RQ is based on a rat LD_{50} of 954 mg ae/kg bw. There are some uncertainties in the acute RQ estimates because the LD_{50} is based on a small sample size, test doses were not analytically verified, and it is unclear if the reported nominal values were adjusted for purity. There are no exceedances for non-listed species.
	Chronic	Dose-based: 0.04–**12.1** Dietary-based: 0.05–**1.40**	**Yes**	Dose-based RQs exceed chronic risk LOC for all labeled uses. The RQ is based on a NOAEL above which there was decrease in the number of viable pups/litter (11-37%) across two generations at the LOAEL. RQs exceed the Agency's chronic risk LOC for all labeled uses when calculated based on the LOAEL. Chronic LOC exceedances for all labeled uses are still observed when using mean Kenaga nomogram values. Residues on food items are expected to result in risk estimates which exceed the Agency chronic risk LOC for up to 90 days (varies based on food item and use pattern). RQs exceeds the Agency chronic risk LOC up to 76 and 7 feet from the treated field when L-glufosinate is applied with aerial and ground equipment, respectively.
Birds	Acute	Not calculated	No	RQs not calculated due to non-definitive endpoint – 10-40% mortality in dietary study at concentrations 3 times above the upper-bound dietary EECs.

Taxa	Exposure Duration	Risk Quotient (RQ) Range[1]	RQ Exceeding the LOC	Additional Information/ Lines of Evidence
	Chronic	Dietary-based: 0.01–0.42	No	The RQs are based on a NOAEC from an avian reproduction study. No effects were observed in the study; therefore, the NOAEC is the highest concentration tested. There is some uncertainty in RQs estimated based on the NOAEC because no data are available to evaluate chronic toxicity at higher dietary concentrations; however, based on uses and rates, dietary-based EECs are not anticipated to exceed the dietary concentrations tested in the available study. There is some uncertainty in RQs estimated based on the NOAEC because no data are available to evaluate chronic toxicity at higher dietary concentrations; however, based on labeled uses and rates, dietary-based EECs are not anticipated to exceed the dietary concentrations tested in the available study. Reproductive effects were observed in other avian species tested but only at dietary concentrations 3 times above the avian dietary EECs.
Bees[2]	Acute Adult	Not calculated	No	No mortality in either acute contact or oral toxicity studies with adult bees.
	Chronic Adult	**20.0-40.8**	**Yes**	RQs exceed chronic risk LOC for all uses. RQs exceed chronic risk LOC for all labeled uses. A NOAEL could not be established in the study due to statistically significant ($p<0.05$) reductions in food consumption at all dose levels; therefore, the RQs are based on the EC_{10} (which was determined to be protective of the lowest detectable difference from controls). There is a 30% decrease in food consumption at the lowest observed adverse effect level (LOAEL). RQs exceed the chronic risk LOC when based on the LOAEL. These results demonstrate that the exposure from most uses could result in decreased food consumption which may also impact growth and foraging behavior.
	Acute Larval	Not calculated	No	An acute (single dose) larval toxicity study is not available; therefore, the acute larval risk assessment is based on the 8-day larval LD_{50} value from the chronic (repeat dose) larval toxicity study. RQs not calculated due to non-definitive endpoint – maximum 31% mortality in study.

Taxa	Exposure Duration	Risk Quotient (RQ) Range[1]	RQ Exceeding the LOC	Additional Information/ Lines of Evidence
	Chronic Larval	**0.94-1.90**	**Yes**	RQs exceed chronic risk LOC for all uses. RQs exceed chronic risk LOC for all labeled uses. The RQ is based on a NOAEL above which there was a decrease in adult emergence (19%) at the LOAEL.
Terrestrial Invertebrates (non-bees)	Acute	Not Calculated	See Additional Information	Acute oral toxicity endpoints are non-definitive; therefore, RQs could not be estimated. Application of L-glufosinate at the maximum rates for all uses is expected to produce residues on-field that will cause significant mortality to terrestrial invertebrate species that encounter surfaces impacted by the spray application. Residues that drift off-site during spray application are expected to exceed the acute toxicity endpoint up to 7 and 53 feet from the field for ground and aerial applications, respectively.
	Chronic	Dietary-based: Adult = **0.30-6.49** Larval = **0.08-2.38**	**Yes**	RQs exceed chronic risk LOC for all uses. RQs exceed chronic risk LOC for all labeled uses. Semi-field studies further suggest that adverse effects resulting from L-glufosinate applications may manifest in non-bee terrestrial invertebrate populations and communities.
Aquatic Plants	N/A	Non-listed FP: 0.01–**1.09** WL: 0.07–**6.42**	**Yes**	Wetland/EOF RQs exceed LOC for non-listed non-vascular species for all uses. Wetland/EOF RQs exceed LOC for non-listed non-vascular species for all labeled uses. Farm pond RQs also exceed the non-listed non-vascular species LOC for use on GMO-corn. Blue-green algae are the most sensitive non-vascular aquatic species tested by several orders of magnitude. Given the low risk to other non-vascular aquatic plant species, impacts to non-vascular plant communities are not expected. Aquatic vascular plants are ~23 times less sensitive than non-vascular aquatic plants. There are no other LOC exceedances for vascular plant species anticipated from the uses. There are no other LOC exceedances for vascular plant species anticipated from the labeled uses.

Taxa	Exposure Duration	Risk Quotient (RQ) Range[1]	RQ Exceeding the LOC	Additional Information/ Lines of Evidence
Terrestrial Plants	N/A	Non-listed Upland: 0.53-**5.66** Semi-Aquatic: 0.80-**10.4**	**Yes**	RQs for all uses for L-glufosinate are greater than the LOC for risk to non-target non-listed upland terrestrial and semi-aquatic dicotyledonous and monocotyledonous plants. RQs for all labeled uses for L-glufosinate are greater than the LOC for risk to non-target non-listed upland terrestrial and semi-aquatic dicotyledonous and monocotyledonous plants. Exposure from spray drift alone exceeds the Agency's LOC for terrestrial plants up to 89 and 10 feet from the field for aerial and ground applications, respectively from the field edge when considering spray drift requirements on the label.

ae = acid equivalent; EC_{10}=concentration resulting in 10% effect relative to controls; EEC=estimated environmental concentration; EOF=edge of field; FP = farm pond; LOAEC=lowest observed adverse effect concentration; LOAEL=lowest observed adverse effect level; NOAEC= no observed adverse effect concentration; NOAEL=no observed adverse effect level; WL = wetland.

Level of Concern (LOC) Definitions:

Terrestrial Vertebrates: Acute =0.5; Chronic=1.0; Chronic = 1

Terrestrial Invertebrates: Acute=0.4; Chronic=1.0; Chronic = 1

Aquatic Animals: Acute=0.5; Chronic=1.0; Chronic = 1

Plants: 1.0

[1] RQs reflect exposure estimates for parent and maximum application rates allowed on labels.

[2] RQs for terrestrial invertebrates are applicable to honey bees (*Apis mellifera*), which are also a surrogate for other species of *Apis* and non-*Apis* bees. Risks to other terrestrial invertebrates (*e.g.,* earthworms, beneficial arthropods) are only characterized when toxicity data are available.

1.5 Final Effects Determination

For the final effects determination included in this BE, EPA first evaluates whether the labeled uses will have No Effect (NE) or if the labeled uses May Affect (MA) an individual of such species or habitat (separate determinations made for each species and critical habitat). For listed species and CHs where EPA makes a MA determination, EPA performs additional analyses to determine if the labeled uses of L-glufosinate are likely to adversely affect (LAA) or not likely to adversely affect (NLAA) those listed species. EPA makes NLAA determinations when effects are either discountable (highly unlikely to occur), insignificant, or wholly beneficial. For those listed species and CHs where EPA determined that there is likely to adversely affect one or more individuals or the CH, the effect determinations also include EPA's prediction as to whether the labeled uses of L-glufosinate have a potential likelihood of future jeopardizing (J) a listed species or adversely modifying (AM) any CH (collectively abbreviated as J/AM), consistent with 50 C.F.R. §402.40(b)(1). While EPA is not required to include J/AM analyses in its effects determinations, EPA is including this analysis to improve the consultation process. EPA used the draft and final biological opinion (BiOp) for malathion, Enlist™ One, and Enlist™ Duo (USFWS, 2021; USFWS, 2022; USFWS 2023) as a guide in this assessment to predict those species and

CHs where the U.S. Fish and Wildlife Service (USFWS) is likely to determine the labeled use of L-glufosinate results in jeopardy or adverse modification. This final BE also considers elements from recent National Marine Fisheries Service (NMFS) BiOps for malathion, diazinon, and chlorpyrifos (NMFS 2022) as they pertain to listed species under the purview of NMFS.

Details on the method, models, and tools used for making NE, NLAA, LAA and predictions of the potential likelihood of future J/AM are in **Section 8**. While EPA is predicting potential likelihood of future J/AM as part of its effects determinations, the Services are responsible for making the final J/AM findings in any biological opinions.

Based on EPA's FIFRA screening-level assessment, there are risk concerns for aquatic invertebrates (chronic RQ range: <0.01-2.01), bees (chronic RQ range: 0.94-40.8), non-bee terrestrial invertebrates (chronic RQ range: 0.08-6.49), mammals (chronic RQ range: 0.04-12.1), non-vascular aquatic plants (RQ range: [0.01 – 6.42]; upland terrestrial (RQ range: listed [0.67-5.66] and semi-aquatic (RQ range: listed [1.02-10.4) plants. For further information on the risk analysis, refer to **Section 4**.

EPA assesses species that are listed as endangered or threatened and CH that are designated as final in its effects determinations. For this BE, EPA focused on the 1,715 species and 826 CHs that were listed as of February 2022. Since February 2022, two species have been delisted due to recovery, one of which also had designated CH. Since determinations are not made for delisted species, in this BE EPA made effects determinations and predictions of the potential likelihood of future J/AM for 1,713 listed species and 825 CH.

EPA made NE determinations for 665 species and 476 CHs, based primarily on low overlap, and/or no direct toxicity and no dependency on mammals, invertebrates, or plants for prey, pollination, habitat, and dispersal (PPHD) such that an effect is not reasonably certain to occur. For those listed species and CHs with MA determinations, EPA distinguished whether L-glufosinate is likely to affect an individual when considering the species-specific habitat, life history, and other considerations of exposure and toxicity. EPA made NLAA determinations for 411 listed species and 152 CHs. EPA made NLAA determinations when an effect is discountable, insignificant, or beneficial (where discountable is defined as "extremely unlikely to occur" and insignificant means that the impact is so small that take does not occur). A majority of the NLAA determinations were based upon low overlap (<1%) after refining the exposure area to account for adverse effects to individuals and CH, when exposure is likely insignificant due to the habitat, or when specific physical and biological features (PBFs) for the CHs are not likely to be impacted by L-glufosinate. EPA made LAA determinations for 637 listed species and 197 CHs. For these species, they were either listed plants that are directly affected or listed animals that rely upon plants for forage/prey and/or habitat. For the 197 CHs with LAA determinations, adverse effects on essential PBFs (or inferred PBFs) related to habitat quality for the listed species, plants for forage and/or habitat, and water quality were the primary factors leading to the determinations. Effects determinations for listed species and designated CHs are summarized in **Table 2**.

EPA further evaluated the LAA species and CH and made predictions about the potential likelihood of future jeopardy to any listed species or adverse modification of any CH from the proposed labeled use of L-glufosinate before consideration of any identified mitigations to address these predictions. Of the 637 species with LAA determinations, EPA predicted a potential likelihood of future jeopardy (J) from labeled uses for 60 listed species. EPA also predicted a potential likelihood of future adverse modification (AM) of 38 CHs from labeled uses. Predictions of the potential likelihood of future J/AM are primarily for listed plants, listed animal species that are highly dependent on plants for forage and/or habitat, and CHs with essential PBFs related to plants. All listed species and CH that are predicted to have a potential likelihood of future J/AM have medium to high overlap with at least one agricultural use data layer (UDL) within the likely exposure area, a medium to high magnitude of effect, and most of the species are classified as having medium to high vulnerability. The predicted potential likelihood of future J/AM for listed species and designated CHs is summarized in **Table 2.** EFED has finalized the effects determinations in the BE after considering comments during the public comment period. If the EPA determines that the uses meet the FIFRA standard, then EPA will initiate formal consultation with the Services because the final effects determinations include May Affect Likely to Adversely Affect determinations.

Table 2. Number of Listed Species Effects Determinations and Predictions of Potential Likelihood of Future Jeopardy or Adverse Modification by Taxon[1] from Labeled Uses of L-glufosinate on Conventional and Glufosinate-resistant Corn, Sweet corn, Soybean, Cotton, and Canola.

Taxon	Number of Species/CH[2]	NE	NLAA	LAA, Predicted Not Likely J/AM	LAA, Predicted Likelihood of J/AM
Amphibians[2]	38	10	4	21	3
Aquatic Invertebrates	174	0	39	134	1
Birds	98*	17	49	31	1
Fish	169*	1	63	98	7
Mammals	94	24	42	26	2
Plants	938	533	175	195	35
Reptiles[3]	45	8	16	19	2
Terrestrial Invertebrates[4]	157	72	23	53	9
Total Listed Species	1,713	665	411	577	60
Designated Critical Habitat	825*	476	152	159	38

*The total number of listed species and designated critical habitat were 1,715 and 826, respectively, as of February 2022. One bird species and one fish species have been delisted due to recovery since that date. Additionally, the delisted fish species had designated CH. Delisted species and CH did not receive determinations; therefore, the total number of species and CH evaluated in this Biological Evaluation (BE) are 1,713 and 825, respectively.

[1] CH = designated critical habitat; NE = no effect; NLAA = not likely to adversely affect; LAA = likely to adversely affect; J = predicted potential likelihood of future jeopardy; AM = predicted potential likelihood of future adverse modification

[2] Reflects the species federally listed as endangered or threatened and critical habitats designated as of February 16, 2022.

[3] "Amphibians" and "Reptiles" include those species that have both a terrestrial and aquatic phase.

[4] "Terrestrial Invertebrates" includes species which have both a terrestrial and aquatic phase.

The registrant proposed, and EPA considered several mitigations for the uses of L-glufosinate to avoid the predicted potential likelihood of future jeopardy/adverse modification and to reduce incidental take and adverse effects to plants which are likely to result from this action without these mitigations. To address direct effects to the only listed plant that is expected to be present on agricultural fields (*i.e.*, Spring Creek bladderpod (*Lesquerella perforate)*) EPA determined that prohibiting spray applications to certain HUC-12 watersheds in Wilson County, TN between the months of September and early May when the listed plant is most likely to be present on agricultural fields would address the potential effects. To address potential effects to the critical habitat for the whorled sunflower (*Helianthus verticillatus*), EPA determined that applications within 60 m of the organism's designated critical habitat must be prohibited.

Mitigations to address direct effects to listed plants that are not present on agricultural fields but are near these use sites and PPHD effects to listed animal species that rely on plants, include wind directional spray drift buffers from surrounding habitat, aimed at minimizing spray drift from ground and aerial applications. To minimize runoff from use sites EPA considered labeling language that prohibits application when the soil is saturated and that one of several practices be employed to reduce runoff including: rain restrictions, contour farming, cover crops, contour buffer strips, vegetative filter strips, mulching with natural materials, reduced tillage management, terrace farming, grassed waterways, and maintaining or establishing riparian areas. EPA determined that implementing these mitigation measures as instructed on the label will avoid the predicted potential likelihood of future jeopardy/adverse modification and reduce incidental take and adverse effects to plants resulting from the use of L-glufosinate.

1.6 Identification of Data Gaps

Table 3 through **Table 5** summarize the status of the environmental fate and ecological effect data requirements specified in Title 40 Part 158 of the Code of Federal Regulations (40CFR158) (sections §630, §660 and §1300) to support the registration of L-glufosinate on glufosinate-resistant corn, sweet corn, soybean, cotton, and canola. Currently all relevant data requirements specified in 40 CFR Part 158 have been completed, waived, or not triggered for L-glufosinate.

Table 3. L-Glufosinate Terrestrial and Aquatic Non-target Animal Data Requirements to Support Section 3 New Active Ingredients.

Guideline Number and Study Type		Required	Data Requirement Status
Birds (surrogates for terrestrial amphibians and reptiles)			
850.2100 – Avian Acute Oral Toxicity Test	Passerine	Yes	Waived
	Upland Game or Waterfowl	Yes	Complete
850.2200 – Avian Sub-acute Dietary Toxicity Test	Waterfowl	Yes	Complete
	Upland Game Bird	Yes	Complete
850.2300 – Avian Reproduction Test	Waterfowl	Yes	Complete
	Upland Game Bird	Yes	Complete

Guideline Number and Study Type		Required	Data Requirement Status
Mammals			
850.2400 – Wild Mammal Toxicity Testing		No[1]	Not Triggered
850.2500 – Field Testing for Terrestrial Wildlife		No[1]	Not Triggered
Aquatic Invertebrates Acute Toxicity (Water-Column Exposure)			
850.1010 – Aquatic Invertebrate Acute Toxicity Test, Freshwater Daphnids		Yes	Complete
850.1025 – Oyster Acute Toxicity Test (Shell Deposition)		Yes	Complete
850.1035 – Mysid Acute Toxicity Test		Yes	Complete
850.1045 – Penaeid Acute Toxicity Test		No[1]	Not Triggered
850.1055 – Bivalve Acute Toxicity Test (Embryo-Larval)		No[1]	Not Triggered
Fish Acute Toxicity (surrogates for aquatic-phase amphibians)			
850.1075 – Freshwater Fish Acute Toxicity Test	Coldwater species	Yes	Complete
	Warmwater species	Yes	Complete
850.1075 – Saltwater Fish Acute Toxicity Test		Yes	Complete
Aquatic Invertebrate Chronic Toxicity			
850.1300 – Daphnid Chronic Toxicity Test		Yes	Complete
850.1350 – Mysid Chronic Toxicity Test		Yes	Complete
Fish Chronic Toxicity			
850.1400 – Freshwater Fish Early Life Stage (ELS) Toxicity Test		Yes	Complete
850.1400 – Estuarine/ Marine Fish Early Life Stage (ELS) Toxicity Test		No[1]	Not Triggered
850.1500 – Fish Life Cycle Toxicity Test	Freshwater	Yes	Waived
	Estuarine/Marine	No[1]	Not Triggered
Bioconcentration Factor (BCF) Study			
850.1710 – Oyster Bioconcentration Factor (BCF)		No[1]	Not Triggered
850.1730 – Fish Bioconcentration Factor (BCF)		Yes	Complete
Aquatic Invertebrates Acute Toxicity (Benthic Exposure)			
850.1735 – Spiked Whole Sediment 10-Day Toxicity Test, Freshwater Invertebrates	Midge	No[1]	Not Triggered
	Freshwater Amphipod	No[1]	Not Triggered
850.1740 – Spiked Whole Sediment 10-Day Toxicity Test, Saltwater Invertebrates		No[1]	Not Triggered
Non-guideline – Whole sediment: chronic (28-65-Day life cycle) Toxicity Test	Freshwater midge	Yes	Complete
	Freshwater amphipod	Yes	Complete
	Estuarine/Marine amphipod	Yes	Complete
Other Aquatic Studies			
850.1850 – Aquatic food chain transfer		No[1]	Not Triggered
850.1950 – Field testing for aquatic organisms		No[1]	Not Triggered
Terrestrial Invertebrate Toxicity (Surrogate for both *Apis* and non-*Apis* bees)			
850.3020 (OECD Test Guideline 214)- Honey Bee [Adult] Acute Contact Toxicity Test		Yes	Complete
OECD Test Guideline 213 – Honey Bee Adult Acute Oral (AAO) Toxicity Test		Yes[2]	Complete

Guideline Number and Study Type	Required	Data Requirement Status
OECD Test Guideline 237 – Larval Honey Bee Acute Oral (LAO) (single dose) Toxicity Test	Yes[2]	Complete
OECD Guidance Document 239 – Larval Honey Bee Chronic Oral (LCO) (repeat dose) Toxicity Test	Yes[2]	Complete
OECD Test Guideline 245 – Honey Bee Adult Chronic Oral (ACO) (repeat dose) Toxicity Test	Yes[2]	Complete
850.3030 – Honey Bee Toxicity of Residues on Foliage	Yes	Complete
OECD Guidance Document 75- Honey Bee Colony Brood Test (Enclosure Study) Under Semi-field Conditions	Yes	Complete
Non-guideline Field Trial of Residues in Pollen/Nectar	Yes	Complete
Non-guideline Semi-field Colony Feeding Study (Oomen *et al*. 1992)	Yes	Complete
850.3040 – Field Testing for Pollinators	No[1]	Not Triggered

NA =not applicable

[1] Per 40 CFR Part 158, specified conditions that require the study are not met.

[2]See EFED guidance on exposure and effects testing for assessing risk to bees. (https://www.epa.gov/sites/default/files/2016-07/documents/guidance-exposure-effects-testing-assessing-risks-bees.pdf)

Table 4. L-Glufosinate Non-target Plant Protection Data Requirements to Support Section 3 New Active Ingredients.

Guideline Number and Study Type		Required	Data Requirement Status
Terrestrial and Wetland Plant Toxicity			
850.4100 – Seedling Emergence and Seedling Growth	Tier 1	Yes	Complete
	Tier 2	No	Complete
850.4150 – Vegetative Vigor	Tier 1	Yes	Complete
	Tier 2	No[1]	Complete
850.4230 – Early Seedling Growth Toxicity Test		No[1]	Not Triggered
850.4300 – Terrestrial Plants Field Study		No[1]	Not Triggered
Aquatic Plant and Algae Toxicity			
850.4025 – Target Area Phytotoxicity		No[1]	Not Triggered
850.4400 – Aquatic Plant Toxicity Test Using *Lemna spp*	Tier 1	Yes	Complete
	Tier 2	No	Complete
850.4450 – Aquatic Plants Field Study		No[1]	Not Triggered
850.4500 – Algal Toxicity Test		Yes	Complete
850.4550 – Cyanobacteria (*Anabaena flos-aquae*) Toxicity Test		Yes	Complete

NA =not applicable

[1] Per 40 CFR Part 158, specified conditions that require the study are not met.

Table 5. L-Glufosinate Environmental Fate Test Data Requirements to Support Section 3 New Active Ingredients.

Guideline Number and Study Type		Required	Data Requirement Status
835.2120 – Hydrolysis		Yes	Complete
835.2240 – Photodegradation in Water		Yes	Complete
850.2410 – Photodegradation in Soil		Yes	Complete
835.2370 – Photodegradation in Air		No[1]	Not Triggered
835.4100 – Aerobic Soil		Yes	Complete
835.4200 – Anaerobic Soil		Yes	Complete
835.4300 – Aerobic Aquatic		Yes	Complete
835.4400 – Anaerobic Aquatic		Yes	Waived
835.1230 – Batch Equilibrium		Yes	Complete
835.1240 – Column Leaching		No[1]	Not Triggered
835.1410 – Volatility Laboratory		No[1]	Not Triggered
835.8100 – Volatility Field		No[1]	Not Triggered
835.6100 – Terrestrial Field Dissipation		Yes	Complete
835.6200 – Aquatic Field Dissipation		No[1]	Not Triggered
835.6300 – Forestry Dissipation		No[1]	Not Triggered
835.7100 – Prospective Groundwater Monitoring		No[1]	Not Triggered
850.6100 – Environmental Chemistry Method/ Independent Laboratory Validation	Soil (supports 835.6100 and monitoring)	Yes	Complete
	Water (supports monitoring)	Yes	Complete
	Sediment (supports monitoring)	No	Not Triggered
Storage Stability	Soil (supports 835.6100)	Yes	Complete
	Water (supports 835.6200)	No[1]	Not Triggered
	(supports 835.6300, 835.6400, and/or 835.7100)	No[1]	Not Triggered
835.6400 – Combination and Tank Mixes		No[1]	Not Triggered
Non-guideline – Comparison of soil taxonomy of global soils to US soils		No[1]	Complete

NA =not applicable

[1] Per 40 CFR Part 158, specified conditions that require the study are not met.

2 Introduction

This screening-level taxa-based Ecological Risk Assessment (ERA) examines the potential ecological risks associated with labeled L-glufosinate uses. While the L enantiomer is believed to be the herbicidally active form, the submitted environmental fate and ecotoxicity data support bridging the fate and toxicity data between the racemic and L-glufosinate for assessing potential risk to non-target species.

The ERA uses the best available scientific information on the use, environmental fate and transport, and ecological effects of L-glufosinate. The general risk assessment methodology is described in the *Overview of the Ecological Risk Assessment Process in the Office of Pesticide Programs* ("Overview Document"; USEPA, 2004). Additionally, the process is consistent with

other guidance produced by the Environmental Fate and Effects Division (EFED) as appropriate.[4] When necessary, risks identified through standard risk assessment methods are further refined using available models and data. This risk assessment incorporates the available exposure and effects data and most current modeling and methodologies. **Section 8** contains a Biological Evaluation (BE) and its associated effects determinations for federally endangered and threatened species and their designated critical habitats based on the federal action, *i.e.*, the registration of the foliar herbicide L-glufosinate for post-emergence control of annual and perennial grass and broadleaf weeds in corn, sweet corn, soybean, cotton, and canola.

3 Problem Formulation

The purpose of the problem formulation is to provide the foundation for the environmental fate and ecological risk assessment being conducted for use of L-glufosinate (USEPA, 2004). The problem formulation identifies the objectives for the risk assessment and provides a plan for analyzing the data and characterizing the risk. The objective of this assessment is to characterize the environmental fate and ecological effects of L-glufosinate and to estimate risk to non-target organisms from the uses of the compound. The objective of this assessment is to characterize the environmental fate and ecological effects of L-glufosinate and to estimate risk to non-target organisms from the labeled uses of the compound.

3.1 Mode of Action

Racemic glufosinate ammonium was first registered in the 2000. Like racemic glufosinate, L-glufosinate is a non-selective foliar herbicide that acts by inhibiting glutamine synthetase needed for the ammonification of glutamate to the amino acid glutamine (Herbicide Resistance Action Committee class 10) (MRIDs 40345632 and 40345633). This disruption in glutamine production leads to cell membrane disruption, buildup of excess ammonia, and death of the cell. Glufosinate is primarily a post-emergence foliar-active herbicide with limited systemic activity and there is no reported residual activity.

The glutamate to glutamine metabolic pathway exists in animals as well as plants; however, animals can compensate for the toxicity with alternative sources of glutamine in the diet. While glufosinate contains an organophosphate moiety, it does not contain the organophosphate ester moiety associated with acetyl cholinesterase (AChE) inhibition in organophosphate insecticides. Glufosinate exposure is not generally associated with detectable AChE inhibition.

[4] Many guidance documents are available at: https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/ecological-guidance-pesticide-risk-assessments and at: https://www.epa.gov/guidance/guidance-documents-managed-office-chemical-safety-and-pollution-prevention-ocspp

3.2 Label and Use Characterization

3.2.1 Label Summary

BASF is proposing the registration of two technical (*i.e.*, BASF L-Glufosinate-Ammonium Technical; 77.62% a.i.; EPA File Symbol 7969-UTL; BASF L-Glufosinate-Ammonium Technical Product; 89.6% a.i.; EPA File Symbol 7969-UOI), one manufacturing product (*i.e.*, BASF L-Glufosinate-Ammonium Manufacturing Use Product; 50% a.i.; EPA File Symbol 7969-UOO), and one end-use product (*i.e.*, BASF L-Glufosinate-Ammonium 211; 18.7% a.i.; EPA File Symbol 7969-LNN). MITSUI is proposing one technical (*i.e.*, L-Glufosinate Free Acid; 92.3% a.i.; EPA File Symbol 86203-GE) and one end-use product (*i.e.*, L-Glufosinate Liquid Formulation; 10.26% a.i.; EPA File Symbol 86203-GG). Both end-use products are soluble liquid (SL) formulations labeled for use as pre-plant/pre-emergence burndown herbicides on a range of agricultural crops, post-emergence weed control and seed propagation in glufosinate-resistant canola, corn, cotton, and soybeans. The labeled use patterns for L-glufosinate are summarized in **Table 6**. Application rates for L-glufosinate are given as both ammonium salt application rate and the glufosinate acid equivalent (ae) application rate. The ERA and BE consider only the labeled agricultural uses mentioned on BASF's end-use product BASF L-Glufosinate Ammonium 211 and MITSUI's end-use product L-Glufosinate Liquid Formulation on conventional and glufosinate-resistant corn, sweet corn, soybean, cotton, and canola.

L-glufosinate can be applied to both glufosinate tolerant and glufosinate sensitive crops. For applications to glufosinate-tolerant corn, cotton, canola, and soybeans, both preplant/pre-emergence burndown applications and post-emergence in season applications can be made in the same year. It may also be applied to fallow fields and/or post-harvest where glufosinate tolerant or glufosinate sensitive corn, cotton, canola, and soybeans are grown. The maximum combined application rate of both pre- and post-emergence applications cannot exceed the maximum annual application rate for the target crop listed in **Table 6**.

Restrictions that apply to the label and use pattern:

- Minimum of medium or coarser droplet size distribution for both aerial and ground applications
- Do not exceed a boom height of 24 inches above target pest or crop canopy.

3.2.2 Label Uncertainties

The final L-glufosinate labels indicate that it can be used for cotton seed propagation; however, cotton seed propagation-specific instructions are not provided on all label with the use pattern. In the absence of information, EFED considered the submitted cotton seed propagation-specific use instruction to be representative of all cotton seed propagation uses for aquatic modeling. **Appendix B** provides a complete list of the model input parameters.

Table 6. Summary of Selected Maximum Labeled Use Patterns for L-Glufosinate.

Use Site/ Location	Form	App Target	App Type	App Equip	App Time	Max Single Rate lbs ae/A[1]	Max # App/yr	Max Annual Rate lbs ae/A/year[1]	MRI (d)	PHI (d)	Comments (*e.g.*, geographic/application timing restrictions, pollinator-specific language)	Drift Restrictions
Burndown and Non-Glufosinate Tolerant Crop Use Patterns - May be combined with the In crop Use Pattterns.[2]												
Canola	S	Weed Foliage	Broadcast	A, G	Pre	0.36	1	0.36	NA	NS	-	Medium or Coarser DSD
Sweet Corn				A, G	Pre	0.36	1	0.36	NA	NS	Not for use in CA	
Field Corn				A, G	Pre	0.36	1	0.36	NA	NS		
Cotton				A, G	Pre	0.36	1	0.60	10[2]	70	Cotton Application Pattern 1 label instructions for combined pre- and post-emergent applications.	
				Hooded Sprayer	Post	0.24	1		NA	70		
				A, G	Pre	0.24	1	0.73[2]	10[2]	70	Cotton Application Pattern 2 label instructions for combined pre- and post-emergent applications	
				Hooded Sprayer	Post	0.24	2			70		
Soybean				A, G	Pre	0.36	1	0.36	NA	NS	-	
Fallow Fields/Post -harvest				A, G	Post	0.36	1	0.36	NA	NS	--	
Glufosinate-Resistant Crop Use Patterns												
Canola	S	Weed Foliage	Broadcast	A, G	Post	0.24	2	0.73[2]	7[2]	65	Not for use in AL, DE, GA, KY, MD, NJ, NC, SC, TN, VA, or WV	Medium or Coarser DSD
Sweet Corn				A, G	Post	0.18	2	0.36[2]	7[2]	50 ears, 55 stovers	Not for use in CA	
Field Corn				A, G	Post	0.36	2	0.73[2]	7[2]	60 forage, 70 grain and fodder		
Cotton				A, G	Post	0.36	1	0.60[2]	NA	70	Not for use in FL south of Tampa or in HI outside of test plots or breeding nurseries	
				A, G	Post	0.24	2	0.73[2]	10[2]	70		

Use Site/ Location	Form	App Target	App Type	App Equip	App Time	Max Single Rate lbs ae/A[1]	Max # App/yr	Max Annual Rate lbs ae/A/year[1]	MRI (d)	PHI (d)	Comments (*e.g.*, geographic/application timing restrictions, pollinator-specific language)	Drift Restrictions
Soybean				A, G	Post	0.36	2	0.73[2]	5[2]	70	-	
Seed Propagation												
Canola	S	Weed Foliage	Broadcast	A, G	Post	0.24	3	0.73	NS	65	Not for use in AL, DE, GA, KY, MD, NJ, NC, SC, TN, VA, or WV	Medium or Coarser DSD
Corn (field and sweet corn)				A, G	Post	0.18	2	0.36	10	NS	Not for use in CA	
Cotton				A, G	Post	0.36	3	0.73	10	70	Not for use in FL south of Tampa or in HI outside of test plots or breeding nurseries Can be applied 3 time per year when using reduced rates.	
Soybean				A, G	Post	0.36	3	0.72	5	NS	Can be applied 3 time per year when using reduced rates.	

App=application; equip=equipment NS = not specified; NA = not applicable; S = Solution; MRI = minimum retreatment interval; Pre = Pre-emergence relative to the crop; Post = Post-emergence relative to the crop; PHI=preharvest interval; A=aerial; G=ground; ai=active ingredient; ae = acid equivalents; CC=crop cycle; d=day; DSD = droplet size distribution; - = no comment

[1] Acid equivalents application rate calculated from ammonium salt application rate via molecular weight conversion factor using the following equation: acid equivalent application rate = ammonium salt application rate x (glufosinate acid molecular weight/glufosinate ammonium salt molecular weight) = ammonium salt application rate x (181.13/198.16) = ammonium salt application rate x 0.914

[2] Can combine pre-emergence (burndown) and post-emergence applications up to the maximum annual application rate for the glufosinate-resistant crop use pattern.

3.3 Residues of Concern

Major degradates of glufosinate include MPP (3-methylphosphinico-propionic acid), MPA (2-methylphosphinico-acetic acid), NAG (2-acetamido-4-methylphosphinico-butanoic acid), HOE 086486 (3-methylphosphinico-3-oxo-propionic acid) and carbon dioxide. Fate studies identified one minor degradate, HOE 065594 (4-methylphosphinico-2-oxo-butanoic acid). While fate studies detected several other degradates, they were not identified.

The Office of Pesticide Programs (OPP) Health Effects Division's (HED) Residues of Concern Knowledgebase Subcommittee (ROCKS) met in January 2012 to re-evaluate the inclusion of MPP, MPA, and NAG into the human health drinking water assessment (DWA), as had been done in previous assessments (USEPA, 2012a, D397644; USEPA 2012b, D387412). The ROCKS committee concluded that MPP is likely to have lower mammalian toxicity than glufosinate, but that its toxicity was not low enough to exclude it from consideration in the DWA. Therefore, the ROCKS recommended that the parent compound in combination and the degradate MPP constitute the residues of concern in the DWA for human health.

The parent compound is the only ROC for ecological risk in this assessment. A review of the toxicity data for the major degradates of racemic glufosinate shows that these compounds are generally equally or less toxic than racemic glufosinate to mammals and aquatic vertebrates, invertebrates, and plants. For taxa where major degradates have similar toxicity, the estimated environmental concentrations (EECs) are orders of magnitude lower than the toxicity endpoint; therefore, including the degradates as a ROC would not influence risk conclusions. There are no degradate toxicity data for the most sensitive non-vascular aquatic plant taxon (*i.e.*, cyanobacteria) nor for birds or terrestrial invertebrates, which are uncertainties. While there are also no degradate toxicity data for terrestrial plants, the toxicity data for aquatic plants suggest the degradates are orders of magnitude less toxic to vascular plants. Based on the available toxicity data, EFED does not expect consideration of exposure to major glufosinate degradates in the ecological risk assessment to impact the risk conclusions for L-glufosinate; therefore, the degradates are not included as ROCs.

3.4 Environmental Fate Summary

Table 7 summarizes the physical chemical properties of racemic glufosinate. Since the physical chemical properties of different enantiomers are identical outside of a chiral environment, except for the direction of rotation of plane polarized light, EFED expects the physical chemical properties of the racemic glufosinate and the enriched isomer to be the same. Given the log dissociation constant (pK_a<2) for glufosinate, the compound is expected to exist primarily as an anion at environmentally relevant pH values. Glufosinate is classified as mobile to highly mobile based on the organic carbon-normalized Freundlich sorption coefficients (K_{FOC}) and the Food and Agriculture Organization (FAO) classification system (FAO, 2000). Based on the mobility of the compound, glufosinate may be transported to surface water via spray drift and runoff or to groundwater via leaching. While it may be found in both water and sediment, the octanol-

water partition coefficient (K_{OW}) and organic-carbon normalized soil-water distribution coefficient (K_{OC}) values are lower than the values that would trigger the need to conduct a separate sediment exposure assessment (40 CFR Part 158.630).[5] Based on a log K_{OW} of <0.1, EFED does not expect the chemical to bioconcentrate in aquatic organisms.[6] Glufosinate is classified as non-volatile from water and dry non-adsorbing surfaces (USEPA, 2010a).

Table 7. Summary of Physical-Chemical, Sorption, and Bioconcentration Properties of Glufosinate.

Parameter	Value[1]			Source/Study Classification/Comment
Molecular Weight (g/mole)	198.2 (ammonium salt) 181.1 (free acid)			Chemical structure
Water Solubility Limit at 20°C (mg/L)	1.37×10^{6}			Acc No 00263025. Acceptable.
Vapor Pressure (torr)	$<7.5 \times 10^{-9}$ (measured) 1.15×10^{-10} (estimated)			MRID 44032901. Acceptable. Estimated values calculated using EPI Suite v. 4.1
Henry's Law Constant at 20°C (atm-m^3/mole)	2.2×10^{-17}			Calculated[1] from the estimated vapor pressure and measured water solubility of glufosinate ammonium at 20°C.
Log Dissociation Constant (pKa)	<2 (free acid)			PubChem Database[2]
Octanol-water Partition Coefficient (K_{ow}) at 25°C (unitless)	<0.1			Acc No 00263025. Acceptable. Supplemental. Not likely to significantly bioconcentrate.
Air-water Partition Coefficient (K_{AW}) (unitless)	9.1×10^{-16}			Estimated[1] from vapor pressure and water solubility at 20°C and pH 7. Nonvolatile from water.
Freundlich Soil-Water Distribution Coefficients (K_F in $(L/kg\text{-}soil)^{-1/n}$))	**Soil/Sediment**	**K_F**	**K_{FOC}**	MRID 40345662/48394101. Acceptable.
	Sand, pH 6.8, 0.85% OM	0.08	16.5	
	Silt Loam, pH 6.4, 0.63% OM	0.53	268	
Organic Carbon-Normalized Freundlich Distribution Coefficients (K_{FOC} in $L/kg\text{-}OC)^{-1/n}$)	Silt Loam, pH 5.9, 0.99% OM	1.56	605	
	Mean	0.72	297	
	CV	105%	99.5	
Fish Bioconcentration Factor (BCF) (L/kg-wet weight fish)	**Species**	**BCF**		MRID 41323130. Acceptable
	Bluegill Sunfish (*Lepomis macrochirus*)	0.19 (whole fish) 0.13 (edible)		

[5] Sediment data may be required if the soil-water distribution coefficient (K_d) is ≥ 50 L/kg, KOC values are ≥1,000 L/kg-organic carbon, or the logarithmic (log) K_{OW} is ≥ 3 (40 CFR Part 158.630). Sediment data may also be requested if there may be a toxicity concern.

[6] Compounds with a (log) K_{OW} ≥3 are generally considered to have the potential to bioconcentrate in aquatic organisms.

Parameter	Value[1]	Source/Study Classification/Comment

CV=Coefficient of Variation; OM = organic matter, Acc No = accession number

[1]All estimated values were calculated according to "*Guidance for Reporting on the Environmental Fate and Transport of the Stressors of Concern in Problem Formulations for Registration Review, Registration Review Risk Assessments, Listed Species Litigation Assessments, New Chemical Risk Assessments, and Other Relevant Risk Assessments*" (USEPA, 2010a).

[2] https://pubchem.ncbi.nlm.nih.gov/compound/Glufosinate (accessed 5-6-2021)

Table 8 summarizes the dissipation times and representative model input half-lives values from laboratory degradation data for glufosinate. EFED calculated the degradation kinetics consistent with the current degradation kinetics guidance (NAFTA, 2012). Glufosinate degrades primarily via aerobic metabolism in soil and water. Glufosinate is non-persistent to slightly persistent at 20 °C in soil based on the Goring persistence scale, with aerobic soil half-lives ranging from 1.71 to 23 days (Goring *et al.*, 1975). Glufosinate degrades in aerobic aquatic systems with DT_{50} values ranging from 1 to 36.1 days. The 1.52-day DT_{50} value is from a 0.1 mg/kg soil application rate to a sand soil system (MRIDs 45204401 and 45204402). A 1 mg/kg soil application rate to the same system resulted in a DT_{50} value of 35.2 days, indicating that the application rate can affect the degradation rate of the compound. Glufosinate degrades slowly in anaerobic aquatic (DT_{50} = 387 d) and in alkaline aqueous photolysis (DT_{50} = 87 d at pH 9) systems and is stable to aqueous hydrolysis between pH 5 and 9 and to aqueous photolysis at pH 5 and 7. The anaerobic aquatic metabolism study was classified as supplemental due to only analyzing the total system concentration and variability in the redox potential, however the degradation kinetics were considered suitable for quantitative use in aquatic modeling. In addition to degradation rates, the new aerobic soil metabolism, abiotic hydrolysis, and aqueous photolysis studies also measured the ratio of glufosinate enantiomers present in the samples. These studies also indicate that L-glufosinate does not convert to D-glufosinate under biotic or abiotic condition.

Table 8. Summary of Environmental Degradation Data for Glufosinate

Study	System Details Test Substance kinetic model	Dissipation Time (days)		Representative Model Input Half-Life[1,2] (days)	Source/Study Classification/Comment
		DT_{50}	DT_{90}		
Abiotic Hydrolysis	pH 5, 7, 9, 25 °C, racemic glufosinate ammonium	Stable	NA	Stable (0)	MRID 40345656; Acceptable
	pH 5, 7, 9, 25 °C, L-glufosinate acid	Stable	NA	Stable (0)	MRID 51036698[N]; Acceptable. No isomerization of the test material was observed.
Atmospheric Degradation	Hydroxyl Radical	0.261	NA	NA	Estimated value EPIWeb Version 4.1
Aqueous Photolysis	pH 5, 7, 9, 25 °C, racemic glufosinate ammonium, SFO-LN	Stable	NA	Stable (0)	MRID 41323115; Acceptable. Sunlight intensity reported as 2.16x natural sunlight, but no latitude value reported
	pH 5, 40 °N, 25 °C Buffered Water, L-glufosinate acid, SFO	Stable	NA	NA	MRID 51036699[N]; Supplemental.
	pH 7, 40 °N, 25 °C	Stable	NA	Stable (0)	

Study	System Details Test Substance kinetic model	Dissipation Time (days)		Representative Model Input Half-Life[1,2] (days)	Source/Study Classification/Comment
		DT_{50}	DT_{90}		
	Buffered Water, L-glufosiante acid, SFO				
	pH 8.3, 40 °N, 25 °C Natural Water, L-glufosinate acid, SFO	87	289	NA	
	pH 9, 40 °N, 25 °C Buffered Water, L-glufosinate acid, SFO	155	515	NA	
Soil Photolysis	Sandy loam, 25°C, racemic glufosinate ammonium, SFO-LN	17	NA	NA	MRID 41920102; Acceptable. Sunlight intensity reported as 1.1x natural sunlight, but no latitude value reported
Aerobic Soil Metabolism	Sandy loam, 21 ºC, pH 5.5, 1.63% OM racemic glufosinate ammonium, SFO	3.42	11.4	3.42	MRID 41323119; Acceptable. Degradation kinetics recalculated to be consistent with current guidance
	Silt loam, 21 ºC, pH 5.6, 1.23% OM racemic glufosinate ammonium, SFO	8.48	28.2	8.48	
	Loamy sand, 21 ºC, pH 5.0, 5.01% OM glufosinate ammonium, SFO	4.83	16.1	4.83	
	Sandy loam, 22 ºC, pH 5.7, 1.6% OM racemic glufosinate ammonium, SFO	22.9	76.1	22.9	MRID 40345659; Acceptable.
	Silt loam, 22 ºC, pH 6.3, 1.5% OM, glufosinate ammonium, IORE	14.8	61.6	18.5	
	Sandy loam, 22 ºC, pH 7.4, 0.9% OM, racemic glufosinate ammonium, IORE	14.8	66.1	19.9	
	Loam, pH 7.0, 20 ºC, L-glufosinate ammonium, IORE	2.25	13.6	4.08	MRID 50982320[N]/ Supplemental. Material balances were <90% in several samples in multiple test systems, however, <5% of the test material had not degraded by those sampling intervals. The low material balance is not expected to significantly affect the calculated degradation rates.
	Loamy Sand, pH 7.2, 20 ºC, L-glufosinate ammonium, IORE	2.31	17.6	5.29	
	Silt Loam, pH 7.2, 20 ºC, L-glufosinate ammonium, IORE	1.71	14.1	4.25	
	Loamy Sand, pH 6.9, 20 ºC, L-glufosinate ammonium, IORE	2.42	16.3	4.91	

Study	System Details Test Substance kinetic model	Dissipation Time (days)		Representative Model Input Half-Life[1,2] (days)	Source/Study Classification/Comment
		DT_{50}	DT_{90}		
	Loam 20°C, pH 6.8, L-glufosinate acid, IORE	4.03	34.9	10.5	MRID 51036701[N]/ Supplemental. Material balances were <90% in several samples in multiple test systems; however, at most only 5.17% of the test material had not degraded by those sampling intervals. Therefore, the low material balance is not expected to significantly affect the calculated degradation rates.
	Loamy sand, 20°C, pH 6.8, L-glufosinate acid, IORE	4.36	23.8	7.17	
	Silt loam 20°C, pH 7.2, L-glufosinate acid, SFO	2.84	9.42	2.84	
	Sandy loam 20°C, pH 6.8, L-glufosinate acid, IORE	3.53	19.3	5.82	
Anaerobic Soil Metabolism	Silt loam, 22 °C, glufosinate ammonium, SFO-LN	56	186	NA	MRID 40501014/ Supplemental. Two degradates detected at ~0.04 mg/kg-soil were not identified
Aerobic Aquatic Metabolism	Sand, 22 °C, pH 7.5, 1.5% OM, racemic glufosinate ammonium, SFO	36.1	120	36.1	MRID 40345660/ Acceptable. Degradation kinetics for the silt loam soil were not calculated due to low material balance and high variability in the data.
	Silt loam, 22 °C, pH 6.2, 1.9% OM, racemic glufosinate ammonium	NA	NA	NA	
	Loam, 20 °C, pH 6.9, 1.87% OM, racemic glufosinate ammonium, SFO	13.6	45.2	13.6	MRID 45204401; 45204402/ Supplemental. Aerobic conditions not adequately assured. Sediment classification, extraction procedure, and storage stability of the samples not fully described. Sand system dosed at two different treatment levels
	Sand, 1 ppm a.i. dosing, pH 7.0, 0.33% OM, 20 °C, racemic glufosinate ammonium, DFOP	35.2	645	276	
	Sand, 0.1 ppm a.i. dosing, 20 °C, pH 7.0, 0.33% OM, 20 °C, racemic glufosinate ammonium, SFO	1.52	5.06	NA	
Anaerobic Aquatic Metabolism	Water/sandy loam, 20°C, pH 6.0, 1.6% OM, racemic glufosinate ammonium, SFO	387	1,287	387	MRID 46258601/ Supplemental.

OM = organic matter; SFO=single first order; DFOP = double first order in parallel; IORE=indeterminate order; SFO DT_{50}=single first order half-life; DFOP $T_{1/2}$ = SFO half-life based on the slow rate DFOP degradation rate; T_{IORE}=the half-life of a SFO model that passes through a hypothetical DT_{90} of the IORE fit; NA=not available or applicable; SFO-LN=SFO calculated using natural log transformed data

[N] New studies submitted since the last risk assessment.

[1] The value used to estimate a model input value is the calculated SFO DT_{50}, SFO-LN DT_{50}, or T_{IORE} half-life. The model chosen is consistent with that recommended using the, *Guidance for Evaluating and Calculating Degradation Kinetics in Environmental Media* (NAFTA, 2012). Some values were calculated using natural log transformed data to estimate the SFO half-life (designated with SFO-LN).

Table 9 summarizes terrestrial field dissipation data. Both bare and cropped fields were treated with L-glufosinate at application rates consistent with the maximum racemic glufosinate application rates. Dissipation half-life (DT_{50}) values in the terrestrial field dissipation studies range from 1.1 to 30 days at seven sites in the United States. Times to 90% dissipation (DT_{90}) range from 3.7 to 100 days. Glufosinate and the major degradates MPP and MPA were detected throughout the soil profile, with MPP detected up to the maximum sampling depth in coarse textured soil (MRID 43110402). Dissipation times in the terrestrial field studies are comparable to the aerobic soil metabolism study dissipation times. No residue carryover was reported in any study. These studies support the conclusions of the laboratory studies that parent glufosinate has low persistence and high mobility in soil.

Table 9. Summary of Terrestrial Field Dissipation Data for Glufosinate and Major Degradates.

System Details	Parent DT_{50} and kinetic model (days)	Parent DT_{90} (days)	Deepest Core in Which Parent and Major Degradates Were Found (cm)	Source/Study Classification/Comment
Terrestrial Field Dissipation				
MD, Loamy sand, bare ground, 0.9% OM, 3.0 lb ai/A app rate	14 (SFO-LN)	47	10 (parent) 10 (MPP)	MRID 40345663/ Supplemental. Formation and decline of MPP was not captured and freezer storage stability data was not provided
WA, Loamy sand, bare ground, 0.8% OM, 2.0 lb ai/A app rate	14 (SFO-LN)	47	7.6 (parent) 7.6 (MPA)	MRID 40345664/ Supplemental. Formation and decline of MPA was not captured and freezer storage stability data was not provided
IL, Silt loam, bare ground, 3.2% OM, 3.0 lb ai/A app rate	15 (SFO-LN)	50	10 (parent) 10 (MPP)	MRID 40345665/ Supplemental. Formation and decline of MPP was not captured and freezer storage stability data was not provided
Fl, Sand, orange orchard, 2.1% OM, 3 x 1.5 lb ai/A app rate	8-23 (SFO-LN)	27-76	71.0 (parent) 91.5 (MPP) 30.5 (MPA)	MRID 43110402/ Acceptable.
MO, Clay, bare ground and soybeans, 1.9% OM, 2 x 1.2 lb ai/A	4 (SFO-LN, bare ground) 6 (SFO-LN, soybeans)	13 (bare ground) 20 (soybeans)	15.2 (parent, bare ground, soybeans) 30.5 (MPP, bare ground) 15.2 (MPP, soybeans)	MRID 43766916/ Acceptable
CA, Loam sand, grapes, 0.7% OM, 3 x 1.5 lb ai/A app rate	1.1-13.6 (SFO)	3.7-47	60 (parent) 30 (MPA) 45 (MPP)	MRID 47542601/ Supplemental. ILV not included with the study report.

System Details	Parent DT_{50} and kinetic model (days)	Parent DT_{90} (days)	Deepest Core in Which Parent and Major Degradates Were Found (cm)	Source/Study Classification/Comment
Terrestrial Field Dissipation				

app = application; ILV=independent laboratory validation; MPA= 2-(methylphosphinico)acetic acid; MPP= 3-(methylphosphinico)propionic acid (MPP); MRID=master record identification; OM = organic matter; SFO = single first order; SFO-LN = single first-order calculated using natural log-transformed data.

EFED does not consider unextracted residues as a significant source of uncertainty in this assessment in terms of exposure, based on the new aerobic soil metabolism studies, which include polar and non-polar extractions of samples with high (>10% of the applied) unextracted residues. These extractions account for <1% additional radioactive material, indicating that the unextracted residues are tightly bound and are not a likely source of ecological exposure in surface water.

Major transformation products resulting from the environmental degradation of glufosinate are:

- 3-(methylphosphinico)propionic acid (MPP)
- 2-(methylphosphinico)acetic acid (MPA)
- 2-acetamido-4-(methylphosphinico)butanoic acid (NAG)
- Carbon dioxide

3.5 Ecological Risk Assessment

3.5.1 Calculating Risk Quotients and Levels of Concern for Listed and Non-Listed Species

In evaluating the ecological impacts of a pesticide action, EPA first conducts a generic, taxa-based assessment (*i.e.*, ERA) that determines if there are potential effects to non-listed species from a given taxon. This approach relies upon risk quotients (RQs) and levels of concern (LOCs) that are designed to identify a potential for effects on taxa and distinguish those taxa where refinements may be needed to better understand whether there may be effects (**Table 8**). The screening-level effects assessment generates a series of RQs for broad taxonomic groups (*e.g.,* mammals, birds, fish, *etc*.) that are the ratio of estimated exposures to effects endpoints. EPA then compares these RQs to EPA-established LOCs to determine potential for effects to the broad taxonomic groups. The LOCs identify a threshold above which there may be potential effects from acute and/or chronic exposures. When a given taxonomic RQ exceeds either the acute or chronic risk LOC for a taxonomic group, EPA identifies a potential for direct toxic effects for that taxon.

Table 8. Risk quotient (RQ) and levels of concern (LOC) by taxon.

Taxon	Exposure duration	RQ[1]	LOC[1]
Fish and aquatic-phase amphibians	Acute	1-in-10-year, Daily EEC/LC_{50}	0.5
	Chronic	1-in-10-year, 60-day EEC/NOAEC	1

Taxon	Exposure duration	RQ[1]	LOC[1]
Aquatic invertebrates	Acute	1-in-10-year, Daily EEC/LC_{50}	0.5
	Chronic	1-in-10-year, 21-day EEC/NOAEC	1
Birds, terrestrial-phase amphibians, reptiles	Acute	Upper bound EEC/LC_{50} (Dietary) Upper bound EEC /LD_{50} (Dose)	0.5
	Chronic	Upper bound EEC /NOAEC	1
Mammals	Acute	Upper bound EEC /LD_{50} (Dose)	0.5
	Chronic	EEC[1]/NOAEC (Dietary) EEC[1]/NOAEL (Dose)	1
Terrestrial invertebrates	Acute	EEC/LD_{50} (contact) EEC/LD_{50} (diet)	0.4[2]
	Chronic	EEC/NOAEC (diet)	1[2]
Aquatic plants	Not applicable	1-in-10-year, Daily EEC/ IC/EC_{50}	1
Terrestrial plants	Not applicable	EEC/ IC_{25}	1

[1]USEPA 2004.
[2]USEPA, PMRA, CDPR 2014.

3.6 Aquatic Exposure Assessment

3.6.1 Aquatic Models

Surface water aquatic modeling was simulated using the Pesticide in Water Calculator (PWC; version 2.001) for use patterns to terrestrial areas. Chemical input parameters used in modeling are presented in **Table 9** and were calculated for parent based on information described in **Section 5.** Input parameters specific to the application scenario are specified in **Table 10** based on the use information described in **Section 3.** Input parameters were selected in accordance with EFED's guidance documents (USEPA, 2009b; USEPA, 2010b; USEPA, 2012c; USEPA, 2013a; USEPA, 2013b; USEPA, 2014a; USEPA, 2014b; USEPA and Health Canada, 2012).

EPA relied upon the Plant Assessment Tool (PAT; v 2.2.1.1 run with Python version 3.9.7 (64-bit)) for estimating environmental exposure to plants. PAT is a mechanistic model that incorporates pesticide fate (*e.g.*, degradation) and transport (*e.g.*, sorption) data that are typically available for conventional pesticides to estimate concentrations in terrestrial, wetland, and aquatic plant habitats. PAT was developed to make runoff exposures consistent with the approaches and assumptions considered for estimating aquatic EECs in the standard farm pond. EPA modeled wetlands using outputs from PRZM and the variable volume water model (VVWM), which are then processed in PAT to estimate aquatic (mass per volume of water; mg ae/L) and terrestrial (mass per area; lbs ae/A) concentrations. The PAT model simulates exposure in three different zones: terrestrial, semi-aquatic (wetland) and aquatic. PAT (version 2.2.1.1) is designed to be compatible with Python (version 2.7 or greater), and with weather files that have more or less than 30 years of data.[7]

[7] The most recent version of PAT is available at https://www.epa.gov/endangered-species/provisional-models-and-tools-used-epas-pesticide-endangered-species-biological.

The terrestrial plant exposure zone (TPEZ) is intended to represent a non-target terrestrial (non-inundated) plant community immediately adjacent to the treated field that is exposed to pesticides via sheet flow[8] and spray drift from the treated field. The TPEZ is defined as an area adjacent to the treated field with a length of 316 m (equal to the length of the edge of the treated field in PWC) and a width of 30 m. The width of the TPEZ represents the distance that overland surface flow can travel before sheet flow transitions into concentrated (channelized) flow (USEPA, 2020c). The TPEZ assumes that runoff to an area immediately adjacent to the treated field is in the form of sheet flow that carries pesticides dissolved in water and/or sorbed to eroded sediment. The model uses a mixing cell approach to represent water within the active root zone area of soil, and accounts for flow through the TPEZ caused by both treated field runoff and direct deposition onto the TPEZ through spray drift. Pesticide loss through the TPEZ occurs from transport (*i.e.*, washout and infiltration below the active root zone) and degradation.

Beyond 30 meters, the runoff is assumed to become concentrated (channelized) into rivulets, gullies, *etc*., which are represented by the wetland plant exposure zone (WPEZ). The WPEZ is intended to represent a non-target wetland plant community that is exposed to pesticide via overland flow[9] and spray drift. The wetland can be immediately adjacent to the treated field or some unspecified distance away. The WPEZ is intended to represent any plant community that can exist in a saturated to flooded environment (*e.g*., a depression or shallow wetland that would collect and hold runoff from an upland area). This wetland system is considered protective of other surface-fed wetland systems (*e.g.*, permanently flooded; riparian) such that it is allowed to dry-down (concentrating contaminants), has a finite volume (considers standing water exposure), and would receive all the runoff from an adjacent treated field. The WPEZ is defined as a one-hectare (ha) wetland receiving inputs from the adjacent 10 ha field. Within the WPEZ, two depth zones are defined: a standing water zone and a saturated soil pore-water (benthic) zone. The maximum depth of the standing water is set to 15 cm, but the water is allowed to dry down to a minimum depth of 0.5 cm using algorithms from the VVWM. The saturated soil pore-water zone is fixed 15 cm depth. This model excludes comparisons of standing water concentrations to aquatic taxa (*e.g.*, vascular and non-vascular aquatic plants) when water depth is less than 0.5 cm. Pesticide concentrations are presented as total mass in the water and benthic zones, expressed on an area-normalized basis (lbs ae/A) for comparison to terrestrial plant toxicity endpoints.

In addition to the TPEZ and WPEZ analyses that are specific to PAT, exposure estimates in the aquatic plant exposure zone (APEZ), were calculated with PWC using the standard farm pond assumptions (*i.e.,* runoff and spray drift from a 10 ha field into a 2 m deep 1 ha pond) to represent exposure concentrations in aquatic environments that could receive runoff and spray drift from the treated field.

[8] A continuous film of water flowing over the soil surface that is not concentrated into channels.
[9] Water flow that moves in swales, small rills, and gullies

3.6.2 Model Input parameters

All the physical chemical and degradation rate data are bridged[10] between the racemic glufosinate and L-glufosinate studies. A detailed discussion of the bridging justification can be found in **Appendix D**. Therefore, the representative half-lives of all the relevant studies were included when calculating the model input half-lives for L-glufosinate (*i.e.*, the only ROC identified for ecological risk). Two separate aerobic soil metabolism studies were conducted using gravel pit water/sand sediment systems; however, they were conducted on sediments with different properties collected several years apart, and therefore are considered separate test systems for the purpose of calculating model input values. For the calculated aerobic aquatic metabolism model input value, the low dose sand system was excluded from model input calculations because it was performed on the identical soil to the high dose system.

Table 9. Aquatic Modeling Input Parameters for Chemical Tab for Glufosinate.

Parameter (units)	Value (s)	Source	Comments
K_{OC} (mL/g)	297	MRIDs 40345662, 48394101	Average organic carbon normalized sorption value. The coefficient of variation (CV) for glufosinate was 99.5% for K_{FOC} and 105% for k_F, indicating that k_{FOC} is a better predictor of the variability in sorption than k_F. Linear sorption coefficients were not previously calculated for use in modeling.
Water Column Metabolism Half-life (days) at 20°C	267	MRIDs 40345660, 45204401, 45204402	Represents the 90 percent upper confidence bound on the mean of 3 representative half-life values from aerobic aquatic metabolism studies. The low dose sand system half-life was excluded from model input value calculations. The test systems in MRID 40345660 and 45204401/45204402 were collected from the similar locations, however the properties of the two sediment systems were different and the samples were collected several years apart, therefore both systems were included in calculating the model input half-life.
Benthic Metabolism Half-life (days) at 20°C	1160	MRID 46258601	3x single system half-life value
Aqueous Photolysis Half-life (days)@ pH 7	0 (stable)	MRIDs 41323115, 51036699	No significant degradation observed at pH 7, 25°C in two studies.
Hydrolysis Half-life (days) @ pH 7	0 (stable)	MRIDs 41323115, 51036699	No significant degradation observed at pH 7, 25°C in two studies.

[10] Bridging refers to the use of an existing dataset to describe the environmental fate and toxicological effects of another chemical for which there is little or no existing data.

Parameter (units)	Value (s)	Source	Comments
Soil Half-life (days) at 20°C	12.4	MRIDs 41323119, 40345659, 50982320, 51036701	Represents the 90 percent upper confidence bound on the mean of 14 representative model input half-life values from aerobic soil metabolism studies.
Foliar Half-life (days)	13.74	USEPA, 2013; DP Barcode 409766	Foliar dissipation data for racemic glufosinate application on GMO crops. EFED expects that L-glufosinate will decline at a similar rate on foliar surfaces.
Molecular Weight (g/mol)	181.1 (free acid)	Chemical structure	Free acid value used for modeling calculations.
Vapor Pressure (Torr) at 25°C	1.15×10^{-10} (estimated)	MRID 44032901. Acceptable. Estimated values calculated using EPI Suite™ v. 4.1	Estimated value used since the measured value is a less than (<) value
Solubility in Water (mg/L)	1.37×10^{6}	Acc No 00263025. Acceptable.	20°C and pH 7, measured value for parent
Henry's Law Constant (unitless)	8.18×10^{-16}	-	Calculated from vapor pressure, solubility, and molecular weight

[1] Other input parameters for the applications tab are shown in **Table 10**.

The modeling input parameters for the use patterns resulting in the lowest and highest EECs for each use site are shown in **Table 10**. These scenarios were selected as representative examples of the lower- and upper-bound EECs for the uses of glufosinate-P. These scenarios were selected as representative examples of the lower- and upper-bound EECs for the labeled uses of glufosinate-P. While the cotton seed propagation use instructions allow for 3 in-season applications per year, EFED modeled 1 burndown plus 2 in-season applications to generate a more conservative estimate of exposure from use on cotton, due to the higher propensity for runoff from burndown applications in the PWC scenarios. The sweet corn and corn use pattern resulted in the lowest and highest aquatic EECs, respectively; sweet corn and cotton uses resulted in the lowest and highest WPEZ EECs, respectively; and applications to sweet corn and soybeans resulted in the lowest and highest EECs in the TPEZ. A complete list of model input parameters, including justifications for the application dates and parameters selected for all modeled uses can be found in **Appendix B**.

Table 10. Selected Pesticide in Water Calculator (PWC) Model Input Parameters Specific to Labeled Use Patterns for Glufosinate-P (Applications Tab and Crop/land Tab).

Use Site	Use Pattern	PWC Scenario	Application Date(s)[1]	App. Rate in lbs ae/A (Kg ae/ha)	App Method[2]	Application Efficiency/ Spray Drift Fraction[3,4]
Corn	1 pre-emergence + 1 post-emergence	MScornSTD	-6, 1	2 x 0.36 (0.40)	Above crop	Aerial: 0.95/0.089 Ground:0.99/0.017
Cotton	1 pre-emergence + 2 post-emergence	MScottonSTD	-9, 1	1 x 0.36 + 0.24 (0.40, 0.27)	Above crop	Aerial: 0.95/0.089 Ground:0.99/0.017
Sweet Corn	1 pre-emergence + 2 post-emergence	NCcornESTD	-6, 1	2 x 0.36 (0.40)	Above crop	Aerial: 0.95/0.089 Ground:0.99/0.017
Canola	1 pre-emergence + 2 post-emergence, high burndown rate	NdcanolaSTD	-6, 1, 8	1 x 0.36 + 2 x 0.18 (0.40, 0.20)	Above crop	Aerial: 0.95/0.089 Ground:0.99/0.017
Soybean	1 pre-emergence + 1 post-emergence	MSsoybeansSTD	-4, 1	2 x 0.36 (0.40)	Above crop	Aerial: 0.95/0.089 Ground:0.99/0.017

ae = acid equivalents; app. = applications.

[1] Application dates relative to PWC scenario emergence date.

[2] Application method corresponds to the options in the PWC applications tab.

[3] Spray drift fraction for ground applications based on fine to medium droplet size distribution (DSD).

[4] Spray drift fraction aerial applications based on fine to medium/coarse droplet size distribution.

Application dates were either calculated from the minimum retreatment interval between the pre-emergence burndown application and the post-emergence in-season applications allowed on the glufosinate-P label or based on absolute dates used in the previous risk assessments, based on extension or grower group reports (USEPA, 2014, DP Barcode 422793). For crops where there were two options for combinations of burndown and in-season applications that could be made in a single growing season, EFED modeled both potential combinations at the maximum label rates to characterize the effect of these different application patterns on the EEC values. When distributing the yearly rates among the single applications, higher rates were assigned to burndown applications than to post-emergence applications. This prioritization of burndown applications will cover more conservative EECs than those expected for post-emergence applications. For applications to glufosinate tolerant crops, EFED modeled both a single burndown application and burndown plus in-season application to characterize the difference in ecological exposure from applications to glufosinate tolerant and glufosinate sensitive crops. Explanations for the selected application dates and rates for all uses can be found in **Appendix B**.

The uses on agricultural use sites allow for ground and aerial applications of a flowable material. Therefore, application to corn, cotton, soybeans, and canola were modeled as both aerial and ground applications made above the crop. Label instructions indicate that glufosinate-P should be applied as a medium or coarser droplet size distribution (DSD); therefore, spray drift parameters were selected based on a medium/coarse DSD for aerial applications and a high boom fine to medium/coarse DSD for ground applications.

Since completion of the previous ecological risk assessment (USEPA, 2017), new abiotic hydrolysis and biotic aerobic soil metabolism data are available. The hydrolysis data are consistent with the existing data showing that glufosinate is stable to hydrolysis at environmentally relevant pH values. For the calculated aerobic soil metabolism model input value, EFED excluded the low dose sand system from model input calculations because the study authors conducted the study on the identical soil used in the high dose system. In addition, EFED recalculated the degradation kinetics for several older studies to be consistent with the current U.S, Mexico, and Canada Agreement (USMCA; formerly the North American Free Trade Agreement (NAFTA)) degradation kinetics guidance (NAFTA 2012). These new data are incorporated into the risk assessment and result in some changes in the aquatic modeling inputs relative to the previous risk assessments of racemic glufosinate. Additionally, EFED is now recommending that the daily average value be used to calculate acute risk quotients for aquatic organisms rather than the peak value used in previous risk assessments (USEPA, 2017).

The PWC scenarios are used to specify soil, climatic, and agronomic inputs in the PRZM and are intended to result in high-end water concentrations associated with a particular crop and pesticide within a geographic region. Each PWC scenario is specific to a vulnerable area where the crop is commonly grown. Soil and agronomic data specific to the location are built into the scenario, and a specific climatic weather station providing up to 30 years of daily weather values is associated with the location. **Table 10** identifies the use sites associated with each PWC scenario.

3.6.3 Aquatic Habitats

In response to the National Academy of Sciences (NAS) Report[11] recommendations, the National Marine Fisheries Service and the U.S. Fish and Wildlife Service (collectively referred to as "the Services") developed ten generic habitat types (*i.e*., aquatic bins 1-10) nine of which are aquatic, and one is a semi-aquatic habitat (or aquatic-associated terrestrial habitat). Aquatic bins have been defined by the Services to facilitate the estimation of pesticides in surface water for comparison to relevant toxicity endpoints for listed species assigned to the appropriate bin, based on habitat requirements. Each bin varies in depth, volume, and flow. **Table 11** summarizes the aquatic bins. It should be noted that the aquatic bin number may be different

[11]NAS, 2013. Assessing Risks to Endangered and Threatened Species from Pesticides. The National Academies Press. 2013

than the PWC bin number (*i.e.*, specified in the model input file). In addition, the same waterbody used in PWC may be used as a surrogate to represent multiple bins defined by the Services.

Aquatic bin 1 represents riparian habitats or other land-based habitats adjacent to waterbodies that may occasionally be inundated with surface water (such as wetlands) and provide habitat or influence the water quality for aquatic and semi aquatic organisms.

Aquatic bins 2, 3, and 4 simulate flowing waterbodies. Bin 2 represents low flow, bin 3 represents moderate flow, and bin 4 represents high flow. Bins 5, 6, and 7 are used to simulate static waterbodies. Bin 5 represents low volume, bin 6 represents moderate volume, and bin 7 represents high volume.

EFED relies on two standard waterbodies which have been traditionally used to estimate concentrations in water using PWC. EFED uses the standard farm pond to develop EECs for the medium and large static bins (*e.g.*, bins 6 and 7) and the index reservoir for the medium and large flowing bins (*e.g.*, bins 3 and 4). For the smallest flowing and static bins (aquatic bins 2 and 5), EFED derived edge-of-field estimates from the Pesticide Root Zone Model (PRZM) daily runoff file (*e.g.*, ZTS file) to be protective of concentrations in a headwater stream or a standing puddle that receives runoff at the edge of a treated field.

Bins 8, 9, and 10 represent estuarine/marine habitats, but EFED does not currently have standard conceptual models to estimate EECs for these environments. EFED has assigned surrogate freshwater flowing or static systems to evaluate exposure for these estuary and marine bins. Aquatic bin 5 is used as surrogate for pesticide exposure to species in tidal pools; aquatic bins 2 and 3 are used for exposure to species at low and high tide, and aquatic bins 4 and 7 are used to assess exposure to marine species that occasionally inhabit offshore areas.

Table 11. Generic Aquatic Habitats (Bins)[1].

Generic Habitat (Bin #)	Depth (meters)	Width (meters)	Length (meters)	Flow (m^3/second)	Representative Waterbody
Aquatic-associated terrestrial habitats (1)	NA	NA	NA	NA	WPEZ
Low-flow (2)	0.1	2	length of treated area	0.001	Edge-of-Field
Moderate-flow (3)	1	8	length of treated area	1	Index Reservoir
High-flow (4)	2	40	length of treated area	100	Index Reservoir
Low-volume (5)	0.1	1	1	0	Edge-of-Field
Moderate-volume (6)	1	10	10	0	Farm Pond
High-volume (7)	2	100	100	0	Farm Pond

Intertidal nearshore (8)	0.5	50	Length of treated area	NA	None
Subtidal nearshore (9)	5	200	Length of treated area	NA	None
Offshore marine (10)	200	300	Length of treated area	NA	None

[1] Length of treated area – The habitat being evaluated is the reach or segment that abuts or is immediately adjacent to the treated area. The habitat is assumed to run the entire length of the treated area. NA = not applicable
N/A = Not Applicable

3.6.4 Surface Water Modeling Results

Table 12 summarizes scenarios with the highest and lowest surface water EECs calculated for L-glufosinate. The 1-day, 21-day, 60-day average, and peak edge-of-field concentrations range from 2.74 to 28.3, from 2.64 to 27.9, from 2.49 to 28.1 µg/L, and from 12.8 to 130 µg/L respectively. The lowest EECs are associated with pre- and post-emergence applications to North Carolina sweet corn and the highest EECs are associated with pre- and post-emergence applications to Mississippi corn. **Table 13** summarizes EECs for plants in the terrestrial and wetland plant exposure zones (*i.e.*, TPEZ and WPEZ). The TPEZ and WPEZ EECs range from 0.011 to 0.123 lb ae/A and from 8.67 to 167 µg/L, respectively. The lowest EECs are associated with burndown applications to California cotton and the highest are associated with aerial applications to cotton for purposes other than burndown.

Table 12. Surface Water Estimated Environmental Concentrations (EECs) for L-Glufosinate (Acid Equivalents) Using the Pesticide in Water Calculator (PWC; version 2.001) based on Labeled Uses of Glufosinate-P.

Use Pattern	Use Site	PWC Scenario	App. Rate in lbs ae/A (kg ae/ha)	Surface Concentration (µg/L)			Edge-of-Field Concentration (µg/L)
				1-Day Average	21-Day Average	60-Day Average	Peak
Corn	1 pre-emergence + 1 post-emergence	MScornSTD	2 x 0.36 (0.40)	**28.3**	**27.9**	**28.1**	74.0
Cotton	1 pre-emergence + 1 post-emergence	CAcotton_WirrigSTD	1 x 0.36 (0.40) + 0.24 (0.27)	5.93	5.61	5.15	**130**
Sweet corn	1 pre-emergence + 1 post-emergence	PAcornSTD	1 x 0.18	3.12	3.08	2.99	12.8

Use Pattern	Use Site	PWC Scenario	App. Rate in lbs ae/A (kg ae/ha)	Surface Concentration (µg/L)			Edge-of-Field Concentration (µg/L)
				1-Day Average	21-Day Average	60-Day Average	Peak
Canola	1 pre-emergence + 2 post-emergence, high burndown rate	NdcanolaSTD	1 x 0.36 + 0.24 + 0.13	11.6	11.3	11.0	38.8
Sweet Corn	1 pre-emergence + 1 post-emergence	NCcornESTD	2 x 0.36 (0.40)	2.74	2.64	2.49	29.4
Soybean	1 pre-emergence + 1 post-emergence	MSsoybeansSTD	2 x 0.36 (40)	22.8	22.0	20.7	72.7

Highest values indicated in **Bold**

Table 13. Terrestrial and Wetland Estimated Environmental Concentrations (EECs) of L-Glufosinate for Labeled Uses of Glufosinate-P (Acid Equivalent) Using the Plant Assessment Tool (PAT; version 2.2.1.1).

Use Pattern	Use Site	PWC Scenario	App Type	App. Rate in lbs ae/A (kg ae/ha)	1-in-10 Year Daily Concentration		
					TPEZ (lb ae/A)	WPEZ (lb ae/A)	WPEZ (µg ae/L)
Corn		KSCornStdsa	Aerial	2 x 0.36	0.105	0.011	137
Cotton		CAcotton_WirrigSTDsa	Aerial	1 x 0.36 + 0.24	0.052	0.079	167
Sweet Corn	Burndown Application to Tolerant Corn	NCCornESTD	Ground	1 x 0.18 (0.20)	0.011	0.012	8.67
Canola		NDcanolaSTDsa	Aerial	1 x 0.25 + 0.24	0.084	0.175	157
soybean		MSsoybeanSTDsa	Aerial	2 x 0.36	0.123	0.112	71.3

TPEZ = Terrestrial Plant Exposure Zone; WPEZ = Wetland Plant Exposure Zone.

3.6.5 Monitoring

EFED searched the Water Quality Portal in April 2021 for data on glufosinate. Consistent with what was reported in the final Registration Review risk assessment (USEPA, 2014, DP Barcode D422793), glufosinate was detected at a maximum concentration of 3.2 µg/L in surface water and 4.5 µg/L in groundwater. These detections reflect usage of racemic glufosinate, as there are no currently registered enantiomerically enriched L-glufosinate formulations. This monitoring was not targeted to areas and times when glufosinate may have been applied; therefore, these data are not expected to capture the full range of concentrations that may occur in the environment. Since monitored concentrations are a function of the amount of material applied, and the maximum application rates for L-glufosinate are approximately half the rate of the racemic form, L-glufosinate is expected to have lower concentrations in the environment than the racemic formulation, with all other conditions (such as sample timing, usage, watershed composition and weather) being constant.

4 Risk Characterization

4.1 Aquatic Animal Rick Characterization

EFED calculated risk quotients (RQs) for fish (a surrogate for aquatic-phase amphibians), aquatic invertebrates, and aquatic plants based on the most sensitive toxicity endpoints for the respective taxa (**Section 3.5**) and the L-glufosinate surface water EECs modeled for each labeled use (**Appendix B**). EFED estimates risk to aquatic species that inhabit low-volume and medium-volume waterbodies based on the edge-of-field and standard farm pond models in PWC, respectively. Further evaluation of aquatic species that reside in a unique low-volume wetland habitat relies on the WPEZ model in PAT. EFED also uses the standard farm pond model to assess exposure and risk in large-volume waterbodies. Given greater dilution with increasing volume, EFED considers the standard farm pond model conservative and thus protective of exposure and risk to aquatic species that inhabit large-volume aquatic environments.

Risk estimates presented for aquatic taxa in subsequent sections are based on toxicity data from a few model species. It is unlikely that the results reflect the actual risks to the most sensitive species in the aquatic environment nor the range of sensitivities of all species within a taxon. This is an uncertainty that is implicit in the risk conclusions presented for all aquatic taxa. Additional uncertainties are present in the aquatic risk assessment and are characterized in the risk conclusions for each taxon as they apply.

4.1.1 Aquatic Vertebrates

Table 14 summarizes the range of acute and chronic RQs for freshwater fish (surrogates for aquatic-phase amphibians) and estuarine/marine fish. Given that the aquatic vertebrate RQs are identical (*i.e.,* either not estimated due to non-definitive endpoints or RQ is <0.01) for all

labeled glufosinate-P uses, a table with individual RQs for each use is not provided in the **Appendix B**.

Table 14. Acute and Chronic Aquatic Vertebrates Risk Quotients (RQ) for Freshwater and Estuarine/Marine Vertebrates based on the Labeled Uses of Glufosinate-P.

Use Sites	Range 1-in-10 Yr Farm Pond EEC (µg ae/L)		Range 1-in-10 Yr Edge-of-Field (µg ae/L)	Risk Quotient			
				Freshwater		Estuarine/Marine	
	1-day Mean	60-day Mean	Peak	Acute[1]	Chronic[2]	Acute[1]	Chronic[1]
				LC_{50} > 92,900 µg ae/L	NOAEC = 24,000 µg ae/L	LC_{50} > 876,000 mg ae/L	No chronic toxicity data available
All Uses	2.74-28.3	2.49-28.1	12.8-130	NC	<0.01	NC	NC

NC = not calculated; see footnotes; ae = acid equivalent; The toxicity endpoints listed in the table are those used to calculate the RQ.

[1] Acute RQs for freshwater and estuarine/marine fish were not estimated because the acute toxicity endpoints for both taxa are non-definitive. Chronic RQs for estuarine/marine fish were not estimated because no chronic data are available for this taxon.

[2] The estimated environmental concentrations (EECs) used to calculate these RQs are based on the highest 1-in-10-year 60-day average value and peak 1-in-10-year peak edge of field concentration of L-glufosinate in **Appendix B**. The values are presented in acid equivalents to be consistent with the toxicity endpoints.

Daily mean EECs in the water column of medium-volume waterbodies based on maximum application rates range from 2.74 to 28.3 µg ae/L and 60-day mean EECs range from 2.49 to 28.1 µg ae/L. Peak EECs in low-volume waterbodies range from 12.8 to 130 µg ae/L. Acute RQs could not be calculated for freshwater or estuarine/marine fish because the acute toxicity endpoints are non-definitive (*i.e.*, LC_{50}>92,900 µg ae/L and LC_{50}>876,000 µg ae/L, respectively). No mortality was observed up to the highest concentration tested in freshwater and estuarine/marine species; the concentrations tested are over three orders of magnitude above the highest daily mean EEC and over two orders of magnitude above the highest peak edge-of-field EEC. Additionally, the only definitive toxicity value for freshwater fish is for Fathead Minnow with an LC_{50} of 421,000 µg ae/L, which is three orders of magnitude higher than the maximum EEC across all size waterbodies. As a result, the likelihood of acute mortality in fish resulting from exposure to glufosinate TGAI from the labeled uses is low.

Based on the definitive chronic toxicity endpoints for freshwater fish, chronic RQs (<0.01 for all scenarios) for fish in all waterbodies do not exceed the Agency's chronic risk LOC of 1.0 for freshwater fish. Therefore, the likelihood of adverse effects on freshwater fish from exposure to glufosinate is expected to be low for all labeled glufosinate-P uses. Although no chronic toxicity data are available to quantify chronic risk in estuarine/marine fish, these fish would have to be over an order of magnitude more sensitive than freshwater fish to result in RQ values that exceed the Agency's chronic risk LOC of 1.0 for fish. Consequently, chronic risk to estuarine/marine fish is also expected to be low. Since freshwater fish serve as surrogates for

aquatic-phase amphibians, there are no acute or chronic risks of concern for this stage of amphibians.

Typical end-use products for glufosinate ais exhibit greater toxicity to fish compared to the TGAI. Although this conclusion is primarily based on aquatic TEP data for the racemic mixture, enhanced toxicity to freshwater fish was also observed for a formulated glufosinate-P ammonium TEP. None of the labeled glufosinate-P uses permit direct application to aquatic systems; however, the TEP may be introduced into the aquatic environment via spray drift from on-field application. EFED estimates aquatic EEC from spray drift using AgDRIFT™ for ground and aerial applications based on particle size and boom height recommendations described on the final glufosinate-P labels (*i.e.,* boom height no greater than 24 inches above the canopy[12] and medium or coarser DSD[13]) and assuming, conservatively, that the water body is at the edge of the application site (*i.e.,* distance to water body is 0 feet). Based on the single maximum application rate, aerial burndown applications on corn, cotton, soybean, and canola are expected to produce the highest 1-day mean spray drift aquatic EECs. Spray drift estimates from this use pattern range from 1.78 µg ae/L in the standard farm pond to 186 µg ae/L in a low-volume (1 m width x 0.1 m depth) waterbody and are one to three orders of magnitude below the LC_{50} for freshwater fish (LC_{50} = 3,290 µg ae/L) exposed to the glufosinate-P ammonium TEP. Consequently, EFED considers the likelihood of adverse effects on freshwater fish and aquatic-phase amphibians from the labeled use of the formulated glufosinate-P ammonium to be low. Additional glufosinate-P ammonium TEP data are not available for estuarine/marine fish; however, EFED expects that the likelihood of adverse effects to be low given that aquatic vertebrates would have to be over two orders of magnitude more sensitive to the TEP compared to the TGAI to result in acute risks of concern and there are no data to support this assumption.

4.1.2 Aquatic Invertebrates

Water Column Invertebrates

Table 15 and **Table 16** present the range of acute and chronic freshwater and estuarine/marine invertebrate EECs and associated RQs for all labeled uses for species that inhabit the water column of low-volume and medium/large-volume waterbodies, respectively. **Appendix E** includes a spreadsheet containing acute and chronic RQs for individual use patterns.

[12] The upper limit of the spray drift boom height restriction on the final labels falls between the low (20 inches) and high (50 inches) boom height options in AgDRIFT™; therefore, spray drift surface water EECs for ground application was determined for high boom height to provide the most conservative estimate.

[13] AgDrift™ does not have a "medium or coarser" droplet distribution for ground applications. The ground assessment, instead, uses a "fine to medium/coarse" distribution to approximate off-field drift for ground applications using equipment that produce medium to coarse droplets. This could result in overestimating the potential off-field exposure.

Daily mean EECs in the water column for waterbodies similar to or larger than the standard farm pond range from 2.74 to 28.3 µg ae/L and 21-day mean EECs range from 2.64 to 27.9 µg ae/L. Acute RQs could not be calculated for freshwater invertebrates because the toxicity endpoint is non-definitive (*i.e.*, EC_{50}>103,000 µg ae/L); however, there was no evidence of immobilization up to the highest concentration tested, which is more than three orders of magnitude above the highest daily mean L-glufosinate EEC (28.3 µg ae/L from corn use) for waterbodies similar to the standard farm pond. Based on a freshwater invertebrate NOAEC of 28,000 µg ae/L and the highest 21-day mean EEC of 27.9 µg ae/L, chronic RQs for freshwater invertebrates (all <0.01) do not exceed the Agency's chronic risk LOC of 1.0 for any of the labeled uses (**Table 15**).

Acute RQs for estuarine/marine invertebrates (all <0.01) in aquatic environments similar to or larger than the standard farm pond also did not exceed the Agency's acute risk LOC (LOC = 0.5) for estuarine/marine invertebrates. Likewise, chronic RQs for estuarine/marine invertebrates (**Table 15**) in these aquatic environments do not exceed the Agency's chronic risk LOC (LOC =1.0). Based on this analysis, there are no risks of concern for freshwater and estuarine/marine invertebrates that inhabit aquatic environments similar to or larger than the standard farm pond.

Table 15. Acute and Chronic Risk Quotients (RQ) for Aquatic Invertebrate (Exposed in the Water-Column) Species Inhabiting Waterbodies of Similar Size to or Larger than the Standard Farm Pond based on the Labeled Uses of Glufosinate-P.

Use Sites	Range 1-in-10 Yr Surface Water EEC (µg ae/L)		Risk Quotient			
			Freshwater		Estuarine/Marine	
	Daily Mean	21-day Mean	Acute[1]	Chronic[2]	Acute[3]	Chronic[2]
			LC_{50} > 103,000 µg ae/L	NOAEC = 28,000 µg ae/L	LC_{50} = 6,900 µg ae/L	NOAEC = 67 µg ae/L
All Uses[4]	2.74-28.3	2.64-27.9	NC	<0.01	<0.01-0.01	0.04-0.42

Bolded value exceeds the level of concern (LOC=1.0) for chronic risk to listed and non-listed species.
NC = not calculated; see footnotes; ae = acid equivalent; The toxicity endpoints listed in the table are those used to calculate the RQ.

[1] Acute RQs for freshwater invertebrates were not estimated because the acute toxicity endpoints for these taxa are non-definitive (>) values.

[2] The estimated environmental concentrations (EECs) used to calculate these RQs are based on the highest 1-in-10-year 21-day average modeled concentration value of L-glufosinate in **Appendix B.** The values are presented in acid equivalents to be consistent with the toxicity endpoints.

[3] The EECs used to calculate this RQ are based on the highest 1-in-10-year 1-day average modeled concentration value of L-glufosinate in **Appendix B.** The values are presented in acid equivalents to be consistent with the toxicity endpoints.

[4] The All Uses row presents the range of EECs and RQs for all uses and scenarios modeled.

Peak EECs in the water column for low-volume waterbodies range from 38.8 to 135 µg ae/L (**Table 16**). As with larger waterbodies, EFED could not calculate acute RQs for freshwater invertebrates because the toxicity endpoint is non-definitive; however, there was no evidence of immobilization up to the highest concentration tested, which is more than an order of

magnitude above the highest peak L-glufosinate edge-of-field EEC (135 µg ae/L from cotton use). The chronic RQs for non-listed and listed freshwater invertebrates (<0.01) that inhabit small waterbodies do not exceed the Agency's chronic risk LOC of 1.0 for any of the labeled uses (**Table 16**).

Acute RQs for estuarine/marine invertebrates that inhabit low-volume waterbodies range from <0.01-0.02 and do not exceed the Agency's acute risk LOC for estuarine/marine invertebrates. Chronic RQs for estuarine/marine invertebrates that inhabit small waterbodies range from 0.58 to 2.01 (**Table 16**) based on the edge-of-field model estimates. Labeled uses on cotton and corn use sites exceed the Agency's chronic risk LOC of 1.0 for estuarine/marine invertebrates.

There are some uncertainties in the extent to which edge-of-field concentrations represent exposure in the environment. The edge-of-field model assumes that runoff is the only contributor to the pesticide load in the waterbody and that the runoff completely replaces or displaces the waterbody water with negligible dilution. While complete replacement is possible, particularly for shallow or small ephemeral waterbodies, EFED expects dilution to occur over time in most lentic and lotic systems. Consequently, EFED considers the edge-of-field EECs as conservative exposure estimates for most low-volume aquatic habitats. Dilution of runoff by 2-3X after entering the waterbody would result in reduction in EECs below the chronic estuarine/marine NOAEC for all uses. Notably, peak EECs modeled for a wetland with up to 15 cm depth (WPEZ, **Section 3.6.1**) are similar to or exceed the edge-of-field EECs for all scenarios. The wetland model considers input from runoff and spray drift and is allowed to dry down to a 0.5 cm depth which may explain the higher peak EECs for some scenarios. Further, similarities between these two models suggest that the edge-of-field model may not be overestimating peak concentration in shallow waterbodies with ≤15 cm depth. There is additional uncertainty in estimating chronic risk to aquatic species based on a one-day peak aquatic EEC rather than a 21-day average. The EECs modeled for the standard farm pond suggest peak edge-of-field EECs do not substantially overestimate 1-in-10 year 21-day average concentrations; however, shallower waterbodies are expected to experience greater fluctuation in concentration over time because of evaporation, rainfall, and other inputs. Consequently, peak edge-of-field values are likely more conservative estimates of the 21-day average concentration than would be predicted based on the standard farm pond.

Table 16. Acute and Chronic Risk Quotients (RQ) for Aquatic Invertebrate (Exposed in the Water-Column) Inhabiting Low-Volume Waterbodies based on the Labeled Uses of Glufosinate-P.

Use Sites	Range 1-in-10 Yr Edge of Field Surface Water EEC (µg ae/L)	Risk Quotient			
		Freshwater		Estuarine/Marine	
	Peak[1]	Acute[2]	Chronic	Acute	Chronic
		LC_{50} > 103,000 µg ae/L	NOAEC = 28,000 µg ae/L	LC_{50} = 6,800 µg ae/L	NOAEC = 67 µg ae/L
Canola	38.8	NC	<0.01	0.01	0.58

Use Sites	Range 1-in-10 Yr Edge of Field Surface Water EEC (µg ae/L)	Risk Quotient			
		Freshwater		Estuarine/Marine	
	Peak[1]	Acute[2]	Chronic	Acute	Chronic
		LC_{50} > 103,000 µg ae/L	NOAEC = 28,000 µg ae/L	LC_{50} = 6,800 µg ae/L	NOAEC = 67 µg ae/L
Cotton	135	NC	<0.01	0.02	**2.01**
Corn	85	NC	<0.01	0.01	**1.27**
Sweet Corn	43.5	NC	<0.01	0.01	0.65
Soybeans	83.2	NC	<0.01	0.01	**1.24**

Bolded values in dark shaded cells indicate RQ that exceeds the Agency's acute risk level of concern (LOC) of 0.5 or chronic risk LOC of 1.0 for aquatic invertebrates.
NC = not calculated; see footnotes; ae = acid equivalent; The toxicity endpoints listed in the table are those used to calculate the RQ.
[1] The EECs used to calculate this RQ are based on the highest 1-in-10-year 1-day average modeled concentration value of L-glufosinate in **Appendix B.** The values are presented in acid equivalents to be consistent with the toxicity endpoints.
[2] Acute RQs for freshwater invertebrates are not estimated because the acute toxicity endpoints for these taxa are non-definitive (>) values.
[3] The highest EEC and RQs is presented for each use where at least one scenario is expected to pose risk of concern.

Based on the available data, EFED expects the likelihood of adverse effects on freshwater invertebrates from acute or chronic exposure because of labeled uses of L-glufosinate to be low in all aquatic environments. However, there are chronic risks of concern for estuarine/marine invertebrates in low-volume aquatic environments. Labeled uses on cotton and corn use sites pose a chronic risk to estuarine/marine invertebrates that inhabit small waterbodies. There are no chronic risks of concern for estuarine/marine invertebrates in medium to large waterbodies.

Acceptable L-glufosinate TEP data are not available to evaluate risk to aquatic invertebrates from acute spray drift exposure. EFED expects risk to be low given that aquatic invertebrates would have to be at least three orders of magnitude more sensitive to the TEP to result in acute risks of concern.

Benthic Invertebrates

Benthic invertebrates may be exposed to L-glufosinate from the sediment, pore water, overlying water, or in the water column depending on their life cycle. EFED does not expect L-glufosinate introduced into the aquatic environment to partition preferentially to the sediment nor accumulate in the sediment based on the fate properties for the racemic mixture (*i.e.,* log K_{ow}<0.01 and K_{FOC}<1,000). The sensitivity of benthic invertebrates to L-glufosinate exposure is an uncertainty given that benthic invertebrate toxicity data are not available; however, the 40 CFR Part 158 does not require such data based on and the chemical/physical properties of glufosinate. Water column invertebrate toxicity data can be used as a surrogate to evaluate benthic invertebrate exposure to L-glufosinate in pore and overlying water. This assumes that the water column invertebrates have similar sensitivity to L-glufosinate exposure as benthic

invertebrates, which is an uncertainty given the lack of benthic invertebrate ecotoxicity data. As noted above, there are no acute or chronic risks of concern identified for aquatic invertebrates that reside in the water column of medium or large waterbodies; however, there are chronic risks of concern for estuarine/marine invertebrates in small waterbodies. Given that exposure to benthic organisms through sediment porewater is expected to be similar or lower than surface water exposure, EFED expects benthic invertebrates to have the same risk concerns as water-column aquatic invertebrates for the labeled L-glufosinate uses assuming that benthic and water column invertebrates are similarly sensitive to L-glufosinate exposure.

4.2 Terrestrial Vertebrates Risk Assessment

4.2.1 Terrestrial Vertebrate Exposure Assessment

Dietary Items on the Treated Field

Potential dietary exposure for terrestrial wildlife in this assessment is based on consumption of L-glufosinate residues on food items following foliar spray applications. EFED calculates the EECs for birds[14] and mammals from consumption of dietary items on the treated field using the Terrestrial Residue Exposure Model (T-REX) v.1.5.2. For the foliar uses, EECs are based on application rates, number of applications, and minimum retreatment intervals presented in **Table 17** and **Table 18**. An initial screening-level risk evaluation with T-REX using the default 35-day foliar dissipation half-life indicates risks of concern for mammals and birds for several size classes and food sources. Acceptable foliar dissipation data are available on two crops (*i.e.*, corn, and canola) to refine the default 35-day half-life used in T-REX to be more representative of L-glufosinate. EFED calculated a 90th percentile mean dissipation half-life of 13.74 days from these data and used this chemical-specific half-life value in its refined T-REX analysis (USEPA, 2013, DP Barcode 409766) presented below. Although the foliar dissipation data are for racemic glufosinate application on GMO crops, EFED expects that L-glufosinate concentrations will decline at a similar rate on foliar surfaces.

EFED uses upper-bound and mean Kenaga nomogram values to derive terrestrial EECs for L-glufosinate exposures for terrestrial mammals and birds on the field of application based on a 1-year time period. Consideration is given to different types of feeding strategies for mammal and birds, including herbivores, insectivores and granivores. T-REX provides dose-based exposure estimates for three weight classes of birds (20 g, 100 g, and 1,000 g) and three weight classes of mammals (15 g, 35 g, and 1,000 g). The exposure estimates assume application at the single maximum application rate (or variable rate that results in highest exposure without exceeding the maximum annual application rate) and the shortest permitted interval between applications in accordance with the final labels. **Table F-1** in **Appendix F** details the use patterns selected to model terrestrial vertebrate EECs.

[14] Birds are also used as a proxy for reptiles and terrestrial-phase amphibians.

The EECs for terrestrial food items range from 5.39 to 86.2 mg ae/kg-diet and 2.51 to 30.5 mg ae/kg-diet based on upper-bound Kenaga values and mean Kenaga values, respectively. Dose-based upper-bound EECs, adjusted for body weight, range from 0.35 to 98.1 mg ae/kg-bw for birds and 0.18 to 82.2 mg ae/kg-bw for mammals, whereas dose-based mean EECs range from 0.09 to 29.1 mg ae/kg-bw for mammals. EFED did not calculate dose-based mean EECs for birds because there are no risks of concern based on upper-bound residue estimates. **Tables F-2, F-3, and F-4** of **Appendix F** summarize the maximum and minimum upper-bound and mean EECs for all size classes and feeding strategies.

4.2.2 Terrestrial Vertebrate Risk Characterization

Terrestrial vertebrate RQs are generated based on the upper-bound EECs discussed above and toxicity values for their respective taxa presented in **Table 16**, **Table 17**, **Table 18**, and **Table 19** summarize the range of acute and chronic mammalian and avian RQs for all labeled uses. **Appendix F** provides a detailed avian and mammalian RQs for each use, size class, and feeding strategy.

Risk quotients for acute dietary and dose-based exposure could not be calculated for birds because the endpoints were non-definitive (**Table 16**). The highest level tested in the acute avian toxicity studies did not result in 50% or greater mortality and the avian upper-bound dietary and dose EECs are at least 15 and 5 times lower than the highest levels tested in those studies, respectively. Up to 40% mortality was observed in the avian subacute dietary toxicity study; however, the dietary concentrations that resulted in mortality were at least 3 times above the upper-bound dietary EECs. Consequently, there is low likelihood of acute mortality to birds, terrestrial-phase amphibians, and reptiles from the labeled uses of glufosinate-P based on the available data.

Chronic dietary-based RQs (**Table 17**) for birds range from 0.01 to 0.42 based on upper-bound EECs. These RQs are based on a lack of effects at the highest dose tested in Mallard Ducks. While the lack of a definitive LOAEC for Mallard Duck is an uncertainty in evaluating the impact of chronic glufosinate exposure on birds, the terrestrial EECs for the labeled uses do not exceed the dietary concentrations tested in the Mallard Duck toxicity study. While there are reproductive effects in the Bobwhite Quail, they are only at dietary concentrations at least 3 times above the upper-bound dietary EECs. Altogether, the lack of chronic exceedances indicates low concern for chronic risk in birds, reptiles, and terrestrial-phase amphibians.

Table 17. Acute and Chronic Risk Quotient (RQ) Ranges for Birds, Reptiles, and Terrestrial-Phase Amphibians based on the Labeled Uses of Glufosinate-P (T-REX v. 1.5.2, Upper-Bound Kenaga).

Food Type	Acute Dose-Based RQ[2] LD_{50} > 1,830 mg ae/kg-bw	Acute Dietary-Based RQ[2] LC_{50} > 4,750 mg ae/kg-diet	Chronic Dietary RQ NOAEC = 366 mg ae/kg-diet
	All Size Classes		
All Uses			

Food Type	Acute Dose-Based RQ[2] LD_{50} > 1,830 mg ae/kg-bw	Acute Dietary-Based RQ[2] LC_{50} > 4,750 mg ae/kg-diet	Chronic Dietary RQ NOAEC = 366 mg ae/kg-diet
	All Size Classes		
Herbivores/Insectivores			
Short grass	NC	NC	0.24-0.42
Tall grass	NC	NC	0.11-0.19
Broadleaf plants	NC	NC	0.13-0.24
Fruits/pods/seeds	NC	NC	0.01-0.03
Arthropods	NC	NC	0.09-0.16
Granivores			
Seeds[1]	NC	N/A	N/A

N/A=not applicable; NC = not calculated. The toxicity endpoints listed in the table are those used to calculate the RQ. Foliar dissipation half-life of 13.74 days.

[1] Seeds presented separately for dose-based RQs due to difference in food intake of granivores compared with herbivores and insectivores. This difference reflects the difference in the assumed mass fraction of water in their diets.

[2] Acute dose-based and dietary-based RQs for birds are not estimated because the acute toxicity endpoints are non-definitive.

For mammals, acute dose-based RQ values using upper-bound EECs range from <0.01 to 0.07 (**Table 18**). The RQ values do not exceed the Agency's acute risk LOC for non-listed mammals (LOC=0.5). The was no mortality at doses ≤457 mg ae/kg-bw; however, there is some uncertainty in the study results. Test concentrations were not verified analytically, and it is not clear whether the study authors adjusted the reported concentrations for the purity of the test material. Furthermore, the LD_{50} is based on a small sample size (*i.e.,* n = 1-3), and the toxicity observed may not be representative of the most sensitive mammalian species.

Table 18. Acute Risk Quotient (RQ) Range for Non-listed Mammals based on Uses of Glufosinate-P (T-REX v. Acute Risk Quotient (RQ) Range for Non-listed Mammals based on the Labeled Uses of Glufosinate-P (T-REX v. 1.5.2, Upper-Bound Kenaga).

Food Type	Acute Dose-Based RQ LD_{50} = 954 mg ae/kg-bw			Acute Dietary-Based RQ[2] No toxicity data available
	Small (15 g)	Medium (35 g)	Large (1000 g)	
Herbivores/Insectivores				
Short grass	0.04-0.07	0.03-0.06	0.02-0.03	NC
Tall grass	0.02-0.03	0.02-0.03	≤0.01	NC
Broadleaf plants	0.02-0.04	0.02-0.03	0.01-0.02	NC
Fruits/pods/seeds	<0.01	<0.01	≤0.01	NC
Arthropods	0.02-0.03	0.01-0.02	≤0.01	NC
Granivores				
Seeds[1]	<0.01	<0.01	<0.01	NC

The toxicity endpoints listed in the table are those used to calculate the RQ. If a single RQ value is presented instead of a range, then all uses have the same calculated RQ value for a particular size class and feeding strategy; NC = not calculated

[1] Seeds presented separately for dose-based estimated environmental concentrations (EECs) due to difference in food intake of granivores compared with herbivores and insectivores. This difference reflects the difference in the assumed mass fraction of water in their diets.

Food Type	Acute Dose-Based RQ LD_{50} = 954 mg ae/kg-bw			Acute Dietary-Based RQ[2] No toxicity data available
	Small (15 g)	Medium (35 g)	Large (1000 g)	

[2] Acute dietary-based RQs for mammals are not estimated because no subacute dietary toxicity data are available for this taxon (the acute oral toxicity study used gavage exposure).

Chronic dose-based RQs for mammals range from 0.04 to 12.1 and chronic-dietary based RQs range from 0.05 to 1.40 based on upper-bound Kenaga values (**Table 19**). Dietary-based RQs do not account for differences in food intake based on size and are provided for characterization purposes only. Dose-based RQs further refine the dietary RQs by accounting for both the residues on food items and the size of the mammal. Dose-based RQs exceed the Agency's chronic risk to non-listed mammal LOC (LOC=1.0) for small, medium- and large-sized mammals that feed on short grass, tall grass, broadleaf plants or arthropods across all labeled uses. Dietary-based RQs exceed the LOC for mammals that feed on short grasses.

Table 19. Chronic Risk Quotient (RQ) Range for Non-listed Mammals based on the Labeled Uses of Glufosinate-P (T-REX v. 1.5.2, Upper-Bound Kenaga).

Food Type	Chronic Dose-Based RQ NOAEL = 5.5 mg ae/kg-bw/day			Chronic Dietary RQ NOAEC = 110 mg ae/kg-diet/day
	Small (15 g)	Medium (35 g)	Large (1,000 g)	
Herbivores/Insectivores				
Short grass	**6.81-12.1**	**5.82-10.4**	**3.12-5.55**	**0.79-1.40**
Tall grass	**3.12-5.55**	**2.67-4.74**	**1.43-2.54**	0.36-0.64
Broadleaf plants	**3.83-6.81**	**3.27-5.82**	**1.76-3.12**	0.44-0.79
Fruits/pods/seeds	0.43-0.76	0.36-0.65	0.20-0.35	0.05-0.09
Arthropods	**2.67-4.74**	**2.28-4.05**	**1.22-2.17**	0.31-0.55
Granivores				
Seeds[1]	0.09-0.17	0.08-0.14	0.04-0.08	N/A

Dark shaded cells indicate at least one use exceeds the Agency's chronic LOC of 1.0 for non-listed mammals. The toxicity endpoints listed in the table are those used to calculate the RQ; N/A= not applicable. Foliar dissipation half-life of 13.74 days.

[1] Seeds presented separately for dose – based RQs due to difference in food intake of granivores compared with herbivores and insectivores. This difference reflects the difference in the assumed mass fraction of water in their diets.

The chronic mammalian LOAEL of 16.5 mg ae/kg bw/day is based on a 11-37% reduction in number of viable pups per female across two generations. This effect occurred at a concentration ~3 times above the NOAEL of 5.5 mg ae/kg bw used to calculate the RQ. While the chronic NOAEL and LOAEL are from a racemic glufosinate study, a similar reproductive effect (*i.e.,* 40-43% reduction in pups/female at 61 mg ae/kg-bw/day) occurred following chronic exposure to L-glufosinate and resulted in a similar NOAEL (*i.e.,* 7 mg ae/kg-bw/day). All labeled uses exceed the most sensitive LOAEL based on upper-bound L-glufosinate EECs for small-, medium- and large-sized mammals. Consequently, there is a greater likelihood that mammals with a diet consisting primarily of short grasses, tall grasses, broad leaf plants, or arthropods on treated fields will experience the reproductive effects observed at the LOAEL.

Dose-based RQs can be further refined using mean exposure estimates. The RQs based on mean Kenaga values range from 0.01 to 4.29 and exceed the Agency's chronic risk LOC for small-sized mammals that consume short grass, tall grass, broadleaf plants, or arthropods; for medium-sized mammals that consume short grass, broadleaf plants or arthropods; and, for large-sized mammals that consume short grass (see **Appendix F** for a full summary of chronic mammalian RQs based on mean Kenaga values).

The exceedances noted above assume that 100% of the mammalian diet comes from food sources present on the treated field and that the food sources contain either the upper-bound or mean residue levels. While the RQs may overestimate the reliance of mammals on food items in treated fields, upper-bound dose-based exposure estimates of residues on food items found on the treated field exceed the Agency chronic risk LOC for up to 64 days and up to 44 days based on mean dose-based exposure estimates (**Appendix F**). This suggests that the residue concentrations on some of the on-field food items may exceed the no-observed-adverse-effect-level up to 2 months after application increasing the likelihood of exposure to these residues in mammals that forage for at least a portion of their diet on the field.

Mammals that forage near the treated site may also be exposed to L-glufosinate when consuming food items that contain residues from spray drift deposition. EFED uses AgDRIFT™ (Version 2.1.1) to model the distance off-field at which chronic risk to mammals is no longer a concern. This analysis relies on particle size and boom height recommendations specified on the final glufosinate-P labels (*i.e.,* boom height no greater than 24 inches above the canopy[15] and medium or coarser DSD). EFED notes that the boom height requirements on the label specify a distance above the canopy whereas as boom height in AgDRIFT™ is measured from the ground. Since the canopy height can vary based on crop and application timing, EFED modeled spray drift for both high (*i.e.,* 50 inches above the ground) and low (*i.e.,* 20 inches above the ground) boom height to capture the range of potential spray drift distances. **Table G-1** of **Appendix G** s provides a summary of the AgDRIFT™ results.

Risk estimates using upper-bound dose-based exposure exceed the Agency chronic risk LOC for mammals up to 76 feet from the treated field when L-glufosinate is applied via aerial equipment. Mammalian chronic risk LOC exceedances for ground applications occur up to 3 or 7 feet from the treated field based on whether the boom height is low (20 inches above the ground) or high (50 inches above the ground), respectively. When assessed based on mean exposure estimates, dose-based RQs exceed the chronic risk LOC up to 16 and 3 feet from the field edge for aerial and ground applications, respectively. The spray drift distances reported above assume mammals are foraging on food items downwind of the treatment site during every application, that the wind is blowing in the same direction during each application, and there are no barriers (*e.g.,* windbreaks) impeding the pesticide residues from reaching the

[15] The upper limit of the spray drift boom height restriction on the final labels falls between the low (20 inches) and high (50 inches) boom height options in AgDRIFT™; therefore, spray drift risk to mammals from ground application was estimated for both high and low boom height.

forage areas. This scenario may overestimate exposure and spray drift distances except for use scenarios where the wind direction is constant or multiple applications are made at different sides of the application site and where there are no obstructions between the use site and the species foraging location.

Consistent with the aquatic assessment, risk estimates presented for birds (surrogates for reptiles and terrestrial-phase amphibians) and mammals are based on toxicity data from one or several model species and there is uncertainty as to the extent to which these data represent the range of sensitivities of all species within these taxa. Therefore, there is uncertainty as to the extent to which risk estimates reflect the actual risks to the most sensitive mammals, birds, terrestrial-phase amphibians, and reptiles. The lack of avian toxicity data for L-glufosinate is an additional uncertainty for the bird risk assessment. Although there were no risks of concern identified for birds, the toxicity endpoints used for the risk evaluation are based on exposure to the racemic mixture. As no acceptable data are available to evaluate the relative sensitivity of birds to L-glufosinate, it is uncertain whether the estimates are representative of avian risk to L-glufosinate. However, L-glufosinate would have to be at least 1.3 times more toxic than racemic glufosinate to result in acute or chronic risks of concern for the labeled uses. Based on the available data for terrestrial and aquatic animals though, there is no indication that L-glufosinate is more toxic to these taxa than racemic glufosinate.

There are several uncertainties in the mammalian risk assessment as well. It is uncertain at what dose level between the NOAEL and LOAEL the reproductive effects occur and how many doses are required to achieve the reproductive effects detected in the laboratory study. As mentioned previously, exposure to upper-bound residues exceeds the chronic risk LOC for mammals up to 90 days which suggests a potential for repeated exposure to residues at concentrations above the NOAEL and increases the likelihood of reproductive toxicity. Likewise, risk estimates exceed the chronic risk LOC for all labeled uses when using the LOAEL which indicates that the EECs are high enough to reach levels that are empirically observed to affect mammalian reproduction.

Based on the available data, EFED expects the likelihood of adverse effects from acute and chronic exposure in birds, reptiles, and terrestrial-phase amphibians to be low. While there are no acute risks of concern for mammals, the labeled uses of glufosinate-P represent potential chronic risks of concern for mammals.

4.3 Terrestrial Invertebrate Risk Assessment

4.3.1 Bee Exposure Assessment

Glufosinate-P is labeled for use to control weeds and/or as a burndown on canola, soybean, corn (sweet and field), cotton. It is also labeled for use on genetically modified (GM) glufosinate-tolerant canola, soybean, corn, and cotton. **Table 20** summarizes which of these labeled uses are attractive to pollinators based on the United States Department of Agriculture (USDA) compendium of pollinator-attractive plants as well as those crops requiring bee

pollination and those requiring managed pollination services (USDA 2018[16]). Most of the labeled glufosinate-P uses are on crops or use sites that are opportunistically attractive to honey bees, and/or social/solitary non-*Apis* bees such as bumble bees (*Bombus spp.*) and mason bees (*Osmia spp*.). Based on the USDA publication, canola is highly attractive to honey bees, bumble bees, and/or solitary bees in all cases and requires managed pollination services on at least a portion of the acreage grown. It is, therefore, expected that bees (both *Apis* and non-*Apis*) will forage on or adjacent to the labeled use sites for glufosinate-P.

The final labels recommend application prior to planting (as a burndown) and/or post-emergence up 50-70 days prior to harvest depending on the crop. In addition, post-harvest burndown is permitted for cotton. It is likely that flowering weeds and plants either on or off-site will be in bloom at the time of application. Although glufosinate has limited systemic activity (USEPA, 2014), foliar broadcast application may result in residues on foliar surfaces, pollen, and nectar of crops and plants at the application site. Residues may also be present on flowering weeds on-site and non-target terrestrial plants and weeds off-site due to spray drift. Based on the attractiveness of the crops and use sites, application method, and timing, there is a reasonable expectation that bees (both *Apis* and non-*Apis*) will be exposed to glufosinate while foraging on or adjacent to the treated field either directly from the foliar spray application or from residues on foliar surfaces, pollen, and/or nectar in plants and weeds exposed to glufosinate.

Table 20. Summary of Information on the Attractiveness of the Labeled Use Patterns for Glufosinate-P to Honey Bees (Apis mellifera) and Non-Apis Bees (USDA 2018).

Crop Name	Honey Bee Attractive?[1,2]	Bumble Bee Attractive?[1, 2]	Solitary Bee Attractive?[1, 2]	Acreage in the U.S.	Notes
Corn (*Zea mays*)	+[3]	+	+	87,668,000	Wind pollinated but can be visited during pollen shedding.
Cotton (*Gossypium hirsutum*; *Gossypium barbardense*)	+[4]	+	+, but only some genera	7,664,400	Used by some beekeepers for honey production
Soybean (*Glycine soja*)	+	+	+	75,869,000	
Rapeseed (including canola) *Brassica napus* var. *oleifera*	++	+	++	1,264,500	Managed bees needed for hybrid seed production

[1] Attractiveness rating is a single "+", denoting a use pattern is opportunistically attractive to bees.
[2] Attractiveness rating is a double "++" denoting a use pattern is attractive in all cases.
[3] Source of pollen only.

[16] USDA. 2018. Attractiveness of Agricultural Crops to Pollinating Bees for the Collection of Nectar and/or Pollen. U.S. Department of Agriculture.

Crop Name	Honey Bee Attractive?[1,2]	Bumble Bee Attractive? [1, 2]	Solitary Bee Attractive? [1, 2]	Acreage in the U.S.	Notes

[4] Source of nectar only.
USDA. 2018. Attractiveness of Agricultural Crops to Pollinating Bees for the Collection of Nectar and/or Pollen. https://www.usda.gov/sites/default/files/documents/Attractiveness-of-Agriculture-Crops-to-Pollinating-Bees-Report-FINAL-Web-Version-Jan-3-2018.pdf

4.3.2 Bee Tier I Exposure Estimates

Contact and dietary exposure are estimated separately using different approaches specific for different application methods. The Bee-REX model (Version 1.0) calculates default (*i.e*., high end, yet reasonably conservative) EECs for contact and dietary routes of exposure for foliar, soil, and seed treatment applications. Additional information on bee-related exposure estimates, and the calculation of risk estimates in Bee-REX can be found in the *Guidance for Assessing Risk to Bees* (USEPA *et al.*, 2014).

In cases where the Tier I RQs exceed the LOC, discussed below, estimates of exposure may be refined using measured pesticide concentrations in pollen and nectar of treated crops (provided measured residue data are available), and further calculated for other castes of bees using their food consumption rates as summarized in the White Paper to support the Scientific Advisory Panel (SAP) on the pollinator risk assessment process (USEPA, 2012d).

4.3.3 Bee Risk Characterization (Tier I)

Tier I Risk Estimation (Contact Exposure)

Since there is an exposure potential of bees for most labeled uses on the treated field and for all labeled uses off the treated field, the next step in the risk assessment process is to conduct a Tier 1 risk assessment. By design, the Tier 1 assessment begins with (high-end) model-generated (foliar and soil treatments) estimates of exposure via contact and oral routes. For contact exposure, only adult females (foragers) and males (drones) are considered since other bees are in-hive, the presumption is that they would not be subject to contact exposure. Furthermore, adult contact toxicity testing protocols have only been developed for acute exposures. Screening-level toxicity estimates are based on laboratory studies of individual honey bees (which serve as surrogates for solitary non-*Apis* bees and individual social non-*Apis* bees).

The estimated foliar contact dose for the labeled uses ranges from 0.50 to 0.97 µg ae/bee. Acute contact RQs for adult bees could not be calculated for the labeled uses given that the LD_{50} values from the available studies are non-definitive; however, no acute contact toxicity is observed in adult bees up to exposure levels approximately 100 times the highest estimated contact dose. Consequently, there is low concern for acute toxicity in adult bees resulting from contact exposure after L-glufosinate application.

Tier I Risk Estimation (Oral Exposure)

On-Field Risk

For oral exposure, the Tier 1 assessment considers just the castes of bees with the greatest oral exposure (*i.e*., foraging adult and larval worker bees). If risks are identified for these castes, then other factors are considered for refining the Tier 1 risk estimates. These factors include other castes of bees and available information on residues in pollen and nectar which are deemed applicable to the crops of interest. These exposure data may have been collected on surrogate crops (*e.g*., phacelia, buckwheat, alfalfa) which are known to be attractive sources of both pollen and nectar for bees).

Dietary-based RQs are calculated for adult nectar foragers and larval workers based on the endpoint of concern (*i.e*., LD_{50} and NOAEL/LOAEL for acute and chronic assessments, respectively) and the maximum single application rate for each labeled use. **Table 21** summarizes the estimated oral dose and corresponding RQ range for all uses for the most highly exposed bee caste/task for each life stage; **Appendix F** presents a full summary of RQs for all labeled glufosinate-P uses.

Estimated oral doses for the labeled uses are 11.6 µg ae/bee and 4.9 µg ae/bee for the adult nectar foragers and larval worker bees, respectively. EFED did not calculate acute oral RQs for adult and larval bees for the new use given that the LD_{50} values from the available studies are non-definitive (*i.e*., adult acute oral LD_{50}>97.7 µg ae/bee; larval acute oral LD_{50}>18 µg ae/larva). There was no acute toxicity in adult bees up to oral exposure levels greater than 4 times the highest estimated oral EEC, which suggests a low likelihood of adverse acute effects in adult bees from the labeled uses. In contrast, the highest larval oral EECs approach levels that are approximately 50% of the highest acute dose tested in the larval chronic toxicity study used to establish the surrogate larval Day 8 LD_{50} value. Furthermore, the study reported larval mortality up to 31% at the highest dose tested. The Agency 's LOC for acute bee risk is 0.4 or, alternatively, when the EEC $\geq$40% of the LD_{50} value. The EECs for all the glufosinate-P uses are at least 3.7 times lower than the highest acute dose tested (*i.e.,* $\leq$27% of the highest acute dose tested); therefore, EFED expects the potential for adverse effects from acute exposure because of the labeled uses to be low.

Based on a NOAEL of 2.6 µg ae/larva/day, the chronic larval bee dietary-based RQs range from 0.94 to 1.90 and exceed the Agency's chronic risk LOC of 1.0 for larval worker bees for all labeled L-glufosinate uses except corn seed propagation. The larval bee LOAEL of 5.0 µg ae/larva/day is based on a 19% decrease in adult emergence at a dose level ~2x the NOAEL used to calculate the chronic RQs for larval bees. Estimated exposure for larval worker bees does not exceed the LOAEL for any of the labeled uses.

A definitive NOAEL could not be established for adult bees given that statistically significant ($p<0.05$) reductions in food consumption were detected at all dose levels tested (*i.e*., NOAEL<6.89 µg ae/bee); therefore, the evaluation of chronic risk for adult bees is based on the ED_{10} as discussed in **Section 3.5**. Chronic adult RQs using the ED_{10} range from 20 to 40.8 and

exceed the Agency's chronic risk LOC (LOC = 1.0) for adult foragers for all labeled glufosinate-P uses. There is uncertainty in using the ED_{10} for risk assessment because the available data only cover a narrow range of the dose-response curve, the ED_{10} point estimate is not bound by the empirical data, and the dose response is weak, particularly at the upper end of the doses tested. The LOAEL for adult bees is based on a 30% reduction in food consumption at a dose 23 times above the ED_{10}. While there is uncertainty in using the ED_{10} to evaluate chronic risk to adult bees, chronic RQs calculated based on the food consumption LOAEL of 6.89 µg ae/bee still exceed the Agency's chronic risk LOC for adult foragers for all labeled uses. These findings suggest that a majority of the labeled glufosinate-P uses will result in chronic exposure at a level that is empirically observed to significantly reduce food consumption. Reduced food consumption can have wide ranging effects on other aspects of bee health including survival and growth. The chronic toxicity study with adult bees did not measure bee weight, leaving it uncertain as to whether the observed reduction in food consumption could lead to statistically significant changes in body weight. A significant, dose-dependent reduction in bee survival (14-81%), however, occurred at oral dose levels ≥37.2 µg ae/bee/day. Chronic RQs calculated based on the survival NOAEL of 17.7 µg ae/bee/day do not exceed the chronic risk LOC for labeled uses of glufosinate-P.

Table 21. Tier 1 (Default) Oral Risk Quotient (RQ) Range for Adult Nectar Forager and Larval Worker Honey Bees (*Apis mellifera*) from BeeRex (ver. 1.0) for the Labeled Uses of Glufosinate-P.

Use Pattern	Max. Single Appl. Rate (lb ae/A)	Bee Caste/Task	EEC (µg ae/mg)	Oral Doses (µg ae/bee)	Acute Oral RQ[1]	Chronic Oral RQ[2]
All Uses	0.184-0.359	Adult nectar forager	0.02-0.04	5.91-11.6	NC	**20-40.8**
		Larval worker		2.5-4.9	NE	0.94-**1.90**

Dark shaded cells indicate at least one use exceeds the Agency's chronic risk LOC of 1.0 for bees.
EEC=estimated environmental concentration. NC = not calculated, see footnotes below.
[1] Acute RQs are not estimated because the acute oral LD_{50} for adults (LD_{50} >97.7 µg ae/bee; MRID 51036686) and larvae (8-d LD_{50} >18 µg ae/bee; MRID 51036689) are non-definitive.
[2] Based on a 10-d ED_{10} of 0.238 µg ae/bee/d for adults (MRID 51102401) and a 22-d chronic NOAEL of 2.6 µg ae/bee/d for larvae (MRID 51036689).

The risk estimates for bees are based on upper-bound food consumption rates and model-estimated exposure values from foliar applications. However, the oral doses estimated using this approach assume a single application whereas, some labeled uses allow up to three applications and could result in higher exposure than estimated. The bee risk assessment, therefore, could be further refined with measured residue values. There is some uncertainty in this assessment as to the extent to which bees will be exposed on treated weeds/plants. Weeds/plants that are the target of the application will likely have the highest concentration of glufosinate residues; however, it is also likely that these plants will not survive the application given that L-glufosinate is an herbicide. While dead and dying plants may be less attractive, it does not rule out the possibility of exposure and will depend on how quickly the plants die after application and whether there are alternate sources of forage for the bees. An exposure pathway for bees is more certain from residues on attractive glufosinate-tolerant crops at the

use site, and non-tolerant plants that are indirectly exposed (*i.e.,* crops and plants/weeds off-field) and contain glufosinate residues that do not significantly affect plant health/survival. It should also be noted that this assessment evaluates risks to individual bees based on studies conducted in a laboratory; however, data from the two semi-field studies with honey bees indicate that the effects recorded in these laboratory studies may not translate to colony-level effects.

Off-Field Risk

In addition to bees foraging on the treated field, bees may also be foraging in fields adjacent to the treated fields. Exposure off-field could occur either directly from spray drift during on-field application or indirectly from residues on terrestrial plants that were exposed via spray drift. EFED evaluated spray drift risk to bees with the AgDRIFT™ model (version 2.1.1) using parameters that are consistent with the mandatory spray drift mitigation requirements on the final label (*i.e.,* boom height and particle size restrictions) as discussed in the chronic mammal risk characterization (**Section 3.5**). **Table G-1** of **Appendix G** provides a summary of the AgDRIFT™ results. Risk estimates exceed the Agency chronic risk LOC for adult bees up to 203 feet from the treated field when L-glufosinate is applied via aerial equipment. Adult bee LOC exceedances for ground applications occur up to 13 or 23 feet from the treated field based on whether the boom height is low (20 inches) or high (50 inches), respectively. Larval bee LOC exceedances for ground applications occur up to 3 feet from the treated field whether the boom height is low or high. The assumptions regarding wind direction and off-field residues discussed for mammal spray drift risk (**Section 4.2.2**) also apply to bees.

4.4 Other Terrestrial Invertebrates

4.4.1 Exposure Estimates

Non-bee terrestrial invertebrates may be soil-dwelling for some or all their life cycle or occupy habitat at (*i.e.,* ground-dwelling) or above (*i.e.,* foliar-dwelling) the soil surface. Exposure to L-glufosinate may occur through contact with residues on plant and soil surfaces and/or from consumption of soil or dietary items containing L-glufosinate residues. Contact exposure on plant surfaces are based on upper-bound whole arthropod EECs modeled in T-REX as described in **Section 3.5**. Whole arthropod EECs range from 33.8 to 44.4 mg ae/kg-arthropod for the final glufosinate-P uses (**Appendix F**). EFED estimates exposure through consumption of residue-containing dietary items based on upper-bound EECs modeled in T-REX (see **Section 3.5**) for grasses, broadleaf plants, fruits/seeds, and arthropods, which are all expected dietary items for non-bee terrestrial invertebrates. Upper-bound dietary EECs range from 5.4 to 113 mg ae/kg-diet (**Appendix F**) for labeled glufosinate-P uses across the dietary items. All exposure estimates assume applications occur at the maximum single application rate and, where applicable, subsequent applications are performed at the minimum retreatment interval to reflect the highest possible exposure for each labeled glufosinate-P use. These exposure estimates also

incorporate the same dissipation half-life (*i.e.,* 13.74 days) used in estimating exposure to terrestrial vertebrates.

On-field soil EECs to assess soil contact and ingestion are estimated by converting the single maximum application rate in lbs ae/A to mg ae/kg-dry soil assuming a soil depth of 2.5 cm and soil bulk density of 1.5 kg/L[17]. Soil EEC range 0.7 mg ae/kg-soil within the upper 2.5 cm of soil for the uses with labeled single maximum application rate of 0.359 lbs ae/A.

Terrestrial invertebrates may also forage or seek shelter in areas adjacent to the treated use-site. Non-bee terrestrial invertebrates foraging or inhabiting areas off-site may be exposed to L-glufosinate directly during on-site application as well as indirectly from residues that deposit on terrestrial plants or in the soil. Spray drift is expected to be the primary exposure route for terrestrial invertebrate species that reside above the soil surface whereas soil-dwelling species or species that utilize the soil surface as part of its life history may be exposed to L-glufosinate in runoff in addition to spray drift. Uptake of L-glufosinate in plants exposed to runoff and subsequent partitioning to edible plant tissues is not expected to be a major off-site exposure pathway for terrestrial invertebrates given this chemical's limited systemic activity in plants.

EFED evaluates risk to non-bee terrestrial invertebrates from exposure to spray drift with the AgDRIFT™ model (version 2.1.1) using parameters that are consistent with the mandatory spray drift mitigation specified on the final label (*i.e.,* boom height and particle size restrictions) as discussed in the chronic mammal risk characterization (**Section 3.5**). **Table G-1** of **Appendix G** summarizes the AgDRIFT™ results; results are discussed in each section below. The assumptions regarding wind direction and off-field residues discussed for mammal spray drift risk (**Section 3.5**) also apply to non-bee terrestrial invertebrates.

4.4.2 Foliar Contact Risk Characterization

L-glufosinate toxicity data (see **Section 4.3.3**) for non-bee terrestrial invertebrates are limited to a small number of studies that report endpoints in units of surface area (µg/cm^2) or application rate (lbs ai/A). Since none of the non-bee terrestrial invertebrate contact toxicity endpoints are on a mass ae per weight basis (*i.e.,* mg ae/kg-bw) they cannot be compared directly to the contact EECs modeled in T-REX. To quantify risk from contact exposure on a per weight basis for non-bee terrestrial invertebrates, the honey bee acute contact toxicity endpoints are first normalized for body weight and then compared to the whole arthropod EECs. The available acute contact toxicity endpoint (LD_{50} > 711 mg ae/kg-bw) is non-definitive which precludes calculation of an acute risk quotient. No acute mortality occurred in this study; however, from contact exposure up to 711 mg ae/kg-bw (assuming the default honey bee body weight of 0.128 g), which is approximately 7 times above the highest estimated whole arthropod EEC.

[17] Soil EECs (in mg ai/kg soil) = Application rate (in mg ae/cm^2) ÷ soil depth (2.5 cm) ÷ soil bulk density (0.0015 kg/cm^3)

This would suggest that there is a low concern for acute contact exposure in terrestrial invertebrates.

Contact toxicity data for the parasitic wasp reported on an application rate basis, however, suggest that the honey bee contact toxicity data may not account for the range of sensitivities observed in non-bee terrestrial invertebrates. The application rate producing 50% mortality (LR_{50}) in adult parasitic wasps from contact exposure is 0.044 lbs ae/A which is below the labeled maximum application rate for all uses. Based on these data, application of L-glufosinate at the maximum labeled rate would be expected to cause mortality to terrestrial invertebrate species that contact residues on foliar surfaces after the spray application. In addition, residues that drift off-site during spray application exceed the LR_{50} up to 7 and 53 feet from the field for ground and aerial applications, respectively (**Appendix G**). Although the apparent sensitivity of the parasitic wasp suggests the honey bee contact toxicity data may underestimate the potential for contact toxicity in non-bee terrestrial invertebrates, the parasitic wasp study represents an upper-bound estimate of exposure and toxicity, and, consequently, likely overestimates contact exposure relative to what is expected in the environment. Furthermore, deficiencies in the parasitic wasp studies introduce uncertainty in utilizing those data for assessing contact risk to non-bee terrestrial invertebrates. While these data suggest acute contact exposure could result in mortality to non-bee terrestrial invertebrate species, the actual risk to non-bee terrestrial invertebrates from acute contact exposure is uncertain. No chronic contact toxicity data are available to assess risk for longer-term exposures nor are contact toxicity data available for larvae or pupae to assess relative sensitivity for different lifestages. These are considered additional uncertainties in the contact risk assessment for non-bee terrestrial invertebrates.

4.4.3 Foliar Dietary Risk Characterization

EFED assesses acute and chronic risk from dietary exposure for non-bee terrestrial invertebrates by comparing the upper-bound dietary item EECs to the acute and chronic adult and larval honey bee dietary toxicity endpoints. Accordingly, the dietary assessment includes considerations of exposure duration and different lifestages. Dietary toxicity data for non-bee terrestrial invertebrates are not available; therefore, the honey bee data are used as a surrogate to represent all non-bee terrestrial invertebrate species. **Table 22** summarizes acute and chronic dietary risk estimates for adult and larval non-bee terrestrial invertebrates based on upper-bound residues for each dietary item. **Appendix F** provides individual adult and larval risk estimates for each use based on upper-bound and mean residues.

Definitive toxicity endpoints are available to assess chronic risk in both adult and larval lifestages. Estimated upper-bound residues for all labeled uses on grasses, broadleaf plants, and arthropod dietary items exceed the most sensitive chronic adult dietary terrestrial invertebrate toxicity endpoint (EC_{10} = 8.38 mg ae/kg-diet for the adult honey bee) based on reduced food consumption (**Table 22**). Dietary exposure to upper-bound residues may result in reduced food consumption for adult non-bee terrestrial invertebrates. Fruit and seeds are not expected to exceed the adult food consumption EC_{10} when considering mean residue levels (**Appendix F**).

Mean residues levels on all other dietary items, however, exceed the adult food consumption EC_{10} (**Appendix F**). While these findings suggest that adult terrestrial invertebrates foraging at the application site may consume less food, it uncertain at what dietary exposure level the reduced food consumption in adults translates to effects on growth. Notably, adult mortality is observed at higher dietary exposure levels ($\geq$1,412 mg ae/kg-diet) but none of the labeled uses result in dietary EECs that reach this level of exposure suggesting low risk of chronic mortality in adult non-bee terrestrial invertebrates.

The most sensitive chronic toxicity endpoint for the larval life stage is based on a reduction in adult emergence. While not as sensitive as the reduction in food consumption observed in adult bees, it is a more sensitive chronic toxicity endpoint compared to adult mortality. Upper-bound residues for all labeled uses exceed the NOAEC for larval emergence on grass and broad-leaf plant dietary items. None of the labeled uses have upper-bound residues on fruits, pods, or seeds that exceed the most sensitive larval terrestrial invertebrate NOAEC. When considering mean residues, none of the labeled uses exceed the adult bee emergence NOAEC.

Table 22. Acute and Chronic Dietary Risk Quotient (RQ) Range for Terrestrial Invertebrates (Non-Bee) based on the Labeled Uses of Glufosinate-P (T-REX v. 1.5.2, Upper-Bound Kenaga).

Lifestage and Duration→		Adult	Larval
Food Type↓	**Upper-bound EEC (mg ae/kg-diet)**	**Chronic EC_{10} = 8.38 mg ae/kg-diet**	**Chronic NOAEC = 64.4 mg ae/kg-diet**
All Uses			
Short grass	86.4 – 113	**3.65-6.49**	**1.34 – 2.38**
Tall grass	39.6 – 52.0	**1.55-2.75**	**0.61 – 1.09**
Broadleaf plants	48.6 – 63.8	**1.93-3.44**	**0.75 – 1.34**
Fruits/pods/seeds	5.40 – 7.10	0.30-0.53	0.08 – 0.15
Arthropods	33.8 – 44.4	**2.79-4.96**	0.53 – 0.93

Dark shaded cells indicate at least one use exceeds the Agency's chronic risk level of concern (LOC) of 1.0 for terrestrial invertebrates.
The toxicity endpoints listed in the table are those used to calculate the RQ.

Upper-bound residues on dietary items exceed the most sensitive adult bee toxicity endpoint (*i.e.,* the food consumption EC_{10}) up to 105 feet from the treated field when L-glufosinate is applied via aerial equipment. With ground applications, upper-bound residues exceed the EC_{10} up to 7 or 10 feet from the treated field based on whether the boom height is low (20 inches) or high (50 inches), respectively (**Appendix G**). Spray drift impacts to larvae are only expected from aerial applications and within 3 feet of the field edge.

The use of honey bee toxicity data as a surrogate for dietary toxicity in non-bee terrestrial invertebrates is an uncertainty in evaluating dietary risk to these species. Differences in contact toxicity noted between bee and non-bee terrestrial invertebrates suggest that honey bees may be less sensitive compared to some non-bee terrestrial invertebrate species. Data, however,

are not available to compare dietary toxicity between bee and non-bee species to determine if this pattern extends to other routes of exposure.

Based on the available data, there is a likelihood of adverse effects on non-bee terrestrial invertebrates from contact and dietary exposure from labeled uses of glufosinate-P. While these data focus on effects in individuals, semi-field studies suggest that adverse effects resulting from L-glufosinate applications may manifest in non-bee terrestrial invertebrate populations and communities. Two semi-field studies reported evidence of decline in arthropod populations and communities following one or two spray applications of a racemic glufosinate TEP in treated apple orchards.[18] The study identifies effects on population and communities in untreated rows between the treated orchard sites; however, the decline in populations were more variable and of lesser magnitude compared to the treated areas. Another semi-field study, however, found no effects on arthropod population or community health in treated GMO-maize fields. Whether the lack of statistically significant effects in the maize study reflects reduced impacts at a lower application rate, differences in non-target arthropod (NTA) communities between orchards and maize fields, impacts from prior pesticide applications, or are a result of different sampling techniques between studies, is unknown. Notably, adverse impacts to individual terrestrial invertebrates are anticipated from spray applications to GMO-corn fields based on the contact and upper-bound dietary exposure estimates (**Appendix F**) and include effects (*e.g.*, mortality and reduced adult emergence) that could affect NTA population size.

The semi-field orchard studies suggest though that while spray applications can have a moderate impact on arthropod populations, the effects are transient and arthropod species are able to recover to their original population levels within the course of the season. These findings may be generally applicable to arthropod communities but may not reflect the response of more vulnerable species with smaller populations that lack the necessary resources and/or have unique life history characteristics that preclude recovery from the initial exposure event.

The uncertainties associated with the results of the semi-field study are outlined in **Section 4.3** but there are several additional aspects of the studies to consider when interpreting the results for characterizing risk of L-glufosinate to non-bee terrestrial invertebrates. These studies were conducted in orchards and a maize field and are assumed to reflect non-target arthropod communities at those uses sites. While there may be similarities in species composition at other uses sites, the arthropod community is expected to vary and may differ in resilience from the communities evaluated in the semi-field studies. The conclusions presented in the semi-field studies reflect population and community-level responses from 1-2 applications whereas several labeled uses can be applied up to 3 times in a year which may further exacerbate the effects on arthropod populations and communities, and delay or inhibit population recovery. It

[18] While glufosinate-P is not proposed for use on orchard crops in this action, these studies are considered appropriate to characterize the effects to non-target organisms.

is also difficult to distinguish in the semi-field studies between direct effects on the species that inhabit treated and adjacent areas and indirect effects due to the herbicidal activity of glufosinate that result in loss of plant food sources, prey that rely on plant food sources, and/or habitat. Regardless, the semi-field studies demonstrate an impact of glufosinate treatment on NTA communities and populations following 1-2 spray applications in orchards at approximately the maximum labeled single application rate for L-glufosinate.

Soil Contact/Ingestion Risk Characterization

None of the available toxicity data for soil-dwelling terrestrial invertebrates are considered reliable to quantitatively assess risk to invertebrate species that may be exposed to L-glufosinate residues from ingestion and/or contact with soil. One study from the open literature (Wang *et al*. 2012; ECOTOX Record Number: 159988) reported a nominal 7-day LD_{50} of 167.2 mg ai/kg soil (equivalent to 152.8 mg ae/kg soil) for earthworms exposed to racemic glufosinate ammonium in artificial soil. Although deficiencies in this study limit the use of this endpoint to qualitative purposes only (as discussed in **Section 4.4**), the reported nominal LD_{50} is 74 times above the highest soil EECs for the labeled glufosinate-P uses (**Section 4.4.1**), which suggests that risk of mortality in soil-dwelling terrestrial invertebrates is low. Other soil-dwelling terrestrial invertebrate toxicity data were classified invalid due to major deficiencies and are not considered in evaluating risk to soil dwelling invertebrates. Off-site transport via spray drift and runoff are not expected to impact soil-dwelling terrestrial invertebrates in adjacent areas given the lack of toxicity anticipated at the site of application.

4.5 Plant Risk Assessment

4.5.1 Terrestrial Plant Exposure Assessment

EPA relied upon the Plant Assessment Tool (PAT)[19] for estimating environmental exposure. PAT is a mechanistic model that incorporates fate (*e.g.,* degradation) and transport (*e.g*., runoff) data that are typically available for conventional pesticides, to estimate pesticide concentrations in terrestrial, wetland, and aquatic plant habitats. EFED developed PAT to enable more efficient evaluations of exposure than have traditionally been carried out through post-processing of PRZM/PWC and VVWM output files, and to ensure runoff exposures are consistent with the runoff approaches and assumptions considered for predicting aquatic EECs (*e.g*., standard pond EECs). For terrestrial plants, runoff and erosion are initially modeled using PRZM and spray drift is modeled using the AgDRIFT™-generated deposition curves (**Appendix G**) These are imported into PAT, and the model uses a mixing cell approach to represent water within the active root zone area of soil and accounts for flow through the terrestrial plant exposure zone (TPEZ) caused by both treated field runoff and direct precipitation onto the TPEZ. Pesticide loss from the TPEZ occur from transport (*i.e*., washout and infiltration below the

[19] Visit this website for more information on PAT: https://www.epa.gov/endangered-species/models-and-tools-national-level-listed-species-biological-evaluations-triazine#Aquatic

active root zone) and degradation. EPA modeled wetlands using PRZM/VVWM, which are then processed in PAT to estimate aquatic (mass per volume of water; mg ae/L) and terrestrial (mass per area; lbs ae/A) concentrations. EPA modeled exposure for aquatic plants using PWC and the standard farm pond conceptual model, which are imported into PAT to provide further characterizations of the exposure and potential risk.

Terrestrial Plant Exposure Zone (TPEZ): Runoff and Spray Drift from a Treated Field Deposited onto a Non-Target Terrestrial (Upland) Plant Area Next to the Field

The TPEZ is intended to represent a non-target terrestrial (non-inundated) plant community immediately adjacent to a treated field, which is exposed to pesticide via sheet flow[20] and spray drift from the treated field. More detail on the conceptual model for the TPEZ is provided in **Section 3.6.1**. **Table 23** provides the resulting EECs and RQs for the most sensitive seedling emergence and vegetative vigor-based endpoints.

Estimated peak exposure in the TPEZ from runoff and spray drift to the middle of the TPEZ (*i.e.,* 15 m) range from 0.074 to 0.164 lbs ae/A. Runoff is the main contributor to the pesticide load in the TPEZ for all PWC scenarios evaluated, with drift contributing 0-14% and 0-35% of the pesticide load for ground and aerial applications, respectively. Based upon the TPEZ EECs and vegetative vigor toxicity endpoints, at least one PWC scenario for all labeled uses result in exceedances of the LOCs for risk to dicots (LOC = 1.0; RQ range 2.54-5.66). Although less sensitive than dicots, LOCs are exceeded for monocots for all labeled uses (RQ range 1.47-3.28) based on vegetative vigor toxicity endpoints. As discussed in **Section 3.5**, the seedling emergence toxicity endpoints are less sensitive than the vegetative vigor endpoints, which is consistent with the contact herbicidal mode of action of L-glufosinate. Despite lower sensitivity, there are plant LOC exceedances based on seedling emergence endpoints across monocots and dicots from labeled uses on cotton, corn, and soybean (RQ range 1.19-2.38) as well as for dicots from the labeled uses on canola and sweet corn (RQ range = 1.07-1.36).

Table 23. Upland Terrestrial Plant Risk Quotients (RQ) in the Terrestrial Plant Exposure Zone (TPEZ) based on the Labeled Uses of Glufosinate-P.

Use Sites	1-in-10-yr Runoff + 15 m Drift EEC (lbs ae/A)	Monocot Risk Quotients[1]		Dicot Risk Quotients[1]	
	Peak	SE	VV	SE	VV
		IC_{25} = 0.11 lbs ae/A	IC_{25} = 0.05 lbs ae/A	IC_{25} = 0.069 lbs ae/A	IC_{25} = 0.029 lbs ae/A
Risks of Concern[2]					
Canola[3]	0.094	0.85	**1.88**	**1.36**	**3.23**
Cotton[3]	0.131	**1.19**	**2.62**	**1.90**	**4.52**
Corn[3]	0.164	**1.49**	**3.28**	**2.38**	**5.66**

[20] A continuous film of water flowing over the soil surface which is not concentrated into channels.

Sweet Corn[3]	0.074	0.67	**1.47**	**1.07**	**2.54**
Soybean	0.151	**1.37**	**3.02**	**2.19**	**5.21**

Bolded values indicate RQ that exceeds the Agency's level of concern (LOC) of 1.0 for risk to terrestrial plants. NC = not calculated; see footnotes; ae = acid equivalent; The toxicity endpoints listed in the table are those used to calculate the RQ. GMO = Genetically Modified Organism, in this case crops that are genetically modified to be resistant to L-glufosinate.

[1] The estimated environmental concentrations (EECs) used to calculate these RQs are based on the highest 1-in-10-year 21-day average modeled concentration value of L-glufosinate in **Appendix B.** The values are presented in acid equivalents to be consistent with the toxicity endpoints.

[2] The highest EEC and RQs is presented for each use where at least one scenario is expected to pose risks of concern.

[3] Risks of concern identified from labeled uses on GMO and non-GMO crops.

EFED uses AgDRIFT™ (Version 2.1.1) to model the distance off-field at which risk is no longer a concern for upland terrestrial plants using parameters that are consistent with the mandatory spray drift mitigation specified on the final label (*i.e.,* boom height and droplet size restrictions) as discussed in the chronic mammal risk characterization (**Section 3.5**). **Table G-1** of **Appendix G** summarizes the AgDRIFT™ results. Spray drift affects terrestrial plants up to 89 feet from the field following aerial application and up to 7 or 10 feet from the field following ground application depending on the boom height. These distances are based on the most sensitive dicot NOAEC and the uses with the highest labeled application rates for ground and aerial applications (*i.e*., 0.686 and 0.668 lbs ae/A, respectively). Spray drift effects are expected to be closer to the treated field for dicots and monocots. The assumptions regarding wind direction and off-field residues discussed for mammal spray drift risk (**Section 3.5**) also apply to terrestrial plants.

There are several reported incidents involving plants and associated with the use of racemic glufosinate. As mentioned earlier, there are no ecological incidents reported specifically for L-glufosinate given that L-glufosinate is not registered at the time of this assessment. A majority of the major and minor incidents for racemic glufosinate ammonium involve terrestrial plant damage. Limited information is available on these incidents, so the route of exposure is uncertain.

The results indicate that there are potential risks to terrestrial plant species within 100 ft (~30 m) of all use sites from surface runoff (*i.e*., sheet-flow). Beyond this distance from the edge of the treated field, EFED expects the surface runoff to transition into concentrated flow resulting in transport to wetland, riparian and aquatic habitats downgradient (USEPA, 2020c; PAT User Manual for ESA[21]). EFED anticipates that spray drift also presents a risk to upland plant species off-site; however, only aerial applications present potential risks at appreciable distances from the edge of the use site that are considered distinct from exposure at the use site.

[21] Available in the zip file "Plant Assessment Tool (PAT), v. 2.0 (ZIP)" at https://www.epa.gov/endangered-species/models-and-tools-national-level-listed-species-biological-evaluations-triazine#Terrestrial

Wetland Plant Exposure Zone (WPEZ): Runoff and Spray Drift from a Treated Field Deposited into a Non-Target Wetland Area

The WPEZ is intended to represent a non-target wetland plant community that is exposed to pesticide via overland flow[22] and spray drift. The wetland can be immediately adjacent to the treated field or some distance away and be exposed via spray drift and runoff or from runoff alone. **Section 3.6.1** provides more detail on the conceptual model for the WPEZ.

Table 24 provides the WPEZ EECs and RQs for all labeled uses. Estimated peak exposure in the WPEZ from runoff and spray drift range from 0.112 to 0.302 lbs ae/A. The likelihood of adverse effects from exposure resulting from the labeled uses extend across both seedling emergence and vegetative vigor-based endpoints with LOC exceedances for monocots and dicots (RQ range 1.02-10.4). All labeled uses have at least one PWC scenario that results in exceedances of the LOC for monocot and dicot seeds and emerged plants. In general, there are exceedances regardless of the application timing (*i.e.,* pre-emergence, post-emergence, or both) and number of applications, though EECs are reduced with fewer applications and applications performed pre-emergence only.

Table 24. Semi-Aquatic Plant Risk Quotients (RQ) Terrestrial Plant Species in the Wetland Plant Exposure Zone (WPEZ) based on the Labeled Uses of Glufosinate-P.

Use Sites	1-in-10-yr EEC (lbs ae/A)	Monocot Risk Quotients[1]		Dicot Risk Quotients[1]	
	Peak	SE	VV	SE	VV
		IC_{25} = 0.11 lbs ae/A	IC_{25} = 0.05 lbs ae/A	IC_{25} = 0.069 lbs ae/A	IC_{25} = 0.029 lbs ae/A
Risks of Concern[2]					
Canola[3]	0.175	**1.59**	**3.50**	**2.54**	**6.03**
Cotton[3]	0.137	**1.25**	**2.74**	**1.99**	**4.72**
Corn[3]	0.302	**2.75**	**6.04**	**4.38**	**10.4**
Sweet Corn[3]	0.112	**1.02**	**2.24**	**1.62**	**3.86**
Soybean[3]	0.112	**1.02**	**2.24**	**1.62**	**3.86**

Bolded values indicate RQ that exceeds the Agency's level of concern (LOC) of 1.0 for risk to terrestrial plants. NC = not calculated; see footnotes; ae = acid equivalent; The toxicity endpoints listed in the table are those used to calculate the RQ. GMO = Genetically Modified Organism, in this case crops that are genetically modified to be resistant to L-glufosinate.

[1] The estimated environmental concentrations (EECs) used to calculate these RQs are based on the highest 1-in-10-year 21-day average modeled concentration value of L-glufosinate in **Appendix B.** The values are presented in acid equivalents to be consistent with the toxicity endpoints.

[2] The highest EEC and RQs is presented for each use where at least one scenario is expected to pose risks of concern.

[3] Risks of concern identified from labeled uses on GMO and non-GMO crops.

[22] Water flow that moves in swales, small rills, and gullies

Monitoring data for glufosinate indicate that the chemical can move to non-target aquatic habitats. The maximum measured concentration through monitoring is 3.2 µg/L and is approximately 20% of the most sensitive toxicity endpoint of 17.2 µg/L, based on the dicot vegetative vigor toxicity endpoint and a 0.15 m wetland depth, indicating that the maximum measured concentrations are unlikely to cause adverse effects in wetland plants (**Section 3.5**). However, the monitoring was non-targeted and therefore may not capture the peak concentration in surface water and could underestimate exposure.

The role of adjuvants in the toxicity of glufosinate-P formulations in the environment is an uncertainty in the terrestrial plant risk assessment. The final labels recommend ammonium sulfate as an adjuvant to improve control of more difficult-to control weed species. A general recommendation for adding an anti-foaming agent is also on the final labels for glufosinate-P formulations. The terrestrial plant toxicity studies did not investigate the extent to which the adjuvants affect the efficacy of L-glufosinate. It is, therefore, uncertain how the recommended adjuvants will affect the toxicity of glufosinate-P formulations to non-target terrestrial plant species that may be exposed on or adjacent to the treated field.

Consideration of the Diversity of Terrestrial and Wetland Species Potentially Impacted by Runoff Exposures.

EPA considered the diversity of plants that may be impacted by exposures through runoff for the labeled uses. This comparison relies upon the SSDs generated for the IC_{25} values from the vegetative vigor studies (**Appendix H**). **Figure 4.1** illustrates the TPEZ and WPEZ highest EECs (MSCorn, 1 pre-emergence and 1-post emergence application to GMO corn fields) as they relate to the SSDs. These results suggest that approximately 87% and 99% of plant IC_{25} values would be exceeded in the TPEZ and WPEZ, respectively, for the higher exposure scenarios. Although not represented in **Figure 4.1**, the scenario resulting in the lowest EECs (NCCorn, 1 pre-emergence application to non-GMO sweet corn fields) does not exceed any of the plant IC_{25} in TPEZ and WPEZ. These results illustrate the broad-spectrum of L-glufosinate toxicity and potential risk to species and habitats in terrestrial and wetland environments from runoff and spray drift.

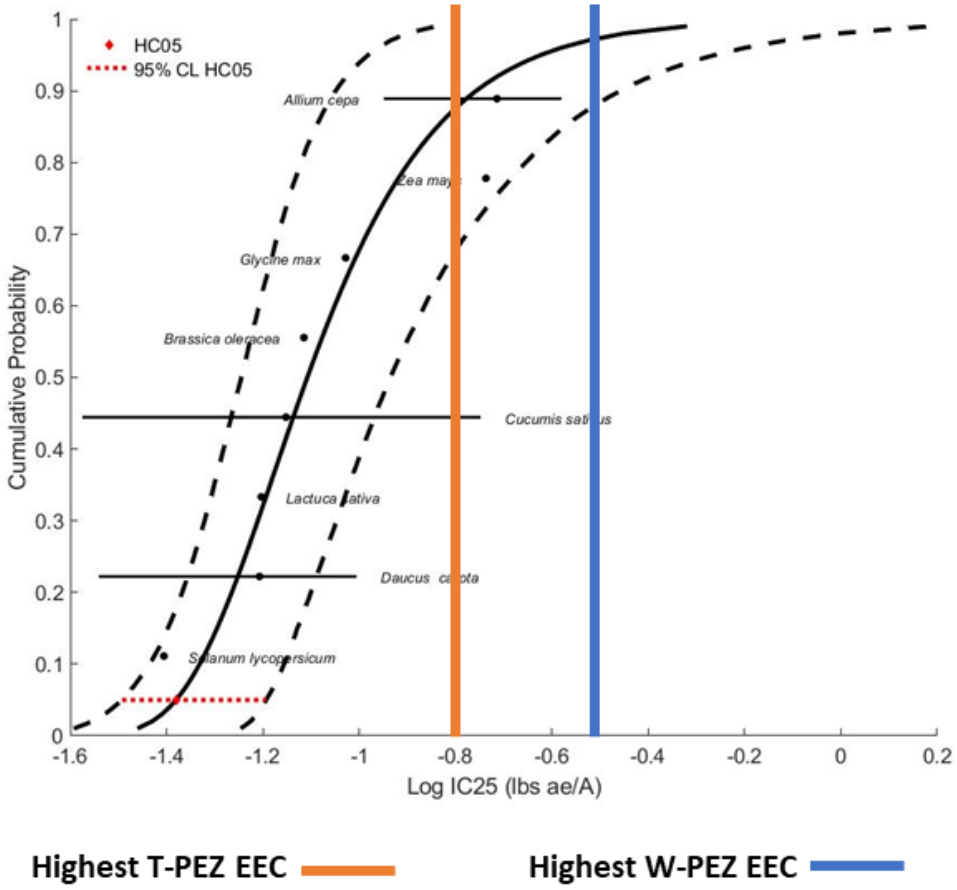

Figure 1. Gumbel Species Sensitivity Distribution (SSD) for glufosinate vegetative vigor endpoints for dry weight. CL=confidence limit; EEC=estimate environmental concentration; HC05=lower 5th percentile of SSD; T-PEZ=Terrestrial Plant Exposure Zone; W-PEZ=Wetland Plant Exposure Zone

4.5.2 Aquatic Plant Exposure Assessment

Aquatic plants are considered within the WPEZ and the Aquatic Plant Exposure Zone (APEZ) which are intended to represent environments where aquatic vascular and non-vascular plants are exposed to pesticide via runoff and/or spray drift. The APEZ aquatic community is the same as the current standard pond model used in aquatic animal assessments.[23] In addition, EFED evaluates effects to aquatic plants in general low volume waterbody based on edge-of-field concentrations compared to the wetland EECs. The evaluation considers that the aquatic plant community in the pond, wetland, or other low-volume waterbody can be immediately adjacent to the treated field or some distance away and be exposed via spray drift and runoff or from runoff alone.

Table 25 and **Table 26** present the range of vascular and non-vascular aquatic plant RQs for all labeled uses for species that inhabit waterbodies similar or larger than the farm pond (*i.e.,* the APEZ) and low-volume waterbodies including wetlands, respectively. **Table E-2** of **Appendix E**. Supplemental Tables for the summarizes vascular and non-vascular aquatic plant RQs for individual labeled uses.

The 1-in-10-year daily mean L-glufosinate EECs for aquatic plants in waterbodies with volume equivalent to or larger than the EPA standard farm pond range from 6.30 to 28.3 µg ae/L (**Section 3.6.1**). The RQs for vascular plants within waterbodies of this size range from 0.01 to 0.05 and do not exceed the Agency LOC for risk to aquatic plants (LOC =1.0). The RQs for non-vascular aquatic plants range from 0.25 to 1.09. Risk to non-listed non-vascular species exceed the Agency's LOC of 1.0 for the labeled uses on corn (GMO uses only).

Table 25. Risk Quotients (RQ) for Aquatic Plants That Inhabit Waterbodies of Similar Size to or Larger than the Standard Farm Pond based on the Use of Glufosinate-P.

Use Sites	1-in-10 Year Daily Mean Surface Water EEC (µg ae/L)	Vascular Risk Quotients[1]	Non-Vascular Risk Quotients[1]
		IC_{50} = 590 µg ae/L	IC_{50} = 26 µg ae/L
Risks of Concern[2]			
GMO-Canola[3]	6.30	0.01	0.25
GMO Cotton[3]	17.6	0.03	0.68
GMO-Corn[3]	28.3	0.05	**1.09**
GMO Sweet Corn[3]	8.86	0.02	0.34
GMO-Soybean[3]	22.8	0.04	0.88

Bolded values indicate RQ that exceeds the Agency's level of concern (LOC) of 1.0 for risk to aquatic plants. see footnotes; ae = acid equivalent; The toxicity endpoints listed in the table are those used to calculate the RQ. GMO = Genetically Modified Organism, in this case crops that are genetically modified to be resistant to L-glufosinate.

[23] USEPA. 2016. The Variable Volume Water Model, Revision A. USEPA/OPP 734S16002. https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/models-pesticide-risk-assessment#PWC

[1] The estimated environmental concentrations (EECs) used to calculate these RQs are based on the highest 1-in-10-year 1-day average modeled concentration value of L-glufosinate in **Appendix B.** The values are presented in acid equivalents to be consistent with the toxicity endpoints.
[2] The highest EEC and RQs is presented for each use where at least one scenario is expected to pose risks of concern.
[3] No risks of concern for the labeled non-GMO uses for these crops.

Peak L-glufosinate EECs in all low-volume waterbodies range from 38.8 to 135 µg ae/L, whereas peak EECs specifically for low-volume wetland habitat range from 70.6 to 167 µg ae/L. The RQs for vascular aquatic plants in low-volume waterbodies and wetlands (RQ = 0.07-0.28) are below the LOC of 1.0 for risk to aquatic plants (**Table 26**) for all labeled uses. Conversely, RQs for aquatic non-vascular plants range up to 6.42 and exceed the LOC of 1.0 for risk to aquatic plants (**Table 26**) for all uses when considering all low-volume waterbodies and wetlands. While there are differences in the EECs in wetlands compared to all low volume waterbodies (as represented by edge-of-field), in general, both models identified risk to non-vascular plants for the same labeled uses.

Table 26. Risk Quotients (RQ) for Aquatic Plants in All Low-Volume Waterbodies (LVW) and Wetland (WL) Habitats based on the Labeled Uses of L-Glufosinate.

Use Sites	1-in-10-yr Edge-of-Field Surface Water EEC (µg ae/L)	1-in-10-yr Wetland Surface Water EEC (µg ae/L)	Vascular Risk Quotients[1]		Non-Vascular Risk Quotients[1]	
			IC_{50} = 590 µg ae/L		IC_{50} = 26 µg ae/L	
	Peak	Daily Average	LVW	WL	LVW	WL
Risks of Concern[2]						
Canola[3]	38.8	157	0.07	0.27	**1.49**	**6.04**
Cotton[3]	135	167	0.23	0.28	**5.19**	**6.42**
Corn[3]	85	137	0.14	0.23	**3.27**	**5.27**
Sweet Corn[3]	43.5	70.6	0.07	0.12	**1.67**	**2.72**
Soybean[3]	83.2	71.3	0.14	0.12	**3.20**	**2.74**

Bolded values indicate RQ that exceeds the Agency's level of concern (LOC) of 1.0 for risk to aquatic plants; ae = acid equivalent. The toxicity endpoints listed in the table are those used to calculate the RQ. GMO = Genetically Modified Organism, in this case crops that are genetically modified to be resistant to L-glufosinate.
[1] The estimated environmental concentrations (EECs) used to calculate these RQs are based on the highest 1-in-10-year 1-day average modeled concentration value of L-glufosinate in **Appendix B.** The values are presented in acid equivalents to be consistent with the toxicity endpoints.The 1-in-10 year edge-of-field surface water values represent exposure in all low-volume waterbodies (LVM) including flowing and static systems, whereas the 1-in-10 year wetland surface water EECs represent exposure in wetlands only.
[2] The highest EEC and RQs is presented for each use where at least one scenario is expected to pose risks of concern.
[3] Risks of concern identified from labeled uses on GMO and non-GMO crops.

The RQs for non-vascular species suggest that the labeled uses are likely to have an impact on non-vascular aquatic plant growth, particularly in low-volume waterbodies; however, non-vascular aquatic plants exhibit a wide range of sensitivities to L-glufosinate among the species for which data are available. Notably, the risk estimates discussed above are based on effects

reported for blue-green algae, which is several orders of magnitude more sensitive compared to the other non-vascular aquatic plant species. Statistically significant growth inhibition in green algae, freshwater diatom, and marine diatom species are observed at concentrations approximately an order of magnitude or more above the aquatic EECs for all waterbodies. Given the unique sensitivity in blue green algae and comparative lack of sensitivity in other tested species, it is expected that effects from L-glufosinate will pose a risk to the most sensitive aquatic non-vascular species but are not likely to impact the non-vascular plant community in aquatic waterbodies of any size.

Risks to vascular aquatic plant species are comparatively more limited, with no concerns across any of the waterbodies modeled. However, data on multiple species are not available to evaluate sensitivity across species and assess potential impacts to aquatic vascular plant communities.

The risk assessment for aquatic plants in all low-volume waterbodies is bound by the same uncertainties related to the environmental relevance of the edge-of-field model discussed for aquatic invertebrates (**Section 3.6.1**). There is less uncertainty in the environmental relevance of the wetland evaluation since it relies on a more deliberate model representation of this unique waterbody; however, uncertainty is introduced when extrapolating exposure estimates across the diverse wetland types found in the US. The WPEZ model is intended to reflect all wetland types but may overestimate exposure in wetlands that experience greater dilution from larger or more constant inputs (*i.e.,* tidal marshes and flow-through), or exhibit smaller fluctuations in water level. Additionally, the standard farm pond EECs are also used as a surrogate for assessing large-volume waterbodies, and it is uncertain if L-glufosinate would represent the same risk to non-vascular species in these waterbodies given additional dilution to the pesticide load with increasing volume.

Acceptable L-glufosinate TEP data are not available to evaluate relative risk of TEP spray drift exposure in aquatic plants. Racemic TEP studies demonstrated lower toxicity to aquatic plants compared to the TGAI; however, it is uncertain whether a similar response would be observed for L-glufosinate TEPs.

Based on the available data, risks to vascular plants are not likely from the labeled uses in any waterbody, whereas risks of concern are identified for non-vascular plants that inhabit all waterbodies.

5 Conclusions

This assessment examines the environmental fate and potential ecological risks associated with labeled uses of glufosinate-P (*i.e*., L-glufosinate and L-glufosinate-P ammonium) on a range of agricultural crops and non-agricultural settings. L-glufosinate is an enriched enantiomer of racemic (D and L) glufosinate. At environmentally relevant pH values, glufosinate-P ammonium exists as glufosinate-P (*i.e*., L-glufosinate). This assessment focuses on L-glufosinate as the sole

residue of concern and all exposure and effect endpoints are expressed as acid equivalents (ae). EPA examined potential ecological risks to non-target organisms under FIFRA.

Given the labeled uses of glufosinate-P and its environmental fate properties, there is a likelihood that non-target terrestrial and aquatic organisms will be exposed to L-glufosinate. Application of glufosinate-P in accordance with final label directions is likely to result in direct effects to mammals, terrestrial and estuarine/marine invertebrates, terrestrial and aquatic plants. Based on RQs below the acute and chronic risk levels of concerns (LOC) for birds, reptiles, terrestrial- and aquatic-phase amphibians, freshwater invertebrates, and freshwater and estuarine/marine fish, there are no direct risks of concern for species within these taxa. There are also no acute risks of concern for estuarine/marine invertebrates nor for bees.

6 Literature Cited

Armitage, J. M., & Gobas, F. A. P. C. 2007. A terrestrial food-chain bioaccumulation model for POPs. *Environmental Science and Technology, 41*, 4019-4025.

Arnot, J. A., & Gobas, F. A. P. C. 2004. A food web bioaccumulation model for organic chemicals in aquatic ecosystems. *Environmental Toxicology and Chemistry, 23*(10), 2343-2355.

Blomquist, J. D., Denis, J. M., Cowles, J. L., Hetrick, J. A., Jones, R. D., & Birchfield, N. 2001. *Pesticides in Selected Water-Supply Reservoirs and Finished Drinking Water, 1999-2000: Summary of Results from a Pilot Monitoring Program*. Open-File Report 01-456. United States Geological Survey. Available at https://pubs.usgs.gov/of/2001/0456/report.pdf.

CADPR. 2012. Surface Water Protection Program Database. Available at http://www.cdpr.ca.gov/docs/emon/surfwtr/surfdata.htm.

CADPR. 2020. *Department of Pesticide Regulation Surface Water Database*. California Environmental Protection Agency. Database accessed on February 27, 2004, by K. Starner, Environmental Research Scientist, Environmental Monitoring Branch. Available at http://www.cdpr.ca.gov/docs/emon/surfwtr/surfdata.htm.

Cain, K.S. and D. J. Lorenz. 2022. L-Glufosinate Ammonium: Assertions of Greater-than-Additive Effects in Granted U.S. Patents. Unpublished report compiled by BASF Corporation Agricultural Solutions, Agricultural Research Center, Research Triangle Park, North Carolina 27709. BASF Corporation Registration Document Number 2022/2041390. Dated 31-Aug-2022; Master Record Identification (MRID) number 51995101.

Cleveland, L., & Hamilton, S. J. 1983. Toxicity of the organophosphorus defoliant DEF to rainbow trout (*Salmo gairdneri*) and channel catfish (*Ictalurus puntatus*). *Aquatic Toxicology, 4*(4), 341-355.

Dierner, J. E. 1986. The ecology and management of the Gopher Tortoise in the Southeastern United States. *Herpetologica, 42*(1), 125-133.

Duke. (2013). Passive Voice in Scientific Writing. Retrieved February 22, 2018, Available at https://cgi.duke.edu/web/sciwriting/index.php?action=passive_voice.

FAO. 2000. Appendix 2. Parameters of pesticides that influence processes in the soil. In FAO Information Division Editorial Group (Ed.), *Pesticide Disposal Series 8. Assessing Soil*

Contamination. A Reference Manual. Rome: Food & Agriculture Organization of the United Nations (FAO). Available at http://www.fao.org/DOCREP/003/X2570E/X2570E06.htm

Goring, C. A. I., Laskowski, D. A., Hamaker, J. H., & Meikle, R. W. 1975. Principles of pesticide degradation in soil. In R. Haque & V. H. Freed (Eds.), *Environmental dynamics of pesticides.* NY: Plenum Press. Available at https://link.springer.com/chapter/10.1007%2F978-1-4684-2862-9_9.

International Union of Pure and Applied Chemistry. *Enantiomerically Enriched*. IUPAC Compendium of Chemical Terminology, 3rd ed. International Union of Pure and Applied Chemistry Online version 3.0.1, 2019. Available at: https://doi.org/10.1351/goldbook.E02071

Kilimstra, W. D., & Newsome, F. 1960. Some observations on the food coactions on the Common Box Turtle, Terrapene C. Carolina. *Ecology, 41*(4), 639-647.

Mushinsky, H. R., Stilson, T. A., & McCoy, E. R. 2003. Diet and Dietary Preference of the Juvenile Gopher Tortoise (*Gopherus polyphemus*). *Herpetologica, 59*(4), 475-483.

NAFTA. 2012. *Guidance for Evaluating and Calculating Degradation Kinetics in Environmental Media*. December 2012. NAFTA Technical Working Group on Pesticides. Available at https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/guidance-calculate-representative-half-life-values.

Oregon Department of Environmental Quality. 2015. *Laboratory Analytical Storage and Retrieval Database (LASAR)*. Available at https://oregonexplorer.info/content/oregon-department-environmental-quality-deq-laboratory-analytical-storage-and-retrieval.

Pennino, K. and L. A. Setliff. 2022. Review of U.S. Patents with Claims of Greater-than-Additive (GTA) Effects Associated with Mixtures of the Proposed New Active Ingredient, L-Glufosinate Free Acid. Unpublished report prepared by Meiji Seika Pharma Co., Ltd. Project ID LI-534-2022-01. Completion Date May 12, 2022. MRID 51911001.

SAP. 2009. *SAP Minutes No. 2009-01. A set of Scientific Issues Being Considered by the Environmental Protection Agency Regarding: Selected Issues Associated with the Risk Assessment Process for Pesticides with Persistent, Bioaccumulative, and Toxic Characteristics. October 28-31, 2008.* January 29, 2009. FIFRA Scientific Advisory Panel. Office of Science Coordination and Policy. Available at https://www.regulations.gov/docketBrowser?rpp=50&po=0&D=EPA-HQ-OPP-2008-0550.

State Water Resources Control Board. 2015. California Environmental Data Exchange Network. California State Water Resources Control Board. Available at http://www.ceden.org/.

Takano, H. K., R. Beffa, C. Preston., P. Westra, and F. E. Dayan. 2020. A novel insight into the mode of action of glufosinate: how reactive oxygen species are formed. *Photosynthesis Research, 144*(3), 361-372.

USDA. 2013. Pesticide Data Program. U.S. Department of Agriculture. Agricultural Marketing Service. Available at http://www.ams.usda.gov/AMSv1.0/ams.fetchTemplateData.do?template=TemplateC&navID=&rightNav1=&topNav=&leftNav=ScienceandLaboratories&page=PesticideDataProgram&resultType=&acct=pestcddataprg.

USDA. 2018. *Attractiveness of Agricultural Crops to Pollinating Bees for the Collection of Nectar and/or Pollen*. Document cites 2017 above the Table of Contents; however, the document was completed in January 2018. U.S. Department of Agriculture. Available at https://www.ars.usda.gov/ARSUserFiles/OPMP/Attractiveness%20of%20Agriculture%20Crops%20to%20Pollinating%20Bees%20Report-FINAL_Web%20Version_Jan%203_2018.pdf.

USEPA. 1993. *Wildlife Exposure Factors Handbook*. EA/600/R-13/187a. Office of Research and Development. U.S. Environmental Protection Agency. Available at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=2799.

USEPA. 2000. *Interim Policy for Evaluation of Stereoisomeric Pesticides*. October 26, 2000. Environmental Fate and Effects Division. Office of Pesticide Programs. Available at https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/interim-policy-evaluation-stereoisomeric-pesticides.

USEPA. 2004a. *Overview of the Ecological Risk Assessment Process in the Office of Pesticide Programs*. Environmental Fate and Effects Division. Office of Pesticide Programs. U.S. Environmental Protection Agency. Available at http://www.epa.gov/espp/consultation/ecorisk-overview.pdf.

USEPA. 2004b. *Government Printing Office. Overview of the Ecological Risk Assessment Process in the Office of Pesticide Programs*. January 23, 2004. Environmental Fate and Effects Division. Office of Pesticide Programs. U.S. Environmental Protection Agency. Available at https://www.epa.gov/sites/production/files/2014-11/documents/ecorisk-overview.pdf.

USEPA. 2009. *Ecological Risk Assessment for the Section 3 New Uses of Acetamiprid on Red Clover, Small Fruit, and Climbing Vines (Except Kiwi)*. DP364328. Memorandum From B. D. Kiernan & D. Lieu to J. Chao & J. Hebert. December 10, 2009. Environmental Fate and Effects Division. Office of Prevention, Pesticides, and Toxic Substances. United States Environmental Protection Agency.

USEPA. 2009a. *EPA Communications Stylebook: Writing Guide*. U.S. Environmental Protection Agency. Available at https://www.epa.gov/stylebook/epa-communications-stylebook-writing-guide#grammar.

USEPA. 2009b. *Guidance for Selecting Input Parameters in Modeling the Environmental Fate and Transport of Pesticides, Version 2.1*. Environmental Fate and Effects Division. Office of Pesticide Programs. U.S. Environmental Protection Agency. Available at https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/guidance-selecting-input-parameters-modeling.

USEPA. 2010a. *Guidance for Reporting on the Environmental Fate and Transport of the Stressors of Concern in the Problem Formulation for Registration Review, Registration Review Risk Assessments, Listed Species Litigation Assessments, New Chemical Risk Assessments, and Other Relevant Risk Assessments*. January 25, 2010. Environmental Fate and Effects Division. Office of Chemical Safety and Pollution Prevention. U.S. Environmental Protection Agency. Available at http://www.epa.gov/pesticides/science/efed/policy_guidance/team_authors/endangered_species_reregistration_workgroup/esa_reporting_fate.htm.

USEPA. 2010b. *WQTT Advisory Note Number 9: Temperature Adjustments for Aquatic Metabolism Inputs to EXAMs and PE5*. Memorandum From D. F. Young to Water Quality Tech Team. September 21, 2010. Environmental Fate and Effects Division. Office of Chemical Safety and Pollution Prevention. U.S. Environmental Protection Agency.

USEPA. 2011. *Guidance for Using Non-Definitive Endpoints in Evaluating Risks to Listed and Non-listed Animal Species*. Memorandum From D. J. Brady to E. F. a. E. Division. May 10, 2011. Environmental Fate and Effects Division. Office of Chemical Safety and Pollution Prevention. U.S. Environmental Protection Agency. Available at http://www.epa.gov/pesticides/science/efed/policy_guidance/team_authors/endangered_species_reregistration_workgroup/esa_non_definitive_endpoints.htm.

USEPA. 2012a. *Glufosinate Ammonium. Report of the Residues of Concern Knowledgebase Subsommittee (ROCKS)*. D397644. March 29, 2012. Health Effects Division. Office of Pesticide Programs. U.S. Environmental Protection Agency.

USEPA. 2012b. *Refined Drinking Water Assessment for Glufosinate-ammonium Use on Rice.* D387412. May 30, 2012. Environmental Fate and Effects Division. Office of Pesticide Programs. U.S. Environmental Protection Agency.

USEPA. 2012c. *Standard Operating Procedure for Using the NAFTA Guidance to Calculate Representative Half-life Values and Characterizing Pesticide Degradation*. November 30, 2012. Environmental Fate and Effects Division. Office of Pesticide Programs. U.S. Environmental Protection Agency. Available at https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/guidance-calculate-representative-half-life-values.

USEPA. 2012d. *White Paper in Support of the Proposed Risk Assessment Process for Bees. September 11-14, 2012*. September 11, 2012. U.S. Environmental Protection Agency. Pest Management Regulatory Agency. California Department of Pesticide Regulation. Available at http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OPP-2012-0543-0004.

USEPA. 2012e. *Environmental Chemistry Guidance*. Memorandum from D. J. Brady to Environmental Fate and Effects Division. December 20, 2012. Environmental Fate and Effects Division, Office of Pesticide Programs. United States Environmental Protection Agency. Available at https://www.epa.gov/sites/production/files/2015-08/documents/ftt_env_chem_methods.pdf.

USEPA. 2013a. *Guidance for Using PRZM-GW in Drinking Water Exposure Assessments*. December 11, 2012. Environmental Fate and Effects Division. Office of Pesticide Programs. U.S. Environmental Protection Agency.

USEPA. 2013b. *Guidance on Modeling Offsite Deposition of Pesticides Via Spray Drift for Ecological and Drinking Water Assessment*. Environmental Fate and Effects Division. Office of Pesticide Programs. Office of Chemical Safety and Pollution Prevention. U.S. Environmental Protection Agency. Available at http://www.regulations.gov/#!docketDetail;D=EPA-HQ-OPP-2013-0676.

USEPA. 2014a. *Development of Community Water System Drinking Water Intake Percent Cropped Area Adjustment Factors for use in Drinking Water Exposure Assessments: 2014 Update*. 9/9/14. Environmental Fate and Effects Division. Office of Chemical Safety and Pollution Prevention. U.S. Environmental Protection Agency. Available at

https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/development-community-water-system-drinking-water.

USEPA. 2014b. *Guidance for Addressing Unextracted Residues in Laboratory Studies*. Memorandum From to E. F. a. E. Division. September 12, 2014. Environmental Fate and Effects Division. Office of Pesticide Programs. Office of Chemical Safety and Pollution Prevention. Available at https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/guidance-addressing-unextracted-pesticide-residues.

USEPA. 2015. *Storet/WQX Data Warehouse*. United States Environmental Protectin Agency. Available at http://www.epa.gov/storet/dw_home.html.

USEPA. 2016. *Refinements for Risk Assessment of Pesticide Treated Seeds - Interim Guidance*. March 31, 2016. Environmental Fate and Effects Division. Office of Pesticide Progams. U.S. Environmental Protection Agency. Available at https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/refinements-risk-assessment-pesticide-treated-seeds.

USEPA. 2017. *Guidance for Using Daily Average Aquatic Concentrations in Ecological and Drinking Water Assessments*. June 27, 2017. Environmental Fate and Effects Division. Office of Chemical Safety and Pollution Prevention. U.S. Environmental Protection Agency.

USEPA. 2019. Process for Receiving and Evaluating Data Supporting Assertions of Greater than Additive (GTA) Effects in Mixtures of Pesticide Active Ingredients and Associated Guidance for Registrants. Office of Pesticide Programs, U.S. Environmental Protection Agency, Washington DC 20460. Dated August 2019. https://www.regulations.gov/document/EPA-HQ-OPP-2017-0433-0002

USEPA, & Health Canada. 2012. *Guidance for Selecting Input Parameters for Modeling Pesticide Concentrations in Groundwater Using the Pesticide Root Zone Model*. Version 1. October 15, 2012. Environmental Fate and Effects Division. Office of Pesticide Programs. U.S. Environmental Protection Agency. Available at https://archive.epa.gov/epa/pesticide-science-and-assessing-pesticide-risks/guidance-selecting-input-parameters-modeling-0.html.

USEPA, Health Canada PMRA, & California Department of Pesticide Regulation. 2014. *Guidance for Assessing Pesticide Risks to Bees*. June 23, 2014. U.S. Environmental Protection Agency. Health Canada Pest Management Regulatory Agency. California Department of Pesticide Regulation. Available at http://www2.epa.gov/pollinator-protection/pollinator-risk-assessment-guidance.

USEPA, USGS, & NWQMC. 2018. Water Quality Portal. United States Environmental Protection Agency. United States Geological Survey. National Water Quality Monitoring Council. Available at https://www.waterqualitydata.us/.

USGS. 2015. National Water-Quality Assessment Program (NAWQA). U.S. Geological Survey. Available at http://water.usgs.gov/nawqa/.

USGSA. 2011. *Federal Plain Language Guidelines*. March 2011. U. S. General Services Administration. Available at https://plainlanguage.gov/media/FederalPLGuidelines.pdf.

Washington State Department of Ecology. 2015. *State of Washington Department of Ecology Environmental Monitoring Data*. Washington State Department of Ecology. Available at http://www.ecy.wa.gov/eim/index.htm.

7 Referenced MRIDs

MRID 50982321. Staggs, M.L. 2019. L-Glufosinate Ammonium - Acute Toxicity Test with Mysids (*Americamysis bahia*) Under Static Conditions. Study conducted by Smithers Wareham, Massachusetts. Study No. 14167.6107. Study sponsored by AgriMetis, LLC, Lutherville, Maryland. Study initiated September 4, 2018, and completed November 12, 2019.

MRID 50982322. Staggs, M.L. 2019. L-Glufosinate Ammonium 280 g/L SC – Acute Toxicity to Rainbow Trout (*Oncorhynchus mykiss*) Under Static Conditions. Study conducted by Smithers Wareham, Massachusetts. Study no.: 14167.6110. Study sponsored by AgriMetis, LLC Lutherville, Maryland. Study initiated on March 8, 2019, and completed on November 12, 2019.

MRID 50982323. Picard, C.R. 2019. L-Glufosinate Ammonium 280 g/L SC – Seedling Emergence Test. Unpublished study performed by Smithers, Wareham, Massachusetts. Laboratory Study ID: 14167.6104. Study sponsored by AgriMetis, LLC, Lutherville, Maryland. Study completed November 13, 2019.

MRID 50982324. Kirkwood, A. 2019. L-Glufosinate 280 g/L SC – Vegetative Vigor Test. Unpublished study performed by Smithers, Wareham, Massachusetts. Laboratory Project ID: 14167.6105. Study sponsored by AgriMetis, LLC, Lutherville, Maryland. Study completed October 31, 2019.

MRID 50982325. Tome, H.V.V. *et al.* 2019. L-Glufosinate Ammonium: A Chronic Larval Toxicity Study with the Honey Bee (*Apis mellifera*). Unpublished study performed by Eurofins EAG Agroscience, LLC. Study No. 897H-101. Study sponsored by AgriMetis, LLC. Study completed October 25, 2019.

MRID 50982326. Staggs, M.L. 2019. L-Glufosinate Ammonium – 96-Hour Toxicity Test with the Freshwater Cyanobacterium, *Anabaena flos-aquae*. Study performed by Smithers, Wareham, Massachusetts. Study number 14167.6106. Study sponsored by AgriMetis, LLC, Lutherville, Maryland. Study initiated March 8, 2019, and completed November 7, 2019. Final report amended on November 14, 2019.

MRID 51036676. Sipos, K. 2013. Acute oral toxicity of Glufosinate-P(AH-01) Tech. on Japanese quail (*Coturnix coturnix japonica*). Study conducted by CiToxLAB Hungary Ltd. H-8200 Veszprém, Szabadságpuszta. Laboratory Project ID: 12/412-115FÜ. Study sponsored by Meiji Seika Pharma Co., Ltd., Tokyo, Japan. Study initiated February 18, 2013, and completed May 30, 2013.

MRID 51036677. Sipos, K. 2013. Avian dietary toxicity test of Glufosinate-P(AH-01) Tech. on Japanese quail (*Coturnix coturnix japonica*). Study performed by CiToxLAB Hungary Ltd. H-8200 Veszprém, Szabadságpuszta. Laboratory project number 12/412-113FÜ. Study sponsored by

Meiji Seika Pharma Co., Ltd., Tokyo, Japan. Study initiated May 22, 2013, and completed July 31, 2013.

MRID 51036678. Sipos, K. 2013. Acute Toxicity Test with Glufosinate-P (AH-01) Tech. on Rainbow Trout (*Oncorhynchus mykiss*). Study conducted by CiToxLAB Hungary Ltd., Veszprém, Szabadságpuszta, Hungary. Study no. 12/412-009H. Study sponsored by Meiji Seika Pharma Co., Ltd., Tokyo, Japan. Study completed June 12, 2013, and amended July 31, 2013.

MRID 51036679. Anai, M. 2005. A 96-hour Acute Toxicity Study of AH-01 Technical with Common Carp. Study conducted by Kurume Laboratory, Fukuoka, Japan. Study no. 93835. Study sponsored by Meiji Seika Pharma Co., Ltd., Tokyo, Japan. Study initiated November 11, 2005, and completed December 16, 2005. Report Amended December 28, 2005.

MRID 51036680. Anai, M. 2005. A 96-hour Acute Toxicity Study of AH-01 Liquid with Common Carp. Study conducted by Kurume Laboratory, Fukuoka, Japan. Study no. 93838. Study sponsored by Meiji Seika Pharma Co., Ltd. Study initiated on September 30, 2005, and completed on November 2, 2005.

MRID 51036681. Yoshikawa, M. 2005. A 48-hour Acute Immobilization Study of AH-01 Technical with *Daphnia magna*. Study conducted by Kurume Laboratory, Fukuoaka, Japan. Study no. 93834. Study sponsored by Meiji Seika Pharma Co. Ltd. Study initiated on November 11, 2005, and completed on December 19, 2005.

MRID 51036682. Yoshikawa, M. 2005. A 48-hour Acute Immobilization study of AH-01 Liquid with *Daphnia magna*. Study conducted by Kurume Laboratory, Fukuoka, Japan. Study no. 93837. Study sponsored by Meiji Seika Pharma Co, Ltd. Study initiated on October 11, 2005, and completed on December 19, 2005.

MRID 51036684. Ross T.L, Elliot S.E, Schneider S.Z., Zhang, L. 2020. L-Glufosinate Free Acid: A 96-Hour Static Acute Toxicity Test with the Saltwater Mysid (*Americamysis bahia*). Study conducted by Eurofins EAG Agroscience, LLC, Easton, Maryland. Study no. 912A-101. Study sponsored by Meiji Seika Pharma Co., Ltd. Tokyo, Japan. Study initiated on January 21, 2020, and completed on April 8, 2020.

MRID 51036685. Milligan, A.L., Elliott, S.E., Schneider S.Z. and Zhang, L. (2020). L-Glufosinate Free Acid: A Flow-Through Life-Cycle Toxicity Test with the Saltwater Mysid (*Americamysis bahia*). Eurofins EAG Agroscience, Easton, MD. Study No. 912A-102B. Study sponsored by Meiji Seika Pharma Co., Tokyo, Japan. Study initiated on January 10, 2020, and completed on April 22, 2020.

MRID 51036686. Ryu, S. 2012. Acute Oral Toxicity Study of Glufosinate-P Tech. 93% on Honey Bees (*Apis mellifera*). Kyung Nong Co. Ltd., Gyeongju-si, Syeongsang-do, Korea. Laboratory Report ID G12021. Study sponsored by Meiji Seika Pharma Co., Tokyo, Japan. Study completed November 23, 2012.

MRID 51036687. Ryu, S. 2012. Acute Contact Toxicity of Glufosinate-P Tech. 93% on Honey Bees (*Apis mellifera*). Kyung Nong Co. Ltd., Gyeongju-si, Syeongsang-do, Korea. Laboratory Report ID G12022. Study sponsored by Meiji Seika Pharma Co., Tokyo, Japan. Study completed November 23, 2012.

MRID 51036689. Tome, H. V.V. and Porch, J.R. 2020. L-Glufosinate Free Acid: A Chronic Larval Toxicity Study with the Honey Bee (*Apis mellifera*). Study conducted by Eurofins EAG Agroscience, LLC, Easton, Maryland. Study no. 912H-101. Study sponsored by Meiji Seika Pharma Co., Ltd. Tokyo, Japan. Study completed February 19, 2020.

MRID 51036690. Sipos, K. 2013. Acute toxicity of Glufosinate-P(AH-01) Tech. on Earthworms (*Eisenia fetida*) in Artificial Soil. Study performed by CiToxLAB Hungary Ltd., Veszprém, Szabadságuszta, Hungary. Study number 12/412-125G. Study sponsored by Meiji Seika Pharma Co., Ltd. Study completed May 27, 2013.

MRID 51036692. Sindermann, A.B., J.R. Arnie, S.E. Elliott, and L. Zhang. 2020. L-Glufosinate: A Toxicity Test to Determine the Effects on Seedling Emergence of Four Species of Plants. Unpublished study performed by Eurofins EAG Agroscience, LLC, Easton, Maryland. Study Number: 912P-101. Study sponsored by Meiji Seika Pharma Co., Ltd., Tokyo, Japan. Study completed April 10, 2020. Amended report date April 15, 2020.

MRID 51036693. Sindermann, A.B., J.R. Arnie, S.E. Elliott, and L. Zhang. 2020. L-Glufosinate: A Toxicity Test to Determine the Effects on Vegetative Vigor of Four Species of Plants. Unpublished study performed by Eurofins EAG Agroscience, LLC, Easton, Maryland. Study Number: 912P-102. Study sponsored by Meiji Seika Pharma Co., Ltd., Tokyo, Japan. Study completed March 26, 2020.

MRID 51036694. Softcheck KA. 2020. L-Glufosinate Free Acid - 7-Day Toxicity Test with Duckweed (*Lemna gibba*). Study conducted by Smithers (formerly Smithers Viscient), Wareham, Massachusetts. Study no. 10934.6176. Study sponsored by Meiji Seika Pharma Co., Ltd. Study initiated on July 15, 2019, and completed on January 31, 2020.

MRID 51036696. Sueta, S. 2005. Algal Growth Inhibition Test of AH-01 Liquid with *Pseudokirchneriella subcapitata*. Study conducted by Kurume Laboratory, Chemicals Evaluation and Research Institute, Fukoka, Japan. Study no. 93836. Study sponsored by Meiji Seika Pharma Co., Ltd., Tokyo, Japan. Study initiated October 4, 2005, and completed November 8, 2005.

MRID 51036697. Softcheck, K.A. 2020. L-Glufosinate Free Acid – Toxicity to the Freshwater Cyanobacterium, *Anabaena flos-aquae*. Study conducted by Smithers, Wareham, Massachusetts. Study No. 10934.6175. Study sponsored by Meiji Seika Pharma Co., Ltd. Tokyo, Japan. Study initiated on July 15, 2019, and completed on March 31, 2020.

MRID 51787603. Mead-Briggs, M.A. 1988. A Laboratory and Field Investigation of the Direct Toxicity to Non-Target Beneficial Arthropods. Study conducted by the Agrochemical Evaluation

Unit of the University Southampton. Laboratory Report ID A37880. Study sponsored by BASF Corporation. Study completed March 4, 1988.

MRID 51787604. Bakker, F. 2015. A field trial to determine the effects of glufosinate-ammonium SL 150 (150 g/L) on the non-target weed and soil-dwelling arthropod fauna of an apple orchard in SW Germany following one and two early season weed applications. Study conducted by MITOX Consultants, Amsterdam, The Netherlands. Laboratory Study No.: B165FFA. Study sponsored by Bayer CropScience AG, Monheim, Germany. Study completed March 31, 2015.

MRID 51787605. Bakker, F. 2015. A field trial to determine the effects of glufosinate-ammonium SL 150 (150 g/L) on the non-target weed and soil-dwelling arthropod fauna of an apple orchard in SW France, following one and two early season weed applications. Study conducted by MITOX Consultants, Amsterdam, The Netherlands. Laboratory Study No.: B164FFA. Study sponsored by Bayer CropScience AG, Monheim, Germany. Study completed March 31, 2015.

MRID 51787606. Oellrich, W. 2000. Evaluation of potential side effects of Liberty to non-target arthropods under field conditions. Study conducted by Arbeitsgemeinschaft. GAB Biotechnologie GmbH & IFU Umweltanalytik GmbH. Laboratory Report ID 99245/G1-FNTO. Study sponsored by Aventis CropSciences GmBH. Study completed July 17, 2000.

MRID 51631401. Takagi Y., Kohjimoto, T., and Wada, Y. 2005. Report of the effects of AH-01 technical product on a predaceous mite (*Phytoseiulus persimilis*). Study conducted by Research Institute of Japan Plant Protection Association. No study ID. Sponsored by Meiji Seika Kaisha, Ltd. Study completed on December 2005.

MRID 51631402. Sipos, K. 2014. Effect of Glufosinate-P(AH-01) Tech. on the parasitic wasp (*Aphidius rhopalosiphi*) in a laboratory trial. Study performed by CiToxLAB Hungary Ltd., Veszprém, Szabadságuszta, Hungary. Study number 14/132-335FD. Study sponsored by Meiji Seika Pharma Co., Ltd. Study completed June 6, 2014.

MRID 51631403. Kohjimoto, T., Takagi Y., and Wada, Y. 2005. Report of the contact toxicity test for AH-01 technical product on a parasitic wasp (*Aphidius colemani*). Study conducted by Research Institute of Japan Plant Protection Association. No study ID. Sponsored by Meiji Seika Kaisha, Ltd. Study completed on September 2005.

MRID 51631404 Takagi Y., Kohjimoto, T., and Wada, Y. 2005. Report of the contact toxicity test for AH-01 technical product on a flower bug (*Orius strigicollis*). Study conducted by Research Institute of Japan Plant Protection Association. No study ID. Sponsored by Meiji Seika Kaisha, Ltd. Study completed on December 2005.

8 Biological Evaluation

8.1 Overview

In its final biological evaluations (BE), EPA conducted an effects determination that considers the potential effects of a pesticide action on listed species and their critical habitat, and subsequently predicts the potential likelihood that an action can jeopardize a listed species existence or adversely modify a species' designated critical habitat (CH[24]) in the future. The listed species assessments are divided into two sections: the effects determination and predictions of potential likelihood of future jeopardy/adverse modification (J/AM).

The effects determination considers whether the pesticide action poses any reasonable expectation of discernible effects to listed species and CH[25] that are within the action area. In making the effects determinations for species, EPA considers direct effects to the listed species as well as impacts to organisms on which the listed species depends for prey, pollination, habitat and/or dispersal (PPHD). The term "direct effects" refers to decreases in the survival, growth, or reproduction of individuals of a listed species due to exposure to the pesticide. When making effects determinations for CHs, EPA considers whether there may be potential effects to listed species within the CH or effects to the physical and biological features (PBF) of the CH.

For listed species, EPA also evaluates the potential for indirect effects. Indirect effects consider the RQs for taxa based on the FIFRA screening-level assessment upon which listed species may depend (*i.e.*, taxa representing prey, pollinators, habitat, or dispersers). If the RQs fall below the LOC for listed species, EPA concludes that direct effects are not reasonably certain to occur. If RQs fall below the LOC for non-listed species, EPA concludes that direct effects are not likely to occur for non-listed species and PPHD effects to listed species would not be reasonably expected to occur because of a listed species' reliance upon a taxon with RQs<LOCs.

In the effects determination, EPA evaluates whether the registration of the pesticide (*i.e.*, the federal action) will have "No Effect" (NE) on a given listed species or CH or a discernable effect that "May Affect" (MA) the species or CH. The U.S. Fish and Wildlife Service (FWS) and National Marine Fisheries Service (NMFS), hereafter referred to collectively as the Services, regulations stipulate that a consultation obligation is triggered when an Agency action may affect one or more listed species or CH. For those species and CH for which EPA determined MA, EPA further determines whether the action: "may affect but is not likely to adversely affect" (NLAA) the listed species or CH; or "may affect and is likely to adversely affect" (LAA) the listed species or

[24] Henceforth in this document, the acronym CH is used to represent designated critical habitat.

[25] This assessment focuses upon currently listed endangered and threatened species and designated critical habitats. During consultation, EPA may confer with the Services to identify any additional species or critical habitats that are relevant to this action.

CH. An LAA determination for an action means that there is a discernible adverse effect to one or more individuals of a listed species or their CH.

It is EPA's obligation under Section 7 of the Endangered Species Act (ESA) to ensure that the registration of the glufosinate-P does not jeopardize the continued existence of listed species or adversely modify CH. To inform consultation with the Services, for those species and CHs with LAA determinations, EPA also predicts the potential likelihood that the pesticide action could lead to future jeopardy of listed species or destruction or adverse modification of CH.[26] The predictions of potential likelihood of future J/AM consider adverse direct effects to the listed species and adverse effects to the species' PPHD as well but reframe the evaluation in terms of impacts at the species-level. EFED has finalized this assessment after considering comments received during the public comment period. If EPA determines that the final uses meet the FIFRA standard, EPA will consult with the Services because the final effects determinations include May Affect determinations.

This listed species assessment uses the best available scientific information on the use, environmental fate and transport, and ecological effects of glufosinate-P. **Section 8.2** describes the action, the scope of the assessment including a summary of the taxa-based screening-level conclusions, and the methodology for the effects determination and predictions of likely J/AM. **Section 8.3** summarizes the conclusions of the effects determinations and predictions of potential likelihood of future J by taxa. **Section 8.4** summarizes the conclusions of the effects determinations and predictions of potential likelihood of future AM for all CH. Details on the quantitative analyses and qualitative considerations that lead to the effects determinations and predictions of potential likelihood of future J/AM for each species can be found in the **Appendices I-N**.

8.2 Description of the Action and Methodology

The purpose of this assessment is to complete effects determinations and predict the potential likelihood of future J/AM for federally listed species and CHs based on the registered use of glufosinate-P. This section provides 1) a description of the federal action, the scope of the listed species assessment, and the associated action area; and 2) the effects determination and J/AM prediction methodology.

This section describes the uses of glufosinate-P that are included on the final product labels, the scope of the listed species assessment in terms of number of species and critical habitat assessed, and this section defines the Action Area. The federal action for the effects determinations and predictions of the potential likelihood of future J/AM is the registration of all formulated products containing the enantiomerically-enriched herbicide L-glufosinate. The compound is intended to provide non-selective post-emergence control of weeds at

[26] 50 CFR 402.40(b)(1) provides that EPA may describe in its effects determination the predictions of the likelihood of future jeopardy to a listed species or adverse modification of any designated critical habitat.

agricultural and non-agricultural use sites. A description of the products for registration under Section 3 of the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) is provided in **Section 3**. Three formulated products containing glufosinate-P as the sole active ingredient, and one technical product are included in the registration. This listed species assessment focuses on the uses for the following crops: This listed species assessment focuses on the uses for the following crops:

- glufosinate-resistant and conventional soybean (in crop, burndown and fallow/postharvest use prior to planting soybean) in the contiguous U.S.;
- glufosinate-resistant and conventional corn and sweet corn (in crop, burndown and fallow/postharvest use prior to planting corn/sweet corn) in the contiguous U.S. excluding California;
- glufosinate- resistant and conventional cotton (in crop, burndown and fallow/postharvest use prior to planting cotton) in the contiguous U.S. excluding counties in Florida below Tampa, Florida;
- glufosinate-resistant and conventional canola (in-crop, burndown and fallow/postharvest use prior to planting canola) in the contiguous U.S. The use on glufosinate-resistant canola is prohibited in numerous states (*i.e.*, Alabama, Delaware, Kentucky, Maryland, New Jersey, North Carolina, South Carolina, Tennessee, Virginia, and West Virginia); and,
- corn, cotton and soybean seed production in Hawaii and Puerto Rico.

A summary of labeled use directions is provided in **Table 6** of **Section 3** and is described briefly here. Glufosinate-P is labeled for application using ground boom or aerial equipment. The maximum single application rates for these uses ranges from 0.184 to 0.359 pounds acid equivalents[27] per acre (lbs ae/A). Glufosinate-P may be applied between one and three times in a year depending on the use resulting in maximum annual application rates that range from 0.359 to 0.727 lbs ae/A. The minimum retreatment intervals (RTI) for these uses range from 7 to 10 days. The final label restricts droplet size to medium or coarser and boom height for ground boom applications cannot exceed 24 inches above the crop canopy.

8.2.1 Scope of the Listed Species Assessment

This section describes the scope of the listed species assessment for glufosinate-P including the number of species and critical habitats assessed and which taxa need to be evaluated for direct effects and effects to PPHD. EPA's BEs consider only species the Services list as endangered and threatened and critical habitats that are designated final. As of February 16, 2022, there are 1,715 species listed as endangered and threatened and 826 CHs designated final which are

[27] Under environmentally relevant pH (pH 5-9) values, the salts of glufosinate (e.g., glufosinate ammonium) will exist primarily as glufosinate acid anion with a counterion determined by the ambient environment; therefore, exposure is expressed in terms of acid equivalents.

evaluated in the glufosinate-P BE. This assessment does not evaluate species federally listed as endangered or threatened and CH designated final after that date.

The taxa-based ERA described in the preceding section (**Section 3**) developed in support of the registration under FIFRA serves as a screening-level analysis for the BE. As described in **Section 3.5**, this approach relies upon RQs and LOCs (**Table 27**) that are designed to identify a potential for effects on taxa and distinguish those taxa where refinements may be needed to better understand whether there may be effects. EPA's taxa-based assessment is used to focus the species-specific analysis on types of direct or PPHD effects that may be relevant to listed species or critical habitats. When EPA's screening-level assessment shows that a RQ exceeds a listed species LOC, it does not automatically mean that the action may affect a species. Instead, it means further species-specific review is needed to determine whether the action may affect a listed species or its CH. Also, when a RQ does not exceed the listed species LOC for a taxon representing a listed species, it does not necessarily mean that the determination is NE, because potential effects to PPHD also need consideration. Therefore, EPA considered the life history, distribution of the species, and effects of glufosinate-P on organisms on which the listed species depends for PPHD before making effects determinations. The sections below discuss the approach EPA used to make effects determinations for listed species and CHs. **Table 27** provides the RQ value and associated LOC for risks to non-listed versus listed species.

Table 27. Risk quotient (RQ) and levels of concern (LOC) by taxon for non-listed and listed species.

Taxon	Exposure duration	Listed/non-listed	RQ[1]	LOC[1]
Fish and aquatic-phase amphibians	Acute	Non-listed, general PPHD effects	1-in-10-year, Daily EEC/LC_{50}	0.5
		Listed direct effects & obligate PPHD effects	1-in-10-year, Daily EEC/LC_{50}	0.05
	Chronic	Listed and non-listed, general and obligate PPHD effects	1-in-10-year, 60-day EEC/NOAEC	1
Aquatic invertebrates	Acute	Non-listed, general PPHD effects	1-in-10-year, Daily EEC/LC_{50}	0.5
		Listed direct effects & obligate PPHD effects	1-in-10-year, Daily EEC/LC_{50}	0.05
	Chronic	Listed and non-listed, general and obligate PPHD effects	1-in-10-year, 21-day EEC/NOAEC	1
Birds, terrestrial-phase amphibians, reptiles	Acute	Non-listed, general PPHD effects	Upper bound EEC/LC_{50} (Dietary) Upper bound EEC /LD_{50} (Dose)	0.5
		Listed direct effects & obligate PPHD effects	Upper bound EEC /LC_{50} (Dietary) Upper bound EEC /LD_{50} (Dose)	0.1
	Chronic	Listed and non-listed, general and obligate PPHD effects	Upper bound EEC /NOAEC	1
Mammals	Acute	Non-listed, general PPHD effects	Upper bound EEC /LD_{50} (Dose)	0.5
		Listed direct effects & obligate PPHD effects	Upper bound EEC /LD_{50} (Dose)	0.1
	Chronic	Listed and non-listed, general and obligate PPHD effects	EEC^{1}/NOAEC (Dietary) EEC^{1}/NOAEL (Dose)	1

Taxon	Exposure duration	Listed/non-listed	RQ[1]	LOC[1]
Terrestrial invertebrates	Acute	Non-listed, general PPHD effects	EEC/LD_{50} (contact) EEC/LD_{50} (diet)	0.4[2]
		Listed direct effects & obligate indirect effects	EEC/LD_{50} (contact) EEC/LD_{50} (diet)	0.05[3]
	Chronic	Listed and non-listed, general and obligate PPHD effects	EEC/NOAEC (diet)	1[2]
Aquatic plants	Not applicable	Non-listed, general PPHD effects	1-in-10-year, Daily EEC/ IC/EC_{50}	1
		Listed direct effects & obligate PPHD effects	1-in-10-year, Daily EEC/ NOEC	1
Terrestrial plants	Not applicable	Non-listed, general PPHD effects	EEC/ IC_{25}	1
		Listed direct effects & obligate PPHD effects	EEC/ NOEC	1

EC_{50}= 50% effect concentration; EEC=estimated environmental concentration; IC_{25}=Concentration resulting in 25% inhibition; LC_{50}=lethal concentration for 50% of the organisms tested; LD_{50}=lethal dose for 50% of the organisms tested; NOAEC=no-observed adverse effect concentration.
[1]USEPA 2004.
[2]USEPA, PMRA, CDPR 2014.
[3]USEPA 2007.

Table 28 summarizes the screening-level results for generic taxa and the direct and indirect effects concerns for each these taxa. Based on EPA's screening-level assessment, there are risk concerns for aquatic invertebrates (chronic RQ range: <0.01-2.01), bees (chronic RQ range: 1.9-40.8), non-bee terrestrial invertebrates (chronic RQ range: 0.07-2.28), mammals (acute RQ range: <0.01-0.04; chronic RQ range: 0.04-6.81), non-vascular aquatic plants (RQ range: Listed [0.36-1.57]; non-listed [0.25-1.09]), upland terrestrial (RQ range: listed [1.60-7.13] and semi-aquatic (RQ range: listed [2.43-13.1) plants. Screening-level RQs exceed the listed species LOCs for mammals, terrestrial invertebrates, aquatic invertebrates, and upland (*i.e.,* occupy terrestrial habitat above flood plain where soil does not remain saturated) semi-aquatic (*i.e.,* occupy permanent or ephemeral aquatic habitat but is not fully submerged) and aquatic (*i.e.,* fully submerged in aquatic habitat) plants. Consequently, EPA is considering the potential for direct effects to listed species within these taxa in this listed species assessment. In addition, EPA is considering the potential for PPHD effects for all listed species that rely on these taxa. Direct effects to birds, reptiles, fish, or amphibians are not a concern based on the screening-level assessment; however, PPHD effects need to be considered for species from these taxa that rely on mammals, invertebrates, and/or plants.

Table 28. Summary of Direct and Prey, Pollination, Habitat and/or Dispersal (PPHD) Effects Considerations by Taxon for Listed Species Based on the Screening-Level Analysis for the Labeled Uses of Glufosinate-P on Conventional and Glufosinate-resistant Corn, Sweet corn, Soybean, Cotton, and Canola.

Taxon	Screening-level RQs Exceed LOC?	Potential Direct Effects	Potential PPHD Effects	Direct Effects Taxa Relevant to Prey, Pollination, Habitat, and Dispersal
Mammals	Listed and Non-listed	Yes	Yes	**Prey/Diet:** Terrestrial/Semi-Aquatic Plants, Mammals, Invertebrates **Habitat:** Terrestrial/Semi-Aquatic Plants
Birds	No	No	Yes	
Reptiles	No	No	Yes	
Fish	No	No	Yes	**Prey/Diet:** Semi-Aquatic and Aquatic Plants, Invertebrates **Habitat:** Terrestrial/Semi-Aquatic and Aquatic Plants
Amphibians	No	No	Yes	
Aquatic Invertebrates	Listed and Non-listed	Yes	Yes	
Terrestrial Invertebrates	Listed and Non-listed	Yes	Yes	
Terrestrial/Semi-Aquatic Plants	Listed and Non-listed	Yes	Yes	**Pollination and Dispersal:** Terrestrial Invertebrates, Mammals
Aquatic Plants	Listed and Non-listed	Yes[1]	No	None

[1] Although risk quotient (RQ) values exceeded the listed species level of concern (LOC) for risk to non-vascular aquatic plants, there are no federally listed non-vascular aquatic plants. The non-vascular aquatic plant RQs exceed the non-listed species LOC, however, indicating possible impacts to species that rely on non-vascular aquatic plants for PPHD.

8.2.2 Action Area

The action area represents all potential exposure areas for the pesticide action which includes potential use sites of glufosinate-P and potential non-target areas where glufosinate-P exposure may occur (*e.g.,* due to spray drift and runoff) from glufosinate-P uses. The action area for this listed species assessment considers only the labeled uses on corn (field and sweet), cotton, soybean, and canola. Several restrictions on the label for these uses limit the extent of the action area. Within the contiguous United States, applications to corn are not permitted in California and applications to cotton in Florida are not permitted south of Tampa Bay. Additionally, glufosinate-P is not labeled for use on glufosinate-resistant canola in Alabama, Delaware, Kentucky, Maryland, New Jersey, North Carolina, South Carolina, Tennessee, Virginia, and West Virginia, but may be used on non-tolerant canola in these states. Applications outside of the contiguous United States are only permitted in Hawaii and Puerto Rico on corn, cotton, and soybean grown for seed production. There are no labeled uses in Alaska, Guam, the Mariana Islands, America Samoa, and the Virgin Islands. There are no geographical restrictions for the uses on soybean within the contiguous US; therefore, it is assumed that glufosinate-P may be applied anywhere in the contiguous US that soybeans are grown.

The labeled uses of glufosinate-P (**Section 3**) are used to identify spatial data that represent potential application sites of glufosinate-P. These data are referred to as Use Data Layers (UDLs; see **Appendix I** for additional information on the generation of the UDLs). The UDLs (**Table** 33) represent the potential locations of glufosinate-P applications in the contiguous US (CONUS) and states and US territories outside of CONUS (referred to as non-lower 48 or NL48).

Table 33. Crosswalk of the Use Data Layer (UDL) with the crop use patterns for the registration of glufosinate-P.

Use Site/ Location (Variety and/or Crop Group)	CONUS Use Data Layer (UDL)	NL48 Use Data Layer (UDL)
Canola: Canola (Rapeseed) (Subgroup 20A)	Other Grains	Ag
Corn (Field), Millet, Sorghum and Teosinte	Corn	Ag
Corn (Sweet, Seed, and Popcorn)	Vegetables and Ground Fruit	Ag
Cotton	Cotton	Ag
Soybean	Soybean	Ag

CONUS = Contiguous United States; NL48 = Non-lower 48 states including Alaska, Hawaii, and the US territories

EPA determined the extent of the off-site area to be included in the action area by adding a buffer to the UDLs. This buffer represents the farthest distance from the treated sites where effects on listed species or CH are reasonably expected to occur. For terrestrial taxa and aquatic taxa exposed to glufosinate-P as a result of spray drift and/or runoff, UDLs were conservatively buffered in all directions.[28] Since EPA's generic taxon-based assessment (**Section 3**) shows that semi-aquatic plants represent the most sensitive taxon for effects from the use of glufosinate-P, EPA conservatively used semi-aquatic plant exposure and toxicity data to establish the farthest off-site distance where effects of glufosinate-P are reasonably expected to occur for the action area. EPA selected 1,500 meters as an upper-bound estimate of the area in which runoff could enter a wetland or other low-volume aquatic habitat within a catchment based on the upper bound distance from the edge of catchment to its main drainage network (USEPA 2022). This upper-bound estimate for runoff distance is intended to be conservative and is set for the purposes of establishing the action area. All other potential direct and PPHD effects identified in the screening level assessment are expected to occur at distances less than 1,500 meters and, thus, are captured within the action area. The action area for the CONUS states, Hawaii, and Puerto Rico are presented in **Appendix J .**

8.2.3 Overlap Analysis

The extent of overlap for glufosinate-P with likely exposure areas and the species' range or CH integrates information on potential use sites and usage data (when available) with the species locations. The exposure area represents different exposure potential based on how the range and CH are defined. The range and CH for all terrestrial species and CH for aquatic species that are defined as distinct waterbodies reflect distinct areas in which the species may occur, or the CH is located; therefore, the exposure area represents the potential geographic space within the action area that exposure can occur to either the species or its CH from the use site and off-site transport. The range and CH for most aquatic species, however, are defined at the watershed scale and for these species the exposure area represents the combined area of the use site and off-site transport located within the watershed(s) that contribute to the species' aquatic habitat. An exposure area is developed for each UDL for each species/CH and encompasses the use site and off-site buffer that accounts for all off-field exposure. The potential pesticide use sites are represented using geographic information system (GIS) layers developed from multiple data sources (**Appendix I**). EPA also leveraged additional non-spatial datasets to support the evaluation of initial spatial overlap results. These additional data provide refinement to the location of potential use and potential treated area and provide qualitative refinement when interpreting the results.

Overlap is considered in identifying which species and CH the action may affect, and in the weight of evidence when deciding whether use of glufosinate-P is likely or not likely to adversely affect (LAA or NLAA) an individual of a listed species, and/or predicting the likelihood

[28] The action area includes an exposure area extending from each pesticide use site found across UDLs in all directions out to this distance.

of jeopardy to the population or adverse modification of the CH. This section describes the approach for determining the exposure area including refinements for different steps of the BE as well as the methods for identifying species and CH within the exposure areas to support the effects determination and the predictions of potential likelihood of future J/AM.

Determining the Exposure Area

EPA made separate considerations for terrestrial species and aquatic species when determining the exposure area given the differences in how the ranges and CH are defined as discussed above. For terrestrial species or species with a terrestrial phase, EPA assumes that there may be direct overlap of the species locations with use sites as well as sites adjacent to the field that receive spray drift and runoff. To determine the exposure area for a given use, EPA, therefore, considered whether the terrestrial species is anticipated to occupy, forage in, or move through the use site, and the extent to which off-site transport affects the species, directly and/or through its PPHD, at the individual and population level. Aquatic species will not be present at the labeled use sites since no labeled uses involve direct to water applications; therefore, off-site transport is the primary route of exposure for aquatic species. However, when the range and CH for the species is at the watershed scale, the use site along with the off-site transport is considered in the overlap as both will contribute to exposure in the watershed. Separate exposure areas are established for direct effects and PPHD effects to understand how each contributes to potential adverse effects in the species or its CH and to the inform development of mitigations that may need to be separately tailored to address direct and PPHD effects.

Direct Overlap Considerations

EPA made initial determinations as to whether a terrestrial species may be present on non-orchard agricultural use sites based on the best available information from the Services' documentation. A terrestrial species is assumed to be on-field unless available information explicitly states the species will not occupy the use site. Similar considerations were not made for aquatic species since there are no direct to water applications. As mentioned above, the range for aquatic species are at the watershed scale and the use site included in the overlap given its contribution to exposure in the watershed.

These initial on/off-field determinations were used in establishing the exposure area for the effects determination and predictions of the potential likelihood of future J/AM. When a terrestrial species is not anticipated to be present at a use site, the on-field area is subtracted from the overall exposure area for that use. An on-field determination could represent the likelihood of single individual entering a use site or a pattern of behavior in a species that could result in a population-level exposure (*i.e.,* a listed species with a preference for pasture habitat). For many terrestrial species, movement of a single individual into a use site could not be discounted based on life history information. EPA did, however, utilize life history information to qualitatively assess the likelihood that a population-level exposure would occur at a use site to support the predictions of the potential likelihood of future J/AM and is discussed further in **Section 8.2.4**. The initial on/off field determinations and any additional

refinements to these determinations for evaluating population-level impacts are summarized in **Appendix M** for each species. On/off-field considerations were not incorporated in the exposure area developed for assessing impacts to CH.

Off-Site Transport

EPA buffered the exposure areas out from the use site based on the farthest distance from the treated sites where effects on listed species or CH are reasonably expected to occur. The buffer distance varies in size based on the sensitivity of the species and its PPHD to glufosinate-P and the level of biological organization (*i.e.*, individual or population-level). EPA also refined several of the assumptions for off-site transport used in establishing the action area to determine the off-site buffers for the exposure areas, which are discussed below. The method used in GIS to add buffers to the UDLs for establishing the exposure area is described in detail in **Appendix J**.

Spray drift into terrestrial, wetland, and aquatic habitats off-field is estimated in AgDRIFT™[29] for ground and aerial applications using particle size and boom height recommendations described on the final glufosinate-P labels (*i.e.,* boom height no greater than 24 inches above the canopy[30] and medium or coarser DSD[31]). For aquatic habitats, the size of the waterbody is based on the representative waterbody for each aquatic bin (**Section 3.6**) and the estimates reflect exposure at the point of deposition and do not account for flow in the waterbody. The buffer distance for spray drift in the effects determination and predictions of the potential likelihood of future J/AM is based on the toxicity thresholds for direct effects to the individual, population, and the species PPHD (**Section 8.2.5**). Spray drift distance to effects for terrestrial and aquatic species with the potential to be directly affected by the labeled L-glufosinate uses are summarized in **Appendix G**. Based on the spray drift analysis, spray drift from ground applications is not likely to impact listed species off the field. Drift from aerial application, in contrast, is likely to impact listed species up to 60 meters from the use site depending on the taxa, the level of biological organization affected (*i.e.,* individual, population, or community), and the UDL.

AgDRIFT™ reports spray drift distances in feet which are then converted to meters and incorporated into the exposure area for a UDL using an omnidirectional buffer. Since the spray drift buffers for the action area are in 30-meter increments based on the data resolution, the AgDRIFT™ output is rounded to the nearest 30-meter increment. Spray drift distances within 3

[29] AgDRIFT™ (version 2.1.1; https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/models-pesticide-risk-assessment), a modified version of the AGricultural DISPersal (AGDISP™) model developed by the US Forest Service. The AgDRIFT™ model has the capability to assess a variety of spray drift conditions from agricultural applications and off-site deposition of liquid formulation of pesticides. This model can be used in estimating downwind deposition of spray drift from aerial, ground boom and orchard/vineyard airblast applications.

[30] The upper limit of the spray drift boom height restriction on the final labels falls between the low (20 inches) and high (50 inches) boom height options in AgDRIFT™; therefore, spray drift surface water EECs for ground application were determined for high boom height to provide the most conservative estimate.

[31] AgDrift™ does not have a "medium or coarser" droplet distribution for ground applications. The ground assessment, instead, uses a "fine to medium/coarse" distribution to approximate off-field drift for ground applications using equipment that produce medium to coarse droplets. This could result in overestimating the potential off-field exposure.

meters (~10 feet) of a lower increment are rounded down; otherwise, the spray drift distance is rounded up (*e.g*., a drift distance of 33 meters would be rounded down to 30 meters, whereas a drift distance of 34 to 63 meters would be rounded to 60 meters). EFED considers drift distances within 1-3 m of the use site to be indistinguishable from exposure at the use-site; therefore, EFED does not consider such drift distances in developing the UDL exposure area. Since the exposure area can only be buffered out in 30-meter increments, drift distances rounded up to the next 30-meter increment are overestimated in the overlap analysis. This is further compounded by the assumption of omnidirectional movement. Drift is most likely to travel off-site based on the direction of the wind, which can shift during application, but is unlikely to result in movement off-field in all directions during each spray event. While the wind direction cannot be predicted, increasing the number of potential applications at a use site increases the likelihood that spray drift exposure reflects the omni-directional assumption in the buffer. Likewise, habitat that is surrounded by use sites will have an increased likelihood of spray drift exposure regardless of wind direction.

Runoff from the use sites will follow the topography of the field and surrounding area and is expected to leave the use site in the same direction unless land use changes or field management practices alter the topography. Due to limited information about use sites, the direction of runoff for every use site is uncertain and, thus, EPA assumes that runoff will occur in any direction. Runoff from treated use-sites into terrestrial, wetland, and aquatic habitats is expected to proceed as sheet flow for the first 30 meters from the field and then become channelized flow thereafter. It is uncertain how far runoff in channelized flow will travel from the field and will be dependent on the topography and land use in surrounding areas. As discussed in **Section 8.2**, the upper-bound distance from the edge of a catchment to its main drainage network is 1,500 meters and this distance is used as the initial upper-bound buffer distance to account for channelized flow runoff.

In the effects determination and predictions of the potential likelihood of future J/AM, the exposure area buffer for runoff exposure to aquatic animal taxa and upland terrestrial plants is refined to 30 meters for all use sites. For aquatic animal taxa, this is supported by the fact that all aquatic listed species are mapped based upon their watershed and vary in scale, such that if the range or CH overlap with the UDL + a 30-meter buffer does not exceed 1%, EPA can reasonably say it is unlikely to have a runoff exposure from glufosinate-P connecting the UDL to the species' range or CH. For upland terrestrial plants, the 30 -meter distance is selected to assess impacts from runoff exposure to terrestrial plants that occupy areas adjacent to the use site. EPA assumes that sheet flow will be driver of exposure from runoff in terrestrial environments consistent with the TPEZ model used to evaluate exposure to plants in upland habitats. While channelized flow may impact upland terrestrial plants at distances greater than 30 meters from the field, the extent of exposure is uncertain.

For runoff exposure to semi-aquatic and aquatic plants, the exposure area buffer initially extends out to 1,500 meters to identify potential discernable effects (*i.e.,* MA/NE determination) and is refined to 60 meters for evaluating adverse effects to individuals of a listed species, its population, and CH (*i.e.,* NLAA/LAA determination and predictions of the

potential likelihood of future J/AM). The 60-meter distance was selected to assess the proximity of the semi-aquatic or aquatic plant habitat to the use site. EPA expects that pesticide exposure in wetland and aquatic habitats in proximity to the use site are likely to reflect the modeled EECs and there is an increased likelihood that impediments or geographic features (*i.e.,* topography and landcover changes), and penetration of glufosinate-P into soil will attenuate runoff exposure with increasing distance from the field. Implicit in the proximity evaluation is that the habitat within 60 meters contains semi-aquatic or aquatic plants whereas it may represent multiple habitat types for a species that is known to reside in and outside of wetland and aquatic habitats. The contribution of glufosinate-P transported downstream from its initial entry into wetland or aquatic systems to exposure of aquatic and semi-aquatic species and the resulting impacts to listed species that rely on these aquatic taxa for PPHD is uncertain.

Table 30 summarizes the off-site buffer distance added to the exposure areas for each UDL for each taxon identified in the generic taxon screening assessment as having the potential to be directly affected by the labeled glufosinate-P uses. These distances are used to define the area in which direct effects to listed species from that taxon (where applicable) may occur and the area in which impacts to other listed species that rely on the taxon for PPHD may occur [e.g., in predicting the potential likelihood of future jeopardy for a listed mammalian species that relies on semi-aquatic plants, EPA evaluated the potential for direct effects based on the overlap with the use site only (*i.e.,* 0 m) and the potential for PPHD effects based on overlap with the use-site and an off-site buffer of 60 meters]. Although EPA separately determined the buffer distance for runoff and spray drift, the exposure area captures potential exposure from both sources of off-site transport.

Table 30. Off-site transport buffer distances considered in the effects determinations and predictions of potential likelihood of future jeopardy/adverse modification from labeled uses of Glufosinate-P.

Taxa	UDL	Off Site Transport (runoff + spray drift) Buffer			Notes
		MA/NE Determinations	LAA/NLAA Determinations	Predicting the Likelihood of Jeopardy/Adverse Modification[1]	
Mammals	Corn, Cotton, Soybean, Other Grain, NL48_Ag	30 m	0-30 m^2	Adverse direct effects to mammal populations are not likely from the uses of glufosinate-P.[3]Adverse direct effects to mammal populations are not likely from the labeled uses of glufosinate-P.[3]	Distance based on aerial drift and runoff (for aquatic mammalian species only). Drift from ground applications is not likely to affect species off-field.
	Vegetable and Ground Fruit	30 m	0 m		
Upland Terrestrial Plants	Corn, Cotton, Soybean, Other Grain,	30 m	30 m	30 m	Distance based on runoff and aerial drift. Drift from ground

Taxa	UDL	Off Site Transport (runoff + spray drift) Buffer			Notes
		MA/NE Determinations	LAA/NLAA Determinations	Predicting the Likelihood of Jeopardy/Adverse Modification[1]	
	Vegetable/Ground Fruit, NL48_Ag				applications is not likely to affect species off-field.
Semi-Aquatic Plants		1500 m	60 m	60 m	Distance based on runoff. Drift impacts from aerial uses anticipated within 30 m of the field. Drift from ground applications is not likely to affect species off-field.
Aquatic Plants		1500 m	60 m[4]	60 m[4]	Discernable effects (NE/MA determination) likely in all waterbodies; however, individual and population-level adverse effects are only likely in low volume waterbodies only (wetlands and Bins 2 and 5). The distance reported are based on runoff. Drift impacts from aerial uses likely within 30 m of the field. Drift from ground applications is not likely to affect species off-field.
Terrestrial Invertebrates		30-60 m[5]	0 m	0 m[6]	Distance based on aerial drift and runoff (for species with aquatic phase only). Drift from ground applications is not likely to affect species off-field.
Aquatic Invertebrates		30 m	Adverse direct effects to aquatic invertebrate individuals or populations are not likely from the uses of glufosinate-P.[7]Adverse direct effects to aquatic invertebrate individuals or populations are not likely from the labeled uses of glufosinate-P.[7]		Effects likely in low volume waterbodies only (Bins 2 and 5). Distance based on runoff only. Spray drift not likely to impact taxa.

Taxa	UDL	Off Site Transport (runoff + spray drift) Buffer			Notes
		MA/NE Determinations	LAA/NLAA Determinations	Predicting the Likelihood of Jeopardy/Adverse Modification[1]	

CONUS=conterminous United State; LAA/NLAA=likely to adversely affect/not likely to adversely affect; MA/NE=may affect/no effect; NL48=non-lower 48 states; UDL=use data layer

[1] The buffer distances reported in the predicting likelihood of jeopardy/adverse modification column also represent the distances relied on for evaluating effects to listed species that rely on the taxon for PPHD.

[2]Off-site transport of glufosinate-P is likely to adversely affect individuals of mammalian species that weigh 15 grams or less. Adverse effects to individuals of mammalian species with average weight greater than 15 g are likely to be at the use site only.

[3]Based on the magnitude of effect analysis, the uses of glufosinate-P are likely to have direct adverse effects on mammal individuals but not mammal populations. [3]Based on the magnitude of effect analysis, the labeled uses of glufosinate-P are likely to have direct adverse effects on mammal individuals but not mammal populations. See **Section 3.4** for more detail.

[4]Adverse effects to aquatic plants are likely for blue-green algae species only. The off-site transport distance reported in this table only apply to listed animal species that rely on blue-green algae for PPHD (*i.e.*, algal mats). See **Section 3.5** for more detail.

[5]Discernable effects to bee species are likely to occur up to 60 meters from the use site whereas discernable effects to non-bee terrestrial invertebrates are likely within 30 meters of the use site. Runoff exposure is likely to have a discernable effect on terrestrial invertebrate species with an aquatic phase; however, it is not likely to contribute to adverse effects to individuals and populations of these species based on conclusions for aquatic invertebrates.

[6]Adverse effects to terrestrial invertebrate populations are likely for bee species only. See **Section 8.4.7** for more detail.

[7] Based on the magnitude of effect analysis, the uses of glufosinate-P are not likely to have direct effects on aquatic invertebrate individuals or populations. [7] Based on the magnitude of effect analysis, the labeled uses of glufosinate-P are not likely to have direct effects on aquatic invertebrate individuals or populations. See **Section 8.4.3** for more detail.

Identifying Species or CHs within the Action Area

EPA used spatial data representing the endangered and threatened species range and CH locations provided by the FWS and the NMFS as of February 16, 2022 (USFWS, 2022; NMFS, 2022). The overlap analysis compares each UDL and the species' range locations resulting in a percent overlap (*i.e.*, the acres of the exposure area for the UDL divided by the total acres for the species range). EPA used ArcGIS software (v. 10.8.1) and the python script in **Appendix L** to calculate the percentage of overlap individually for each UDL exposure area and each species range/CH.

To identify species or CHs within the action area, EPA looked across the maximum overlap for the individual UDLs and representative exposure areas.[32] This analysis captures the full geographic footprint of the action area by considering the exposure area where effects are reasonably expected to occur for each of the UDLs. A species or CH is within the action area if it is found within one or more of the UDL exposure areas identified using the maximum overlap for each UDLs and was not exclusively found in any of the use restricted counties.

Given the categorical and temporal aggregations of UDLs described in **Appendix I** (*i.e.*, the UDLs may contain more than one crop and are based on 5 years of data from 2013-2017), a single place (represented by a 0.22 acre or 900 m^2 area) could be accounted for in several UDLs. In the UDL method, this is referred to as "redundancy" in the UDLs. Buffering the UDLs to account for off-site exposure area further compounds the redundancy. Because of this redundancy and that it is not possible for a single site to simultaneously be multiple uses, the sum of the individual UDLs would overestimate the total percent overlap, and consequently, EPA does not add overlaps for a species or CH generated from multiple UDLs. EPA instead considers the maximum value of each individual UDL at the maximum off-site distance to determine if a species is within the action area. While the use of maximum overlap across exposure areas for the UDLs does not represent the total overlap across all uses, given the existing redundancy of the use site and exposure areas, EPA considers this protective.

For species and CH identified as in the action area, further analysis of overlap was conducted based on the refined exposure areas established for each UDL as described in the preceding section. Refinements to the overlap were also considered in each determination and the predictions of potential likelihood of future J/AM and are discussed in the next section. **Section 8.2.1** and **Section 8.2.2** describe how the percent overlap of the exposure area and the species' range or CH was factored into the weight of evidence in making the effects determinations and predictions of potential likelihood of future J/AM, respectively. Additional details on overlap for each UDL with the listed species range and CH are provided in **Appendix M** and **Appendix N**, respectively.

[32] The Use Data Layer Overlap Tool can be found at: https://www.epa.gov/endangered-species/provisional-models-and-tools-used-epas-pesticide-endangered-species-biological.

8.2.4 Refinements to the Overlap

This assessment incorporated several quantitative and qualitative refinements to the UDLs to support the weight of evidence evaluation of the species or CH within the action area. These refinements fall into two broad categories (*i.e.,* characterization of the use site, and consideration of available usage data). For both types of refinements incorporation of additional non-spatial datasets with the overlap results supports either quantitative or qualitative characterization of the impacts to the species.

Use Site Refinements

The UDLs considered in this assessment to define the use sites for glufosinate-P represent either a single crop (*i.e.,* corn, soybean, and cotton), an aggregate of crops within a crop group (*i.e.,* Other Grains and Vegetable and Ground Fruit), or an aggregate of all agricultural areas (*i.e.,* NL48_Ag). While the EPA has high confidence in the overlap for single crop UDLs for the labelled uses of glufosinate-P (*i.e.,* field and silage corn, cotton, soybeans), the aggregate UDLs include crops that are not registered for use on glufosinate-P (see **Appendix I** for more detail on crops included in the aggregate UDLs and how aggregation affects the confidence in UDLs). Therefore, EPA is less confident in the quantitative spatial overlap for the three aggregate UDLs since the UDL area could be representing locations where glufosinate-P would not be used, resulting in overestimating the extent of the use sites (see **Appendix I** for a full list of crops included in the aggregate UDLs).

The labeled uses of glufosinate-P on canola are mapped using the Other Grains UDL; however, this UDL represents the agricultural footprint of 14 grain crops and any other small grains. Likewise, the labeled uses for sweet corn are mapped using the Vegetables and Ground Fruit UDL which represents the agricultural footprint of 39 crops. The NL48_Ag UDL represents all agricultural sites in the Hawaii, Puerto Rico, Alaska, Guam, the Mariana Islands, America Samoa, and the Virgin Islands, whereas glufosinate-P is only labeled for use on corn, cotton, and soybean grown for seed production in Hawaii and Puerto Rico. The Other Grains, Vegetable and Ground Fruit, and NL48_Ag UDLs do not distinguish between the locations of the different crops within the UDL; thus, it is uncertain whether the overlap represents a potential use site for glufosinate-P. As a result, the geographic extent of these UDLs overestimate the area of the labeled crops, and therefore, overestimates where glufosinate-P can be applied for this use pattern.

It is not possible to refine the locations of the labeled uses based solely on available GIS data, while maintaining the accuracy thresholds outlined in **Appendix** I. The goal of the use site refinement is to determine the amount of area (by labeled uses) upon which glufosinate-P is reasonably expected to be used based on the reported acres from two years of Census of Agriculture (CoA) data (when available) reported by the U.S. Department of Agriculture (USDA). EPA has developed a tool (known as the CoA tool; **Appendix K**) that compares the acreage of a given crop reported in the CoA for a county to a listed species' range or CH that includes that county. The tool provides an estimated percent area within the species range or CH that may be

impacted by pesticide application to the crop of interest. EPA leveraged this tool to better understand the scope of glufosinate-P use within the Other Grain, Vegetable and Ground Fruit, and NL48_Ag UDLs in evaluating the likelihood of adverse effects to individuals of a listed species, its population, and CH (*i.e.,* NLAA/LAA determination and predictions of the potential likelihood of future J/AM). The percent area of the species range and CH that may be impacted by uses on canola, sweet corn, corn, soybean, and cotton determined by the CoA tool are reported for each species in **Appendix M** and **Appendix N**.

Usage Refinement

Applying usage data, either quantitively or qualitatively, is another refinement that can be made to the spatial UDLs, when data are available. EPA relies on usage data from different sources including historical usage for the active ingredient and more generalized usage data for a chemical class (*i.e*., all herbicides). Usage data specific to this active ingredient are not available to refine the exposure areas for the labeled glufosinate-P uses. Glufosinate-P is, however, part of the racemic glufosinate ammonium ai, which has been registered in the United States for decades. The most recent usage data for racemic glufosinate ammonium was collected in 2014 to support Registration Review of that ai. Although glufosinate-P products are likely to replace some racemic glufosinate use across the United States, Hawaii, and Puerto Rico, it is uncertain whether glufosinate-P usage will be comparable to historic racemic glufosinate usage given economic (*i.e.,* cost of product), weed pressure, and other factors that will impact glufosinate-P usage after registration. General herbicide usage data from the Census of Agriculture may be used in lieu of chemical specific usage data to qualitatively refine the UDLs based on the amount of herbicide usage within counties that include the species range and/or CH (similar to the use site refinements discussed above). Applying general herbicide usage data to row crops UDLs, however, is not expected to result in a substantial refinement of the overlap given widespread use of herbicides on these crops. Due to uncertainty in the historical usage data and low utility of the general herbicide usage data, EPA did not consider usage data to refine the glufosinate-P spatial analysis.

8.2.5 Magnitude of Effect Analysis

A magnitude of effect analysis is conducted for individuals and the population of listed species to support the species LAA/NLAA effects determination and the predictions of the potential likelihood of future J, respectively. The magnitude of effect is a synthesis of the direct and PPHD effects anticipated for a listed species. To assess direct and PPHD effects, EPA first determines how the action will affect a taxon at different level of biological organization by comparing the terrestrial, wetland, or aquatic EECs to toxicity thresholds that represent individual, population, and community-level effects. Where the EECs exceed the toxicity threshold, EPA considers the effect to be a concern for that level of biological organization for that taxon (*i.e.,* the level of concern is 1.0). The results of the effects analysis then inform an assessment of individual and population-level direct effects to the listed species and population or community level effects to a listed species' PPHD, culminating in a magnitude of effect conclusion. The effect analysis approaches for the individual and population magnitude of effect analyses are summarized

below. Toxicity thresholds and model results used to evaluate individual, population, and community impacts for each taxon are reported in their respective taxon sections within **Section 8.4**.

Individual Magnitude of Effect

An individual magnitude of effect analysis is conducted for all species that receive an MA determination to evaluate the potential of direct and PPHD effects to adversely impact listed species individuals. The results of the individual magnitude of effect are one line of evidence considered in the species NLAA/LAA determination. EPA did not assign a classification for the individual magnitude of effect but noted when the magnitude of effect identified concerns for direct and PPHD effects to listed species individuals.

To assess direct effects to listed species individuals, EPA selected endpoints that represent an effect level more likely to result in adverse effects to the individual (*e.g.,* the geometric mean of the NOAEL and LOAEL, rather than the NOAEL). Exposure modeling is refined to evaluate individual direct effects including incorporating listed species-specific body weight into the terrestrial EEC modeling, waterbody characteristics specific to the species aquatic habitat, and reassessing the relevance of the exposure estimates to the areas where the species may be found. Aquatic habitats for aquatic species and terrestrial species with an aquatic phase are binned based on the volume and flow characteristics of the waterbody with waterbody-specific EECs produced based on different models. A description of aquatic bins and the models used to produce EECs for each bin is provided in **Section 3.6.**

To assess effects to listed species individuals resulting for impacts to PPHD, EPA considered how the action will impact populations and communities of species on which the listed species relies for PPHD. Population-level effects were considered in evaluating impacts to obligate relationships since they represent a connection to a single species or small number of species. Conversely, EPA considered community-level effects to evaluate impacts to generalist relationships since those relationships rely on a broader group of species to meet its PPHD needs instead of specific species. When data were not available to assess community-level impacts, EPA considered effects at the population level to evaluate generalist relationships since those would be protective of community level effects that would impact those relationships. Tertiary indirect effects such as the loss of prey's habitat or prey's dietary items were not considered in the magnitude of effect analysis.

Population Magnitude of Effect

A population magnitude of effect analysis is conducted for all species that receive an LAA determination to evaluate the potential of direct and PPHD effects to adversely impact a listed species' population. The population magnitude of direct and PPHD effects analysis follows the same concepts described for the individual magnitude of effect analysis but incorporates additional considerations for the direct effects analysis in the endpoint selection and exposure modeling to address exposure and effects to a species population. For glufosinate-P, the main difference between the individual and population-level direct effects analysis is the shift from upper-bound residues to mean residues for estimating exposure in terrestrial animal listed species. Exposure considerations for other taxa are the same as the considerations for the individual direct effects. Given limited available data for glufosinate-P across species within a taxon (except for plants), EPA relied on the same endpoints selected for the individual direct effect analysis to evaluate population direct effects. Although based on individual effects, the endpoints selected to evaluate direct effects for all taxa represent an effect level that are likely to result in a population-level impact. The assessment of PPHD effects on a species population relies on the same population and community level effects analysis considered in PPHD effects to individuals. Although the assessment of PPHD effects does not distinguish between impacts to the listed species individual and its population, the addition of life history modifiers contextualize the likelihood that PPHD effects will result in population-level impacts.

Based on the results of the effect analysis for direct and PPHD effects (**Section 8.3**), EPA assigned a high, medium, or low population magnitude of effect classification to each listed species. **Table 31** summarizes the population magnitude of effects classification system used in predicting the potential likelihood of future jeopardy for listed species. The classification considers the likelihood of direct effects to the species, generalist and obligate PPHD relationships with plants, and, for aquatic species, the volume and flow of waterbody. The magnitude of effect classification does not account for many of life history modifiers described in **Section 8.4** that might alter the likelihood and extent of exposure. These modifiers are considered on a species-specific basis. The most influential modifiers are captured in the rationales for the predictions of the potential likelihood of future jeopardy for each taxon (**Section 8.4**) and the modifiers considered for each species are discussed in more detail in **Appendix M**.

Table 31. Population magnitude of effects classification.

Population Magnitude of Effect Classification	Characteristics of Species with Classification[1]
High	- Population-level direct effects are likely - Obligate relationship with upland herbaceous plants and semi-aquatic herbaceous plants for habitat or diet
Medium	- Only population-level PPHD effects are likely - Generalist relationship with upland herbaceous plants and semi-aquatic herbaceous plants for habitat - Obligate relationship to other listed species for which population-level effects are a concern (*i.e.*, Pacific Salmon are the primary prey of the Killer Whale)

Population Magnitude of Effect Classification	Characteristics of Species with Classification[1]
	- Diet includes plant items (*i.e.,* grasses, leaves, pollen, fruit, seeds) either exclusively or in addition to other dietary items (*i.e.,* arthropods, fish, aquatic invertebrates, *etc*.) - Inhabit low-volume, low- to no-flow waterbodies only or in addition to larger or higher flow waterbodies
Low	- Does not rely on upland or semi-aquatic herbaceous plants for habitat or diet - Moderate/swift flow, or medium-volume or larger waterbodies only

[1]Species that receive a given classification may have one or more of the characteristics described for that classification.

8.2.6 Effects Determinations and Predicting the Potential Likelihood of Future Jeopardy

The listed species assessment is designed as a tiered approach. In the first tier (as described in **Section 3.5** and referred to as the "screening-level" and "taxa-based methodology"), EPA makes conservative, simplifying assumptions that are intended to identify those taxa or groups of species where effects are not expected to occur. This allows EPA to focus time and effort in the second tier (referred to as the "species-specific assessment"), refining assumptions relevant to species or CHs where those assumptions may influence conclusions. The goal of the assessment is to refine assumptions related to species and glufosinate-P exposure such that EPA has confidence in determinations that one or more individuals are NE, MA, NLAA or LAA and subsequent predictions of which species there is or in not a potential likelihood of future jeopardy.

Since the screening-level assessment indicated that the labeled uses of glufosinate-P have taxa-based RQ values that exceed the LOCs for listed and non-listed species, EPA conducted a refined assessment to consider potential effects to specific listed species. The species-specific assessment consists of two stages: an effects determination and predictions of the potential likelihood of future J/AM with species-specific refinements at each stage based on life history (*e.g.,* diet, habitat) and spatial overlap of range and glufosinate-P exposure areas. For taxa where the listed species LOC is exceeded in the screening-level assessment, EPA identifies those listed species that fall within those taxa and inhabit spaces within the action area. For taxa where the non-listed species LOC is exceeded in the screening-level assessment, EPA identifies any listed species within the action area that depend upon those taxa for PPHD. EPA also used the listed species LOC for PPHD when a listed species has an obligate relationship to a specific non-listed species. Information on listed species PPHD is provided in **Appendix M**.

Data on listed species utilized in this assessment originate from USFWS or NMFS documents. Life history information such as PPHD and critical habitat PBFs is obtained from USFWS and NMFS documents (*e.g.,* recovery plans, 5-year reviews) and spatial overlap analyses for the species-specific evaluation are based on species range data that were downloaded in February 2022 (USFWS, 2022b).

Species Effects Determinations

In the species-specific effects determination, EPA made no effect (NE), may affect (MA) but not likely to adversely affect (NLAA), and MA and likely to adversely affect (LAA) determinations based on the potential for effects to an individual of a listed species. Distinguishing between NE and MA is a conservative approach that is based on potential direct and PPHD effects (based on EECs, toxicity endpoints, RQs and life history) and location of the species or CH. EPA also considers the degree of overlap of the species range and potential exposure areas (direct use sites and off-site exposure areas). If a MA determination is made, EPA refines assumptions related to overlap and considers the likelihood of effects to an individual (considering whether life history may impact this likelihood). Additional information is provided below on the overlap analysis and the determinations.

Distinguishing between May Affect (MA) and No Effect (NE) to an Individual

To determine the potential for a discernable effect, EPA uses the results of the generic taxa-based screening-level assessment to identify the listed species with direct effects concerns and the taxa on which the species depends for PPHD (**Sections 3.5**). For any listed species that does not have direct effects or PPHD effects (*i.e.,* when all relevant RQs are less than listed species LOCs) or the species is found outside of the action area, EPA made a NE determination. For any species where the taxa-based RQs indicate potential direct and/or PPHD effects, EPA considered the overlap of the species range and glufosinate-P potential exposure area established for the MA/NE determination. Given the known spatial relationship and correlation across the landscape, and the accuracy[33] of the available UDLs, if the resulting overlap is <1%[34] for all UDL exposure areas for a species, EPA made NE determinations for the species. For any NE determination, no additional analyses are needed.

Several species did not have GIS files available for range or CH as of February 2022. Since overlap cannot be relied on for these species, EPA made an MA determination for these species unless they were determined to be outside of the action area or were from a taxon that is not expected to have direct effects or PPHD effects based on the generic taxa-based screening-level assessment. Species for which range or CH GIS files are not available are identified in **Appendix M**.

For all species with ≥1% overlap of their locations and at least one UDL exposure area, and for which EPA identified potential direct or PPHD effects, EPA made may affect (MA)

[33] EPA has used this 1% overlap criteria because of known sources of error within spatial datasets are positional accuracy and precision. The National Standard for Spatial Data Accuracy outlines the accepted method for calculating the horizontal accuracy of a spatial dataset (FGDC, 1998). To prevent false precision when calculating area and the percent overlap it rounded to whole number to account for significant digits, where values <0.44% are represented as 0 and values from 0.44 to 1% is represented as 1%.

[34] The overlap is rounded to whole numbers due to the precision of the remotely sensed data; therefore <1% represents <0.44% with anything over 0.44% rounding up to 1%.

determinations. For all species with MA determinations, EPA completed additional analyses to determine if glufosinate-P is likely or not to adversely affect (*i.e*., LAA/NLAA determinations) at least one individual of a species.

Distinguishing between Likely to Adversely Affect (LAA) and Not Likely to Adversely Affect (NLAA) to an Individual

In the LAA/NLAA determinations, refinements are made to the effects, exposure, and overlap analyses relied on for the MA/NE determination such that EPA can determine if the uses that may affect a listed species are likely to lead to adverse effects on an individual. In the LAA/NLAA determinations, refinements are made to the effects, exposure, and overlap analyses relied on for the MA/NE determination such that EPA can determine if the labeled uses that may affect a listed species are likely to lead to adverse effects on an individual. EPA conducted an individual magnitude of effect analysis to refine the effects and exposure as outlined in **Section 8.2.3** and the use site and exposure area refinements are applied to the overlap analysis as discussed in **Section 8.2.2**.

EPA also incorporated life history considerations to determine if glufosinate-P is likely to adversely affect an individual of a listed species. For those species presumed extinct (and recommended for delisting) by the Services[35], EPA made NLAA determinations. EPA also made NLAA determinations for species that are not reasonably expected to be exposed because exposure is considered insignificant due to their habitats. **Table 32** lists the habitats identified for glufosinate-P and the rationale for why EPA expects minimal exposure. While other habitat types may have reduced exposure relative to the EPA's exposure models, EPA cannot discount that an individual may occupy areas within these habitats (*i.e.,* the periphery of a forest) where exposure is significant.

Table 32. Descriptions of habitats where EPA anticipates insignificant exposure to listed species from the uses of glufosinate-P. Descriptions of habitats where EPA anticipates insignificant exposure to listed species from the labeled uses of glufosinate-P.

Habitat with Insignificant Exposure for uses of glufosinate-P. Habitat with Insignificant Exposure for labeled uses of glufosinate-P	Rationale
Remote Islands	Remote islands (*i.e.,* Laysan and Nihoa islands) are uninhabited and EPA assumes there is no agricultural activity on these islands. Thus, there is a low likelihood of exposure to the species that inhabit them.
Open Ocean	Runoff and spray drift from conventional pesticides applications are not reasonably expected to reach the open ocean environments at concentrations high enough to impact an individual of a species because of dilution. Additionally, tidal reversal in freshwater streams and vertical stratification of the freshwater inflow due to differences in salinity and

[35] All the species that are presumed extinct are under the authority of FWS. Species identified as presumed extinct are consistent with the FWS's most recent national level biological opinion (BiOp; *i.e.,* for malathion).

Habitat with Insignificant Exposure for uses of glufosinate-P. Habitat with Insignificant Exposure for labeled uses of glufosinate-P	Rationale
	temperature can enhance the mixing process at the freshwater/marine interface and disperse potential pesticide concentrations that may occur in freshwater streams and rivers that discharge into marine environments, limiting the potential for a pesticide to reach individuals of the listed species. Since glufosinate-P is not considered bioaccumulative and is not expected to accumulate in the tissue of prey, exposure from eating contaminated fish is also expected to be very low.
Interior Forests	Forest habitat with a well-established understory, midstory, and canopy are likely to limit the penetration of pesticide drift transported off-site into the forest interior. While species may be exposed on the periphery of the forest, spray drift exposure is likely to be low for species that occupy habitat only in the interior. This modifier is applicable to terrestrial species only.

EPA made an LAA determination for species with ≥1% overlap of their locations and at least one UDL after considering the effects and refinements to account for adverse effects to individuals, and for which EPA identified likely adverse direct and/or PPHD effects. Species that did not meet these criteria received an NLAA determination.

In addition, EPA identified species where direct and/or PPHD effects were possible, but EPA's exposure models are unreliable for this species habitat or the spatial data available for this species is incomplete or unavailable. For these species, EPA qualitatively evaluated the likelihood of adverse effects to the individual and population. The species that were assessed qualitatively and the approach used to evaluate these listed species is discussed in **Appendix M**.

For those species with an LAA determinations, EPA completed additional analyses to predict if there could be a likelihood of jeopardy. EPA's approach to predicting the potential likelihood of future jeopardy is described below. For any NLAA determination, no additional analyses are needed.

Predicting the Potential Likelihood of Future Jeopardy

EPA's obligation under the Endangered Species Act (ESA) is to ensure that its actions are "not likely to jeopardize the continued existence of any endangered species or threatened species" (listed species). For those species where EPA made LAA determinations, the Agency then predicted the potential likelihood of future jeopardy for the species. Predictions of the potential likelihood of future jeopardy are included in this assessment to better inform any needed mitigation discussions prior to completion of a final BE and during any consultation with the Services. When assessing whether there is a potential likelihood of future jeopardy, EPA considers exposures and potential effects across the population. It considers life history information that may modify the magnitude of effects. EPA also considers any label changes or mitigations agreed upon by the registrant. The rest of this section explains in more detail the

approach to making population-level effects determinations and predictions of the potential likelihood of future jeopardy to listed species for glufosinate-P.

EPA used the USFWS' draft biological opinion (BiOp) for malathion (USFWS, 2021) as a guide in this assessment to predict the likelihood that those species could be jeopardized by the uses of glufosinate-P.[36] EPA used the USFWS' draft biological opinion (BiOp) for malathion (USFWS, 2021) as a guide in this assessment to predict the likelihood that those species could be jeopardized by the labeled uses of glufosinate-P.[37] Although the USFWS malathion BiOp was finalized (USFWS, 2022), EPA used the draft BiOp because the final BiOp contained a no jeopardy opinion and the draft BiOp includes analyses of how USFWS could identify a likelihood of jeopardy. EPA also considered the recently published USFWS final BiOp for the herbicide products Enlist™ One and Enlist™ Duo (USFWS, 2023) which included modifications to the FWS approach from previous BiOps and incorporated herbicide specific considerations relevant to this action. EPA used this information to inform the combination of potential exposure and species life history characteristics that could potentially lead to a likelihood of future jeopardy. Although EPA relied upon the USFWS' BiOp, recent BiOps published by NFMS for malathion (and diazinon and chlorpyrifos; NMFS 2022) have similar considerations. In the future, EPA may revisit the approach used to predict the potential likelihood of future jeopardy for species under the authority of NMFS with more species-specific considerations that were incorporated into NMFS' BiOp.

In this analysis for glufosinate-P, EPA predicted the potential likelihood of future jeopardy by primarily relying upon overlap[38] and magnitude of effect.[39] While the magnitude of effect and spatial overlap analyses for the predictions of the potential likelihood of future jeopardy are similar to those conducted in the LAA/NLAA determination, EPA incorporates additional refinements and considerations to address the likelihood of adverse impacts to a species' population as described in **Sections 8.5** and **8.6**, respectively. EPA also integrated life history information[40] to account for species-specific behavior and characteristics that could modify exposure and effects to a listed species population. Although USFWS incorporated species vulnerability directly into their determinations, EPA considered this factor as an additional line of evidence alongside the life history information to assess confidence in the predictions of the potential likelihood of future jeopardy. A discussion of how these additional lines of evidence factor into the weight of evidence is provided below.

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[36] Because 98% of the species and critical habitats for which EPA made LAA determinations are under the authority of USFWS, EPA primarily relied upon USFWS' approach when predicting the likelihood of future jeopardy and adverse modification. During consultation, EPA will consider adjusting the approach as needed for those species and critical habitats under the authority of NMFS.

[37] Because 98% of the species and critical habitats for which EPA made LAA determinations are under the authority of USFWS, EPA primarily relied upon USFWS' approach when predicting the likelihood of future jeopardy and adverse modification. During consultation, EPA will consider adjusting the approach as needed for those species and critical habitats under the authority of NMFS.

[38] Referred to by USFWS as "usage"

[39] Referred to by USFWS as "risk"

[40] Similar to the USFWS "risk modifiers"

For each species, EPA assigned a high, medium, or low classification to both overlap and magnitude of effect for the population-level impacts as discussed in **Section 8.2.3**. If overlap was considered low (<5%), EPA predicted that there was not a likelihood of jeopardy. If overlap was medium (≥5 to ≤ 10 %) or high (> 10%) and magnitude of effect was considered low (based on both direct and PPHD effects), EPA predicted that there was not a potential likelihood of future jeopardy. For species that have medium to high overlap and magnitude of effect, EPA considered the weight of evidence incorporating life history characteristics and the overall vulnerability of the species in predicting the potential likelihood of future jeopardy. If there were the life history modifiers for a species did not decrease the likelihood of effects or degree of overlap, EPA predicted that there could be a potential likelihood of future jeopardy.

Additional Lines of Evidence

Life History Modifiers

Life history information was incorporated in the weight of evidence to further refine the population-level magnitude of effect and spatial overlap conclusions. EPA uses the term life history modifier to describe relevant life history information and it is analogous to the "risk modifiers" described by USFWS in the malathion BiOp. EPA considers modifications that fall broadly into three aspects of a species' life history (*i.e.*, habitat, diet, and pollinator/dispersal mechanisms). EPA expects that direct exposure to plants and bees at the site of application and off-site exposure to plants from spray drift and runoff in terrestrial, wetland, and aquatic habitats will be the primary contributors to potential population-level effects in listed species for this action and dictate the modifiers considered in this assessment. Since direct effects to plant species are expected to contribute to a potential population-level effect independent of a species' pollinator and dispersal mechanism, modifiers for this aspect of the plant life history were not considered for glufosinate-P as they would not impact EPA's confidence in a likely population-level effect.

These modifiers are used to qualitatively assess the impact of life history on the likelihood of pesticide exposure to a listed species and do not account for other stressors which may impact population health and/or critical habitat integrity, which are captured in the vulnerability classification. These modifiers contextualize the magnitude of effect and spatial overlap analyses with species-specific information and provide a measure of confidence in the likelihood of a population-level impact. The extent to which each of these modifiers impacts confidence in the predictions of the potential likelihood of future jeopardy varies by taxa and species. The modifications are discussed broadly for each aspect of the species' life history below. The life history modifiers considered for each species and how these modifiers impacted predictions of the potential likelihood of future jeopardy for that species are summarized in **Appendix M**.

<u>Habitat</u>

EPA considered how the habitat requirements of a species will influence the likelihood of direct exposure at the use site (for plants and bees only), and the extent to which pesticide application will affect availability of forage and shelter within its habitat(s). EPA relied on the habitat descriptions in the EFED database and additional Services' documentation to determine the likelihood that the species will inhabit/shelter, forage, or move through the exposure area including the use site resulting in a potential exposure to the applied pesticide. EPA then considered the likelihood of a population of a species utilizing a use site, the impact of the habitat features on off-site exposure, and the number and variety of habitats a species is known to occupy including preference for certain habitat/foraging sites, and the size of the species range. Since most listed species rely on plants for a source of forage and/or for habitat EPA also considered the resilience of the vegetative community in the habitat to pesticide exposure.

Pesticide exposure is expected to be greatest for species that inhabit or forage at the use site. As discussed in **Section 8.2.1**, the initial determination of whether a species will be at a use site were incorporated in the overlap analysis for evaluating individuals and populations. To refine these assumptions for predicting the likelihood of potential future J/AM, EPA further considered life history information to qualitatively evaluate the likelihood that enough individuals would utilize the pesticide use site to result in population-level exposure. EPA considers population-level exposure on-site less likely for species whose habitat requirements suggest limited reliance on row crop fields either actively managed or fallow (*e.g.,* species habitat is primarily forest and no mention of foraging outside of forest habitat). EPA did not make refinements to the use-site determinations for aquatic taxa given that the ranges are based on the watershed.

Exposure of listed species in off-site habitat will depend on the features of that habitat that may increase or decrease the potential for exposure to runoff and spray drift. Off-site habitats that present few barriers to exposure (*i.e.*, few windbreaks are anticipated in open fields next to use sites that might limit spray drift) are expected to be of greatest concern for population-level impacts. Conversely, habitat features such as elevation, soil type, as well as the amount of precipitation are expected to limit runoff and/or spray drift from the field into montane, cliff, desert and dryland, and beach habitats. Likewise, dilution of glufosinate-P in flowing and tidal-influenced waterbodies is anticipated to result in exposure that is lower than estimated based on EPA's exposure models for standing waterbodies. Confidence in a likely population-level effect is increased for species that inhabit or forage at the use site and/or in habitats off-site with few barriers to protect against exposure from off-site transport.

EPA differentiated between habitat specialists and generalists in considering the number of habitat types available to a species and habitat preferences. EPA expects habitat generalists (*i.e*., a species that occupies a variety of habitat types) to have an equal probability of utilizing each habitat unless the Services' documentation indicates a preference or life stage requirement for a specific habitat among those they are known to occupy. The relative size of the species range was also considered alongside habitat requirements to characterize the likelihood of exposure as the species moves or disperses within and between habitats. Confidence in a likely population-level effect is increased for species when pesticide exposure is

likely in most or all habitats, or in a species' preferred habitat and when the species is not expected to move or dispersal over large areas.

The composition of the plant community was also considered in determining the scope of pesticidal effects to a species habitat. Toxicity to plants from glufosinate-P applications are expected to manifest primarily from contact exposure on external surfaces (*i.e.,* leaves and shoots) given limited systemic activity. According to the final labels for glufosinate-P ammonium, a higher application rate range is required to control woody species of weeds and it was recommended to avoid contact with "…*green tissue, or green, thin, or uncalloused bark of desirable vegetation*". Based on this information, exposure for woody species is likely to have the greatest impact on saplings, new growth on more mature individuals, and individuals with damaged bark, and more limited impacts to mature, healthy trees. While some woody plant individuals are more susceptible to exposure, it is unlikely that this would be the case for an entire community of woody plants lowering the likelihood of a widespread loss of woody plants for shelter/food. Conversely, deleterious effects are anticipated in emerged herbaceous plants regardless of life stage or health and are more likely to lead to large-scale loss of habitat/food. Consequently, EPA expects that habitats consisting primarily of woody shrubs and trees will be more resilient to large-scale impacts compared to habitats consisting of herbaceous plants. Confidence in a likely population-level effect is increased for listed species for which habitat information indicate a reliance on herbaceous upland and semi-aquatic plants for habitat.

Diet

The diet of a listed species can serve as a direct exposure route for pesticide residues and/or a decline in prey or dietary item availability following pesticide exposure can have an indirect effect on the fitness of the listed species. The diet composition of a listed species was considered in assessing the likelihood of direct exposure to pesticide residues in food and/or the extent to which losing one or more dietary items would impact resource availability. EPA relied on the diet descriptions in the EFED database and additional Services' documentation for life history information pertaining to a species' diet. Generalist consumers rely on multiple dietary items and are assumed to be equally likely to consume any of their dietary items depending on availability unless the Services' documentation indicate that a species has greater reliance on or preference for one or more dietary items over others during some or all seasons. Generalist can also be opportunistic in that their consumption habitats will shift depending on what is available. Specialist consumers, conversely, rely on a narrow range of dietary items and would be less capable compared to generalist consumers to adjust their feeding habits if exposure affected their dietary items. Generalist consumers are expected to be less susceptible to loss of dietary items and less likely to be exposed given multiple dietary options; however, they may be unable to avoid exposure if the pesticide action is anticipated to affect a majority of their dietary items or their preferred dietary items. Confidence in a likely population-level effect is increased for species for which a majority (*i.e.,* >50%) of a its dietary items or the species preferred dietary items are likely affected by the pesticide action.

Vulnerability

EPA considered the vulnerability of the species and how pesticide use might contribute to the vulnerability as an additional line of evidence in assessing confidence in its predictions of the potential likelihood of future jeopardy. Species vulnerability is a determination made by the USFWS based on multiple factors such as distribution, population size, species trends, whether pesticides were identified as a threat, and the environmental baseline. USFWS assigned a low, medium, or high vulnerability to the listed species evaluated in the malathion BiOp. For NMFS species and USFWS that were not classified in the malathion BiOp, vulnerability was assumed to be high unless the species narrative in recent NMFS or USFWS documentation suggested otherwise. EPA's confidence in predicting the potential likelihood of future jeopardy from pesticide exposure is increased for species with medium to high vulnerability and those where pesticides are noted as a threat. Confidence was not decreased, however, in species with low vulnerability or where pesticides are not identified as a stressor as a pesticide action may still pose a threat to these species' existence. The overall vulnerability for each species (as already determined by USFWS or presumed based on NMFS or USFWS documentation) is captured in **Appendix M**. EPA may revisit the impact of species vulnerability in predicting the potential likelihood of future jeopardy of a species.

8.3 Critical Habitat Effects Determination Methodology

There are many similarities between the species analysis (discussed in **Section 8.2**) and the CH analysis. EPA also used the overlap approach described above to determine the extent of overlap between the action area and CHs. EPA obtained spatial locations of CHs from USFWS and NMFS.

For CH, EPA made NE determinations if the species or its PPHD are not expected to be impacted within the CH (*i.e.,* if all relevant taxa based RQs are < LOCs; based on life history information for the species). EPA also made NE determinations if exposure area of each UDLs had <1% overlap with the CH.

One key difference between the CH and species evaluations is that the Services define physical or biological features (PBFs) that are necessary for the CH to support the species for which it was designated. In addition, several species have special management considerations (SMC) for the critical habitat that elucidate the critical features when PBFs are not defined or provide additional context to the features of the CH. Based on the screening level taxa-based assessment conclusions (see **Section 5**), EPA considered the following PBFs or SMCs relevant to evaluating adverse effects to CH from the labeled glufosinate-P uses:

> (1) Habitat quality as determined based on direct effects to listed terrestrial, wetland, and aquatic species;
> (2) Terrestrial and semi-aquatic herbaceous plants that serve as habitat and/or diet; and
> (3) Water quality which is dependent on the health of terrestrial and semi-aquatic plant communities.

The relevance of the habitat quality PBF to CH is determined based on the direct effects conclusions for listed species with different thresholds considered when evaluating adverse effects versus adverse modification to the CH. The habitat quality PBF is considered relevant for listed species in the NLAA/LAA determination when direct effects are likely to impact individuals of that listed species. When predicting adverse modification, however, habitat quality is considered relevant only for listed species for which population-level direct effects are likely. While CH PBFs/SMCs for some listed species include PPHD relationships with other taxa identified as having potential direct effects (*i.e.,* mammals, non-vascular aquatic plants, terrestrial invertebrates, and aquatic invertebrates), these PPHD relationships are not considered relevant for evaluating adverse effects to CH because the labeled L-glufosinate uses are not likely to result in population or community-level impacts to these taxa (**Section 8.2.7**). EPA also distinguished between herbaceous and woody plant species when identifying relevant PBF/SMCs. As discussed above in **Section 4.5**, glufosinate-P is likely to have a limited impact on trees or woody shrubs and is unlikely to result in large-scale loss of woody plant habitat. Accordingly, PBFs/SMCs related to woody species are not considered relevant for the labeled glufosinate-P uses. Where PBFs or SMCs are not defined for a CH, EPA assumed all PPHD for the listed species are relevant PBFs of the CH for the LAA/NLAA determination and predictions of the potential likelihood of future adverse modification. Likewise, if the CH GIS shapefile is unavailable (*e.g.,* EPA downloaded the shapefiles before the CH was designated final), EPA utilized the range to evaluate overlap for the CH.

EPA made an LAA determination for CH if it had 1% or more overlap with any UDL and its off-site transport exposure area and the species' CH included one or more of the relevant PBFs/SMCs. NLAA determinations were made for CH with >1% overlap but which did not include the relevant PBFs/SMCs. For all listed species with PBFs or SMCs listed above and with 1-5% overlap, EPA made LAA determinations but predicted that there was not a potential likelihood for future adverse modification. For those CHs with relevant PBFs and >5% overlap, EPA made LAA determinations and predicted that there could be a potential likelihood of future adverse modification. As with the predictions of the potential likelihood of future jeopardy, EPA considered life history modifiers relevant to the PBFs/SMCs to evaluate confidence in the predictions of the potential likelihood of future adverse modification. Since habitat, rather than the species, is the focus of these predictions, many of the modifiers considered in the predictions of the potential likelihood of future jeopardy do not apply. The primary consideration for predicting the potential likelihood of future adverse modification is whether the use site is likely to occur within or adjacent to the CH. **Appendix N** provides more detail on the PBFs and SMCs for each CH.

8.4 Listed Species Final Effects Determinations and Predictions of the Potential Likelihood of Future Jeopardy

This section presents the rationale supporting the glufosinate-P final effects determinations and predictions of the potential likelihood of future jeopardy made for the 1,715 species federally

listed as endangered or threatened as of February 16, 2022.[41] It is split into eight subsections, each covering a taxon with one or more federally listed species. Each subsection is split into three parts which cover 1) direct effects for individuals, populations, and communities of species from that taxon and how these effects inform the likelihood of direct effects to listed species within that taxon and PPHD effects to listed species that rely on that taxon; 2) PPHD effects that are likely for listed species from that taxon; and 3) a summary of the effects determinations/predictions of the potential likelihood of future jeopardy conclusions along with a list of the justifications for each determination/prediction based on the synthesis of the magnitude of effect, spatial overlap, and additional lines of evidence. A list of species with predicted potential likelihood of future jeopardy is provided along with additional details on the effects and routes of exposure driving this conclusion. More detailed information on the species diet and habitat, its overlap with UDLs, the direct and PPHD effects concerns and magnitude of effect classification, life history modifiers, vulnerability, and the species-specific rationale for effects determination and predictions of the potential likelihood of future jeopardy for each listed species within a taxon are captured in **Appendix M**.

8.4.1 Fish

Direct Effects

Discernable and adverse direct effects are not likely to fish individuals, populations, or communities from the labeled glufosinate-P uses based on the conclusions of the generic taxa-based screening level assessment (**Section 5**). Consequently, direct effects are not likely for listed fish species nor are the labeled uses of glufosinate-P likely to affect listed species through their obligate or generalist relationships with fish.

PPHD Effects

Listed fish species have generalist diet/prey relationships with aquatic plants, invertebrates, and other fish. EFED's listed species database does not indicate if the fish species' habitat includes plants, therefore, all listed fish species were initially assumed have a generalist relationship with upland, semi-aquatic, and/or aquatic plants for habitat if not explicitly stated in the habitat description. EPA searched through Services documentation to further define the plant relationships for each listed fish species. Semi-aquatic or aquatic plants are explicitly identified for some listed fish species as an important component of their habitat. EPA assumes all fish species rely on riparian plant communities to maintain high water quality whether or not it is explicitly stated. None of the listed fish species have reported obligate relationships. Based on the generic taxa-based screening-level assessment, discernable effects are likely for listed fish species with relationships to plants and invertebrates.

[41] This count of endangered and threatened species reflects separate species in addition to listed distinct population segments (DPS) or evolutionarily significant units (ESUs) as of 2023.

The uses of glufosinate-P are likely to adversely affect the health of upland and semi-aquatic plant communities and blue-green algae populations (**Section 8.4.8**); therefore, listed fish species with a generalist relationship to terrestrial upland and semi-aquatic plants or an obligate relationship with blue-green algae for habitat are likely to experience adverse effects. While the habitat description of some listed fish species does mention blue-green algae (*i.e.,* algal mats) as a feature, there are no obligate relationships reported among listed fish species with blue-green algae. As a result, it is assumed that fish species only have generalist relationships with non-vascular aquatic plants for which community level effects are not likely. Effects to semi-aquatic plant communities in low-volume, low-no flow aquatic habitat and wetlands will, however, affect listed fish species that occupy these habitats either exclusively or preferentially. In addition, effects to riparian semi-aquatic plant communities may result in loss of habitat for species that rely on overhanging vegetation or submerged roots for shelter as well as affect water quality of any aquatic habitat adjacent and downstream of the affected riparian area. Community-level effects to upland terrestrial plants are also likely to occur within 30 meters of use sites which may be in proximity to the aquatic habitat for a listed aquatic species or at some distance from the waterbody within the watershed(s). Terrestrial plants provide important ecosystem functions for aquatic waterbodies and their inhabitants (e.*g.,* reduced erosion and contaminants), but it is often not clear when a listed aquatic species only relies on terrestrial plants for these functions. The extent to which effects to upland terrestrial plants impact aquatic species is, therefore, highly uncertain. Consequently, except for cave species (as discussed below), relationships with terrestrial upland plants are not considered in evaluating adverse PPHD effects to individuals or the population of aquatic species.

The extent to which impacts on vegetative habitat will contribute to adverse effects in individuals and populations varies based on the composition of the plant community and the size and type of waterbody inhabited by the listed species. Listed species that have generalist relationship with diverse plant communities consisting of herbaceous and woody plants, or exclusively woody plants and shrubs are less likely to experience large scale loss of habitat. Further, the effects across species in riparian plant communities are likely to be variable and more diverse riparian plant communities are likely to have greater resilience to an exposure event resulting in limited loss of function in terms of its contributions to the aquatic ecosystem. Low-volume waterbodies and wetlands have less capacity to mitigate effects on plant community structure in the waterbody and changes in water quality that accompany the effects to the riparian community and, therefore, these effects are more likely to impact enough individuals to result in a population-level effect. Listed fish species that inhabit medium or larger freshwater waterbodies and subtidal nearshore marine habitat, however, are likely to experience individual but not population-level effects. Given the depth of these waterbodies, emergent plants are not likely to be present except in shallow nearshore habitat (which is captured in analysis of the low-volume aquatic bins), thus the only potential PPHD impacts to fish species in these waterbodies are the consequences of effects to the surrounding riparian habitat. While effects on riparian plant communities from the uses of glufosinate-P are likely to affect the individuals in larger waterbodies that are most sensitive to water quality changes and those in proximity to the affected riparian habitat, the variation in sensitivity among plants within the riparian plant community is likely to limit the scale of adverse effects in that

community which will reduce the likelihood of a population-level adverse effect in listed fish species. While effects on riparian plant communities from the labeled uses of glufosinate-P are likely to affect the individuals in larger waterbodies that are most sensitive to water quality changes and those in proximity to the affected riparian habitat, the variation in sensitivity among plants within the riparian plant community is likely to limit the scale of adverse effects in that community which will reduce the likelihood of a population-level adverse effect in listed fish species. Neither individual nor population-level adverse effects are likely for fish species that are only known to inhabit the open ocean (*e.g.,* sharks, rays) given the only likely PPHD effects are from impacts to riparian communities on the shore which are likely to have a minimal effect on this habitat.

Several fish species are also known to occupy subterranean aquatic habitats (*e.g.,* Ozark Cavefish and Alabama Cavefish) that range from low to medium volume. Glufosinate-P may enter these caves via runoff from use sites through sinkholes or in groundwater; however, these species are not likely to rely extensively on semi-aquatic or aquatic plant communities given the limited amount of sunlight in their habitat. These cave ecosystems rely on other animals (*e.g*., bats) and surface runoff for organic matter to sustain the aquatic invertebrate communities. Upland plants contribute to these nutrient inputs and adverse effects to the plant community in and around the cave system will affect to some extent the amount of nutrients flowing into the cave system. It is possible that the resulting reduction in nutrient loading could affect a cave species individual, but given variation in response and range of sensitivities among plants/trees/shrubs within upland communities, that the source of nutrients could be from impacted and unimpacted areas, and that there are multiple sources of nutrient inputs aside from upland plants that can support the cave ecosystem, it is unlikely that the adverse effects to upland plant communities resulting from application of glufosinate-P will affect an entire population of a cave fish species.

Community-level effects are not likely for aquatic plants other than blue green algae (**Section 4.5.2**), aquatic invertebrates (**Section 4.1.2**), terrestrial invertebrates (**Section 4.3**), or fish (**Section 4.1.1**); therefore, species that have a generalist relationship with these taxa are unlikely to experience adverse effects related to a decline in these prey/dietary items or loss of aquatic plant habitat in all waterbodies.

Effect Determinations and Predictions of Likelihood of Jeopardy

Species determinations were made for 169 fish species federally listed as endangered or threatened as of February 16, 2022. Although 170 fish species were listed as of February 2022, one species, the Snail darter (*Percina tanasi*), was delisted due to recovery and thus was not further evaluated in this BE. An NE determination was made for 1 species, NLAA determination for 63 species, and LAA determination for 105 species. Of the 105 species with LAA determinations, EPA predicts that the labeled glufosinate-P uses have no potential likelihood of jeopardy (*i.e.,* LAA- Not Likely J) 98 species and there is a potential likelihood of future jeopardy (*i.e.,* LAA-Likely J) 7 species. The rationale for each determination and J prediction is summarized in **Table 33** and discussed in more detail for each species in **Appendix M**.

Table 33. Species effects determination and prediction of the potential likelihood of future jeopardy summary for listed fish species.

Species Determination	Number of species	Rationale for the Species Determination
NE	1	<1% overlap with any of the unrefined UDLs when considering the potential for an effect to the species.
NLAA	63	Adverse effects to individuals are not likely because direct effects to individuals are unlikely **AND** 1) the species' range has <1% overlap with any of the refined UDLs when considering likelihood of adverse direct and PPHD effects to the individual; **OR** 2) the species range has >1% overlap with the Other Grain, Vegetable and Ground Fruit, and/or NL48 Ag UDLs only but the Census of Agriculture tool indicates that the total acreage of canola, sweet corn, and corn, cotton, and soybean grown within counties that overlap the species range would cover <1% of the species range; **OR** 3) the species' only known habitat is the open ocean where PPHD effects to vegetative communities on the shore are not likely to adversely affect the species
LAA-Not Likely J	98	While it is likely that the uses will adversely affect individuals through effects to their PPHD, it is not likely to result in a species-level impact because direct effects to populations are unlikely **AND** 1) overlap of the exposure area with the species range is low (<5%) for any individual UDL; **OR** 2) overlap is >5% but the species can occupy multiple habitats including several in which effects to plant communities are not likely to result in population-level effects (*e.g.,* While it is likely that the labeled uses will adversely affect individuals through effects to their PPHD, it is not likely to result in a species-level impact because direct effects to populations are unlikely **AND** 1) overlap of the exposure area with the species range is low (<5%) for any individual UDL; **OR** 2) overlap is >5% but the species can occupy multiple habitats including several in which effects to plant communities are not likely to result in population-level effects (*e.g.,* medium to large volume waterbodies) and does not prefer or require low-volume waterbody habitat for its life cycle; **OR** 3) overlap is >5% and the species utilize low-volume waterbodies, but the species' only known habitat is subterranean caves where semi-aquatic and aquatic plants are not likely to grow in large numbers and PPHD effects to vegetative communities on the surface are not likely to adversely affect populations.
LAA – Likelihood of J	7	Species-level impacts are expected because: 1) Exposure area overlap with species range considering PPHD population-level effects is medium to high (>5%) for any individual UDL **AND** the species inhabits only low-volume, low to no flow waterbodies or has a reported preference or life-stage requirement for low-volume, low to no-flow waterbodies where adverse effects to emergent plant habitat is likely to occur and changes in water quality resulting from adverse effects to surrounding riparian plant communities are likely to have the greatest impact. All species also have medium to high vulnerability.

J=jeopardy; NE=no effect; NLAA=not likely to adversely affect; LAA=likely to adversely affect; PPHD= prey, pollination, habitat, and dispersal; UDL=use data layer

Table 34 summarizes the listed fish species for which EPA predicts that glufosinate-P has the potential likelihood of future jeopardy. For all these species, at least one UDL overlaps with >5%

of the watershed(s) contributing to their aquatic habitat, and they either occupy low-volume, no to low flow waterbodies exclusively or require these habitats during one or more life stages (*e.g.*, salmonid juveniles frequent near-shore habitat and spawning occurs in off-channel habitat). The life history for several of these species also indicates a reliance on semi-aquatic plants for habitat. Runoff and spray drift from the use site will have a substantial impact on the semi-aquatic plant communities in the species' aquatic habitat and riparian plant communities on the periphery of their habitat. The impacts to these plant communities will result in loss or degradation of shelter that these fish rely on for reproduction, to escape predation, or to hide while hunting prey, as well as a decline in the water quality.

Table 34. Listed fish species with predicted potential likelihood of future jeopardy.

Entity ID	**Common Name (Scientific Name)**
239	Slackwater darter (*Etheostoma boschungi*)
311	Topeka shiner (*Notropis topeka*)
3069	Trispot darter (*Etheostoma trisella*)
3525	Rush darter (*Etheostoma phytophilum*)
4300	Chinook salmon (*Oncorhynchus tshawytscha*)
4318	Barren's topminnow (*Fundulus julisia*)
7332	Spring pygmy sunfish (*Elassoma alabamae*)

8.4.2 Amphibians

Direct Effects

Direct effects to amphibian individuals, populations, or communities from the labeled glufosinate-P uses are not likely based on the generic taxa-based screening-level assessment (**Section 4.1.1**). Consequently, direct effects are not likely for listed amphibian species nor are the labeled uses glufosinate-P likely to affect listed species through their obligate or generalist relationships with amphibians.

PPHD Effects

Listed amphibians have generalist diet and habitat relationships with plants, aquatic and terrestrial invertebrates, mammals (*i.e.,* use of burrows of small mammals) and other amphibians. EFED's listed species database does not report on whether several aquatic amphibian species rely on upland or semi-aquatic plants for habitat; therefore, EFED initially assumed these species have a generalist relationship with upland and semi-aquatic even if not explicitly stated in the habitat description. Obligate relationships among listed amphibians are with terrestrial plants and mammals. Based on the generic-taxa based screening level assessment, the uses of glufosinate-P are anticipated have a discernable effect on listed amphibian species that have PPHD relationships with plants, mammals, and invertebrates. Based on the generic-taxa based screening level assessment, the labeled uses of glufosinate-P are anticipated have a discernable effect on listed amphibian species that have PPHD relationships with plants, mammals, and invertebrates.

The labeled use glufosinate-P are further likely to adversely affect listed amphibian species with obligate or generalist relationships with upland or semi-aquatic plants for shelter and diet based on adverse effects to upland and semi-aquatic plant populations and communities (**Section 4.5.2**). As with other aquatic species, amphibians with an aquatic phase were assumed to rely on riparian habitat whether or not it is specified in the USFWS documentation and waterbody size was accounted for in determining the likelihood of adverse effects to individuals and populations (See **Section 8.4.2** for more details on assumptions). Several of the aquatic only amphibian species inhabit springs and subterranean waterbodies that are fed by aquifers and, in some cases, surface waterbodies. Impacts to riparian vegetation in the watershed can affect runoff into these waterbodies and aquifer recharge areas leading to decline in water quality in the aquifer and the springs or other aquifer-fed habitats in which these species reside. Variation in sensitivity among plant communities within the watershed is likely to limit the loss of ecological function in upland and riparian plant communities that help to maintain high water quality. Furthermore, it is likely that changes in water quality because of adverse effects to plant communities will occur in some but not all waterbodies contributing to the aquifers that feed these environments since applications are not likely to occur at all potential use sites within the watershed in a given year. While adverse effects to individuals that are most sensitive to water quality changes cannot be discounted, there is a low likelihood of a population-level adverse effect in the subterranean listed amphibian species. Community-level effects are not likely for aquatic plants (**Section 8.4.8**), mammals (**Section 8.4.4**), aquatic invertebrates (**Section 8.4.3**), or terrestrial invertebrates (**Section 8.4.7**); therefore, species that have a generalist relationship with these taxa are unlikely to experience adverse effects related to a decline in these prey/dietary items or loss of aquatic plant habitat.

Obligate relationships for listed amphibians include the California tiger salamander (*Ambystoma californiense*) which rely on the burrows of small mammals for shelter and the Golden Coqui [*Eleutherodactylus jasperi*] which rely on bromeliads, a family of monocot upland terrestrial plants, for habitat. While adverse effects to upland plant populations are likely to result from the labeled uses, the exposure to the bromeliads that the Golden Coqui inhabit within its range is not likely given that the species occurs outside of the action area for the labeled uses of glufosinate-P. The California tiger salamander does occur within the action area; however, a reduction in burrow habitat within its range is not likely given that population-level effects are not likely for small mammals (**Section 8.4.4**).

Effect Determinations and Predictions of Likelihood of Jeopardy

EPA made its initial effects determinations for 38 amphibian species with NE determinations for 10 amphibian species, NLAA determinations for 4 amphibian species, and LAA determinations for 24 amphibian species. Of the 24 amphibian species with LAA determinations, EPA predicts that the labeled uses of glufosinate-P have no potential likelihood of future jeopardy for 21 species and predicts a potential likelihood of future jeopardy for 3 species. **Table 35** summarizes the rationales for each effects determination and these are discussed in more detail for each determination below.

Table 35. Species effects determination and prediction of likely jeopardy summary for listed amphibian species.

Species Determination	Likelihood of J Prediction	Number of species	Rationale for the Species Determination
NE	N/A	10	<1% overlap with any of the unrefined UDLs when considering the potential for an effect to the species.
NLAA	N/A	4	Although exposure is likely, it is not likely to adversely affect the individuals of the listed species because direct effects to the species individuals is unlikely **AND** 1) the species' range has <1% overlap with any of the refined UDLs when considering likelihood of adverse PPHD effects to the individual; **OR** 2) the species range has >1% overlap with the Other Grain, Vegetable and Ground Fruit, and/or NL48 Ag UDLs only but the Census of Agriculture tool indicates that the total acreage of canola, sweet corn, and corn, cotton, and soybean grown within counties that overlap the species range would cover <1% of the species range; **OR** 3) the species occupy uninhabited islands where exposure to glufosinate-P is not likely due to no agricultural lands
LAA	Not Likely J	21	While there is potential for adverse PPHD effects to individuals, it is not likely to result in a species-level impact because direct effects to species populations is unlikely **AND** 1) overlap of the exposure area (considering PPHD population-level effects) with the species range is low (<5%) for any individual UDL **OR** 2) the species range has >5% overlap with the Other Grain, Vegetable and Ground Fruit, and/or NL48 Ag UDLs only but the Census of Agriculture tool indicates that the total acreage of canola, sweet corn, and corn, cotton, and soybean grown within counties that overlap the species range would cover <5% of the species range **OR** 3) overlap is >5% but the species' relies entirely or in part on dietary items that do not come from plants and the species is known to occupy multiple habitats with varied vegetative communities which will be more resilient to the adverse effects from glufosinate-P exposure.
LAA	Likely J	3	Although direct population-level adverse effects are unlikely, species-level adverse PPHD effects are likely because: 1) Exposure area overlap with species range considering PPHD population-level effects is medium to high (>5%) for any individual UDL **AND** the species occupy wetland or low-volume waterbody habitat either exclusively or for critical lifestages that is likely in the exposure path and the species is reliant on herbaceous semi-aquatic plants for habitat is likely to occur and changes in water quality resulting from adverse effects to surrounding riparian plant communities are likely to have the greatest impact. Both species have high vulnerability.

J=jeopardy; NE=no effect; NLAA=not likely to adversely affect; LAA=likely to adversely affect; PPHD= prey, pollination, habitat, and dispersal; UDL=use data layer

Table 36 summarizes the listed amphibian species for which EPA predicts glufosinate-P has potential likelihood of future jeopardy. For all these species, at least one UDL overlaps with >5% of the species range, and they utilize low-volume, no to low-flow waterbodies or wetlands for breeding and is the primary habitat of the larval life stage. The life history for these species further indicates a reliance on herbaceous semi-aquatic plants for habitat during their critical life stage. For the frog species, runoff and spray drift from the use site will have a substantial impact on the semi-aquatic plant communities in the species' aquatic habitat and riparian plant communities on the periphery of their habitat. The two salamander species occupy forest habitat which is likely to limit the effects of spray drift on the semi-aquatic vegetative communities in and around their breeding habitat; therefore, runoff is the main contributor to likely adverse effects in these species. The impacts to these plant communities will result in loss or degradation of shelter in the breeding habitat as well as changes in water quality that are likely to adversely affect the critical lifestages of these listed amphibians.

Table 36. Listed amphibian species with predicted potential likelihood of future jeopardy.

Entity ID	**Common Name (Scientific Name)**
195	Puerto Rican crested toad (*Peltophryne lemur)*
242	Frosted Flatwoods salamander (*Ambystoma cingulatum*)
3069	Reticulated flatwoods salamander (*Ambystoma bishopi*)

8.4.3 Aquatic Invertebrates

Aquatic invertebrate species listed as federally endangered or threatened include crustaceans, insects, mollusks (*i.e.,* freshwater mussels, nautilus, and snails), and corals.

Direct Effects

Direct effects to aquatic invertebrate species may result from off-site transport of glufosinate-P residues in runoff and spray drift. Since direct application to waterbodies is not permitted for the labeled uses of glufosinate-P, direct spray of the species habitat is not a source of exposure. **Table 37** below summarize the exposure models and endpoints used to evaluate mortality and sublethal effects in aquatic invertebrates for each level of biological organization. Based on the generic taxa-based screening assessment, sublethal effects from repeated exposure are the primary concern for listed aquatic invertebrate species; therefore, the individual and population, and community adverse effects assessment for this taxon is based on sublethal effects. EPA used different aquatic exposure models depending on the aquatic bins as described in **Table 37** and in **Section 3.6.3**.

Aquatic invertebrate toxicity data for glufosinate are available for crustacean (*i.e., Daphnia magna* and mysid shrimp [*Americamysis bahia*]) and mollusk (*i.e.,* Eastern oyster [*Crassostrea virginica*]) species (**Section 4.1.2**). The available data demonstrate similar acute sensitivity to glufosinate between estuarine/marine mollusks and mysid shrimp, whereas the freshwater

cladoceran *D. magna* is two orders of magnitude less sensitive. From these data, EPA selected the maximum acceptable toxicant concentration (MATC; the geometric mean of the NOAEC and LOAEC) of 108 µg ae/L for mysid shrimp to assess both individual and population effects for crustacean and mollusk aquatic invertebrates. The MATC is based on reproductive (30% decrease in offspring/female), and growth (*i.e.,* 9% decrease in length, and 22% decrease in dry weight) effects observed at the LOAEC of 173 µg ae/L. Since no toxicity data are available for aquatic insects or coral, the endpoints for mysid shrimp are used as a surrogate for evaluating effects to these species as well. The lack of data is an uncertainty in evaluating individual and population effects to listed aquatic insects and coral species. Although many listed aquatic invertebrate species inhabit freshwater, all species were evaluated based on the estuarine/marine mysid endpoints given that it is the most protective endpoint, and it cannot be determined from the limited data available if the lower sensitivity in the only freshwater species tested reflects a species-specific response or a true difference in sensitivity between freshwater and estuarine/marine invertebrate species. The available data are limited to a small number of species and were not sufficient to evaluate community level impacts; therefore, the conclusions for the population-level assessment were used to evaluate the likelihood of a community-level effect.

Table 37. Description of Toxicity Endpoints and Exposure Models Used in Direct Effects Analysis for Aquatic Invertebrates.

Exposure Models	Direct Effects	
	Mortality	**Growth/Reproduction**
On/Off-Site: Pesticide in Water Calculator (PWC) v. 2.001 Low-Volume (Bins 2 and 5) – Peak 1-in-10 year Peak Edge-of-Field EECs from PWC Medium/Large-Volume (Bins 3, 4, 6, and 7) – 1-in-10 year 1-day (acute) and 60-day (chronic) average in standard farm pond from PWC	Not a concern for the labeled uses of glufosinate-P.	Individual/Population: MATC = 0.108 mg ae/L

EEC=estimated environmental concentration; MATC=maximum acceptable toxic concentration representing the geometric mean of natural log of the no-observed adverse effect concentration (NOAEC) and the lowest-observed adverse effect concentration (LOAEC).

Based on the direct effects analysis (**Table 38**), only the labeled use of glufosinate-P on cotton exceeds the toxicity threshold for individual and population-level sublethal effects in aquatic invertebrates inhabiting low-volume waterbodies. As discussed in **Section 7.3**, edge-of-field (EoF) EECs used to represent exposure in low volume waterbodies reflect estimated concentrations without dilution or aqueous phase degradation of the glufosinate-P in the runoff. Dilution, degradation, and other environmental fate processes are likely to reduce the resulting concentrations in low volume/low flow waterbodies over time, rendering EoF ECCs as

overestimates of exposure. The EoF does not account for the contribution of spray drift to the aquatic EECs. An analysis with AgDrift™ (**Appendix G**) indicates that spray drift exposure will exceed the toxicity threshold in low-volume waterbodies within 13 feet of the field; however, this is based on the smallest representative waterbody in Bins 2 and 5 (*i.e.,* 1 m wide x 0.1 m deep) and reflects the peak exposure at the time of deposition. As stated in **Section 7.3,** because there is uncertainty in estimating chronic risk to aquatic invertebrates based on a one-day peak aquatic EEC rather than a 21-day average, EoF values are likely more conservative estimates of the 21-day average concentration than would be predicted based on the standard farm pond. Therefore, although the EECs for aquatic invertebrates exceed the toxicity threshold for direct effects in low-volume waterbodies, EPA considers the EoF EECs for this waterbody to be highly conservative estimates of chronic exposure. As a result, glufosinate-P is not likely to adversely affect individuals, populations, or communities of aquatic invertebrates in low-volume waterbodies. Furthermore, no exceedances are observed for medium to large volume waterbodies indicating that direct effects are also unlikely for aquatic invertebrates that occupy larger waterbodies including marine ecosystems.

Table 38. Direct effects analysis summary for aquatic invertebrates.

Level of Biological Organization	Low-Volume Waterbodies (Aquatic Bins 2 and 5)			Medium to Large-Volume Waterbodies (Aquatic Bins 3, 4, 6, and 7)		
	1-in-10-year Peak Edge-of-Field EECs (µg/L)	Exposure to Effects Ratio (EEC/Toxicity Endpoint)[1]	UDL Exceedances	1-in-10-year 21-day mean Farm Pond EECs (µg/L)	Exposure to Effects Ratio (EEC/Toxicity Endpoint)[1]	UDL Exceedances
Individual	12.8 – 135	0.12 – **1.25**	GMO: Cotton Non-GMO: Cotton	1.18 – 27.9	0.01 – 0.26	None
Population						

EEC=estimated environmental concentrations; GMO=genetically modified organism; UDL=use data layer
[1]Based on the 28-day chronic maximum acceptable toxicant concentration (MATC=geometric mean of the natural log of the no-observed adverse effect concentration [NOAEC] and the lowest-observed adverse effect concentration [LOAEC]) of 108 µg ae/L for estuarine/marine invertebrates (MRID 51036685). The same endpoint (MATC) is used to evaluate adverse effects to the individual and the population. Acute toxicity to aquatic invertebrates was not identified as a potential concern in the taxa-based screening-level assessment (**Section 7.3**); therefore, acute effects were not considered in determining the magnitude of effects for individuals of aquatic invertebrate species or its population.

PPHD Effects

Aquatic invertebrates have generalist diet/prey relationships with plants, fish, and other aquatic invertebrates. Based on the generic-taxa based screening level assessment, the labeled uses of glufosinate-P are likely to have a discernable effect on listed aquatic invertebrate species that have PPHD relationships with plants and other aquatic invertebrates. The labeled uses of glufosinate-P are likely to adversely affect upland and semi-aquatic plant populations and communities (**Section 8.3.8.1**); therefore, listed aquatic invertebrate species with a generalist or obligate relationship to upland or semi-aquatic plants for food and shelter are

likely to experience adverse effects at both the individual and population level. EFED's listed species database does not indicate if the aquatic invertebrate species' habitat includes plants, therefore, all listed aquatic invertebrate species were assumed have a generalist relationship with upland, semi-aquatic, and/or aquatic plants for habitat if not explicitly stated in the habitat description. As with other aquatic species, aquatic invertebrates were assumed to rely on riparian habitat whether or not it is specified in the USFWS documentation and waterbody size and location (*e.g.*, subterranean) was accounted for in determining the likelihood of adverse effects to individuals and populations (See **Section 8.3.1.2** for more details on assumptions). Community-level effects are not likely for aquatic plants (**Section 8.3.8.1**) and aquatic invertebrates (**Section 8.3.3.1**); therefore, adverse effects related to a decline in these prey/dietary items or loss of aquatic plant habitat are not likely.

Aquatic invertebrate obligate relationships include the Unionidae freshwater mussels which require certain species of freshwater fish to complete their life cycle and coral species which rely on single-celled dinoflagellates referred to as Zooxanthellae. Since adverse population-level effects are not likely for fish (**Section 8.3.1.1**) or for non-vascular aquatic plants other than blue-green algae (**Section 8.3.8.1**), the labeled uses of glufosinate-P are not likely to adversely affect these obligate relationships.

Effect Determinations and Predictions of Likelihood of Jeopardy

The initial species determinations were made for 174 aquatic invertebrate species as of February 16, 2022. A NE determination was made for 0 aquatic invertebrate species. There are NLAA determinations for 39 aquatic invertebrate species and LAA determination for 135 aquatic invertebrate species. Of the 135 aquatic invertebrate species with LAA determinations, EPA initially predicted that the labeled uses of glufosinate-P have no potential likelihood for future jeopardy for 134 species and there is a potential likelihood for future jeopardy for 1 species. **Table 39** summarizes the rationales for each determination and J prediction and these are discussed in more detail for each species in **Appendix M**.

Table 39. Species effects determination and predictions of potential likelihood of future jeopardy summary for listed aquatic invertebrate species.

Species Determination	Likelihood of J Prediction	Number of species	Rationale for the Species Determination
NE	N/A	0	
NLAA	N/A	39	Although exposure is likely, it is not likely to adversely affect the species because direct effects to individuals are unlikely **AND** 1) the species' range has <1% overlap with any of the refined UDLs when considering likelihood of adverse direct and PPHD effects to the individual; **OR** 2) the species range has >1% overlap with the Other Grains, Vegetables and Ground Fruit, and/or NL48 Ag UDLs only but the Census of Agriculture tool indicates that the total acreage of canola, sweet corn, and corn, cotton, and soybean grown within counties that overlap the species range would cover <1% of the species range; **OR** 3) the species' only known habitat is the open

Species Determination	Likelihood of J Prediction	Number of species	Rationale for the Species Determination
			ocean where PPHD effects to vegetative communities on the shore are not likely to adversely affect the species;
LAA	Not Likely J	134	While it is likely that the labeled uses of glufosinate-P will adversely affect individuals through effects to their PPHD, it is not likely to result in a species-level impact because direct effects to populations are unlikely **AND** 1) overlap of the exposure area with the species range is low (<5%) for any individual UDL; **OR** 2) overlap is >5% but the species can occupy multiple habitats including several in which effects to plant communities are not likely to result in population-level effects (*e.g.,* medium to large volume waterbodies) and does not prefer or require low-volume waterbody habitat for its life cycle; **OR** 3) overlap is >5% and the species utilize low-volume waterbodies, but the species' only known habitat is subterranean caves where semi-aquatic and aquatic plants are not likely to grow in large numbers and PPHD effects to vegetative communities on the surface are not likely to adversely affect populations.
LAA	Likely J	1	Species-level impacts are expected because: 1) Exposure area overlap with species range considering PPHD population-level effects is medium to high (>5%) for any individual UDL **AND** the species inhabits only low-volume, low to no flow waterbodies or has a reported preference or life-stage requirement for low-volume, low to no-flow waterbodies where adverse effects to emergent plant habitat is likely to occur and changes in water quality resulting from adverse effects to surrounding riparian plant communities are likely to have the greatest impact. This species also has high vulnerability.

J=jeopardy; N/A= not applicable; NE=no effect; NLAA=not likely to adversely affect; LAA=likely to adversely affect; PPHD= prey, pollination, habitat, and dispersal; UDL=use data layer

Table 40 summarizes the listed aquatic invertebrate species for which EPA predicted that the uses of glufosinate-P have a potential likelihood of jeopardy. **Table 40** summarizes the listed aquatic invertebrate species for which EPA predicted that the labeled uses of glufosinate-P have a potential likelihood of jeopardy. For this species, at least one UDL overlaps with >5% of the watershed(s) contributing to their aquatic habitat and they occupy low-volume, no to low-flow waterbodies exclusively. The life history further indicates a reliance on semi-aquatic plants for habitat. Runoff and spray drift from the use site will have a substantial impact on the semi-aquatic plant communities in the species' aquatic habitat and riparian plant communities on the periphery of their habitat. The impacts to these plant communities will result in loss or degradation of shelter that this aquatic invertebrate rely on as well as a decline in the water quality.

Table 40. Listed aquatic invertebrate species with predicted likelihood of jeopardy.

Entity ID	Common Name (Scientific Name)
417	Slender campeloma (*Campeloma decampi*)

8.4.4 Mammals

Direct Effects

Listed mammals include terrestrial (*e.g.,* felines, canids, rodents, ungulates) and aquatic (*e.g.*, pinnipeds, mustelids, polar bears, manatees) species. Since routes of exposure differ between terrestrial and aquatic mammals they are discussed separately below. In addition, listed species rely on mammals for prey, pollination, dispersal, and shelter.

Terrestrial Mammals

Direct effects to mammal species may result from direct spray during application, consumption of residues in prey, dietary items, and drinking water, or from incidental ingestion of residues in soil. Residues in prey and other dietary items are expected to be the main source of direct exposure to glufosinate-P for mammals. **Table 41** below summarize the exposure models and endpoints used to evaluate mortality and sublethal effects in mammal individuals, populations, and communities. Since acute mortality was not identified as an effect of concern for mammals in the generic taxa-based screening level assessment for the labeled uses of glufosinate-P (**Section 7.4**), the effects analysis for mammals focuses on sublethal responses in growth and reproduction.

Table 41. Description of Toxicity Endpoints and Exposure Models Used in Evaluating the Magnitude of Effect to Mammals.

Exposure Models	Direct Effects to Mammal Species	
	Mortality	**Growth/Reproduction**
On-Site: Terrestrial Residue Exposure Model (T-REX) v. 1.5.2 Off-Site: AgDrift™ v. 2.1.1 Step 1: Upper-bound residues for reported dietary items; default body weight Step 2: Upper-bound residues and listed species body weight Step 3: Mean residues and listed species body weight	Not a concern for the labeled uses of glufosinate-P.	Individual/Population: MATC = 9.5 mg ae/kg-bw (208 mg ae/kg-diet)

MATC=maximum acceptable toxic concentration representing the geometric mean of the natural log of the no-observed adverse effect concentration (NOAEC) and the lowest observed adverse effect concentration (LOAEC).
Step 1 = May Affect or No Effect (MA/NE) Determination; Step 2 = Likely to Adversely Affect or Not Likely to Adversely Affect (LAA/NLAA) Determination; Step 3 = Likely future Jeopardy/Adverse Modification or Not Likely future Jeopardy/Adverse Modification (J/AM) Determination.

The dietary needs of mammalian species are diverse and include terrestrial and semi-aquatic plants, terrestrial invertebrates, mammals, birds, reptiles, amphibians, aquatic invertebrates, fish, carrion, pollen and nectar, and fungi. Residues on plant dietary items (*i.e*., grasses, leaves, seeds, fruits, pods) and arthropods are modeled in T-REX and were estimated in the ERA (**Section 7.4**). Residues in pollen and nectar and fungi were estimated using the T-REX dietary EECs in tall grass and broadleaf plants as surrogates, respectively. Terrestrial vertebrate species and carrion may be a source of exposure to glufosinate residues; however, it is likely that the residue levels in the prey and carrion will be low when consumed by the mammal predator or scavenger given that glufosinate is rapidly metabolized and excreted in birds (USEPA 1996) and mammals (USEPA 2021) without appreciable accumulation in tissues. Likewise, glufosinate-P is not likely to bioaccumulate in aquatic organisms based on its physical chemical properties; therefore, consumption of glufosinate-P residues in aquatic invertebrates, fish, aquatic-phase amphibian prey is likely to be a minor source of exposure relative to terrestrial prey/dietary items. Consequently, the effects analysis focused on exposure from plants, fungi, and arthropods.

Toxicity data is available for four mammalian species and cover multiple durations of exposure, exposure routes (e.g., oral gavage, dietary, dermal, and inhabitation), and a range of apical and non-apical endpoints. The effect analysis for both individual and population was based on the sublethal reproductive effects which was the most sensitive response observed among the apical endpoints for mortality, growth, and reproduction. EPA selected the MATC of 9.5 mg ai/kg-bw to evaluate both individual and population-level adverse effects in mammals. Given the severity of the reproductive effect at the LOAEL (*i.e.,* 11-37% decrease in viable offspring) and the relatively narrow dose spacing between the NOAEL and LOAEL (2.5x), consumption of residue levels equal to or greater than the MATC are likely to result in a decrease in reproductive success among individual listed mammals that will lead to a decline in the population size. The limited number of mammal species tested precluded selection of endpoints that represented mammal community level impacts; therefore, the conclusions of the population-level analysis informed assessment of potential adverse effects in mammal communities. The dose-based endpoints and exposure estimates are adjusted for different body weight classes that capture the range of body weights across the listed species as well as body weight of small (15 g) and large (1,000 g) mammal species that are connected to listed species through obligate or generalist relationships. No additional species-specific adjustments were incorporated, but this may be an option for further refinement, particularly of the food intake rate. Exposure to the individual and population were based on T-REX upper-bound and mean Kenaga residues, respectively. EPA relied on the mean residue levels for the population effect analysis because EPA considers the average exposure level to better represent the spatial and temporal variability in exposure amongst individuals within the population. Although the dietary exposure estimates and endpoints could be used to evaluate individual and population-level effects, EPA relied on the dose-based analysis because it is species-specific.

Upper-bound and mean exposure estimates along with effect analysis results for mammal individuals and populations are summarized in **Table 42**. Upper-bound exposure estimates for some or all the labeled uses exceed the individual toxicity threshold for mammal species whose

diet include grasses, leaves/flowers, and arthropods regardless of body weight. Conversely, the body weight of the mammal species was a determining factor in which dietary items are exceed the population-level threshold (**Table 42**). The labeled glufosinate-P uses result in the highest exposure to mammal species weighing less than 100 grams that consume grasses, leaves, and arthropods. For these species, the estimated mean residues levels in dietary items for at least one labeled use are exceed both the MATC and the LOAEL. Mammal species weighing 100 to 1,000 g that consume grasses and arthropods are also likely to be exposed to mean residues that exceed the MATC. Grasses are the only dietary items that exceed the MATC for mammal species weighing >1,000 g and only in species that are 1,000 to 2,000 g. Mean residues for species weighing 100 to 2,000 g are do not exceed the LOAEL in any dietary item; however, this does not indicate that the species are unlikely to experience reproductive effects from consuming contaminated dietary items. Mean residues do not exceed the MATC in any dietary item for species that weigh greater than 2,000 g.

Exceedances of the MATC for upper-bound and mean residues suggest that that mammal species consuming those dietary items are likely to experience individual and population-level effects. The EECs calculated for each dietary item, however, reflect the peak upper-bound or mean residue level at the use site based on the labeled use rate. Residues in dietary items will dissipate between applications and are not likely to persist in tissues or on foliar surfaces. Upper bound residue levels are estimated to drop below the MATC in all dietary items for all mammal weight classes within 45 days when considering use patterns with multiple applications and the shortest reapplication window, and within 28 days from a single application to an untreated use site. Likewise, dietary items at use sites with mean residues are estimated to drop below the MATC within 25 or 7 days from multiple and single applications, respectively. The reproductive effects were observed in rats chronically exposed to glufosinate-P in their diet, but it is unknown how many days of exposure are necessary to elicit the reproductive effects. Similar reproductive/developmental effects are noted in rabbits at a comparable dose following a 14-day exposure during the gestational period suggesting that reproductive consequences may manifest from a shorter duration of exposure.

In order to consume enough residues to achieve a dietary concentration likely to cause reproductive effects, a mammalian individual would need to obtain 40 to 100% of its daily diet from the use site depending on the weight class, dietary item, and whether the use site contained upper-bound or mean residues. It is likely there will be forage available both on and off-site and unlikely that all use sites will be treated simultaneously. Spray drift is likely to deposit residues on dietary items away from the field presenting another source of dietary exposure; however, exceedances of the MATC are only likely within 43 feet of the field assuming all spray applications drift off field in the same direction or within 20 feet from any single spray event, and only from use sites containing upper-bound residues. EPA cannot rule out that an individual mammal would forage regularly in areas with glufosinate-P residues (either on or adjacent to the use site) and consume enough residues in their diet to reach the threshold for reproductive effects. Given that mean residues are limited to the field and likely to dissipate within 28 days, it is, however, unlikely that many individuals would exhibit the foraging behavior necessary to result in widespread reproductive effects that lead to a

population or community level effect. Consequently, the labeled uses of glufosinate-P are likely to result in adverse effects to mammal individuals that consume plant dietary items, fungi, and arthropods, but not mammal populations or communities. Since adverse effects are not likely in mammal populations or communities, it is unlikely that the labeled uses of glufosinate-P will affect obligate and generalist relationships between listed species and mammals.

Table 42. Dose-based effects analysis for mammals at different levels of biological organization.

Level of Biological Organization→	Individual			Population		
Dietary Item↓	**Upper-bound Dose-based EEC Range (mg ae/kg-bw)**	**Exposure to Effects Ratio (EEC/Toxicity Endpoint)[1]**	**Use Exceedances**	**Mean Dose-based EEC Range (mg ae/kg-bw)**	**Exposure to Effects Ratio (EEC/Toxicity Endpoint)[1]**	**Use Exceedances**
Mammals <100 g (*e.g.,* bats, voles, mice, rats, shrews, and gophers)						
Grasses[2]	28.3-197	**1.99-7.96**	GMO: All Uses Non-GMO: All Uses Fallow fields	10.0-69.7	0.71-**2.82**	GMO: All Uses Non-GMO: All Uses Fallow fields
Leaves[3]	15.4-166	**1.11-5.32**	GMO: All Uses Non-GMO: All Uses Fallow fields	5.30-55.4	0.37-**1.77**	GMO: Field Corn (excluding seed production), Canola, Soybean Non-GMO: Cotton
Fruits/pods	1.95-18.5	0.13-0.59	None	No exceedances based on upper-bound residues		
Seeds	0.35-4.1	0.03-0.13	None	No exceedances based on upper-bound residues		
Arthropods[4]	11.1-116	0.78-**3.7**	GMO: All Uses Non-GMO: All Uses Fallow fields	7.66-80	0.54-**2.56**	GMO: All Uses Non-GMO: All Uses
Mammals 100 to 1000 g (*e.g.,* prairie dogs, woodrats, giant kangaroo rats, ferrets, rabbits, beavers, martens)						
Grasses[2]	8.87-53.4	**1.21-4.56**	GMO: All Uses Non-GMO: All Uses Fallow fields	3.14-18.9	0.43-**1.62**	GMO: All Uses Non-GMO: All Uses
Leaves[3]	4.99-30.1	0.68-**2.57**	GMO: All Uses Non-GMO: All Uses Except Fallow Fields	1.66-10.2	0.23-0.86	None
Fruits/pods	0.72-2.19	0.08-0.24	None	No exceedances based on upper-bound residues		
Seeds	0.15-0.74	0.02-0.06	None	No exceedances based on upper-bound residues		

Arthropods[4]	4.21-20.9	0.52-**1.79**	GMO: Field Corn (excluding seed production), Canola, Soybean, Cotton; Non-GMO: Cotton	2.91-14.5	0.36-**1.24**	GMO: Soybean, Field Corn (excluding seed production)
Mammals > 1,000 g (*e.g.,* bears, large felines wolves, foxes, ungulates						
Grasses[2]	1.13-20.3	0.50-**3.02**	GMO: All Uses Non-GMO: All Uses Fallow fields	0.40-7.17	0.18-**1.07**	GMO: Soybean, Field Corn (excluding seed production)
Leaves[3]	0.64-9.55	0.28-**1.57**	GMO: Field Corn (excluding seed production), Canola, Soybean, Cotton Non-GMO: Cotton	0.20-3.18	0.09-0.52	None
Fruits/pods	0.07-1.27	0.03-0.19	None	No exceedances based on upper-bound residues		
Arthropods[4]	0.44-7.93	0.20-**1.18**	GMO: Soybean, Field Corn (excluding seed production)	0.31-5.49	0.14-0.82	None

EEC=estimated environmental concentration; GMO=genetically modified organism.

Bolded value exceeds chronic risk level of concern (LOC) of 1.0.

[1] The individual and population magnitude of effect calculation are based on the maximum acceptable toxicant concentration (MATC) of 9.5 mg ae/kg-bw from the 2- generation reproduction study in rats (MRID 40345612). In calculating the dose-based magnitude of effect, each dietary item EEC and the MATC are adjusted for the reported body weight of the listed species. A magnitude of effect that is greater than 1.0 indicates that exposure exceeds the toxicity threshold.

[2] The exposure to effects ratio for grasses is based on the short grass Kenaga values and are considered for both short and tall grass dietary items.

[3] Leaves EECs are based on the broadleaf plant Kenaga values and serve as a surrogate for estimating exposure from consumption of flowers and fungi.

[4] Based on the arthropod Kenaga values and serve as a surrogate for estimating exposure from soil-dwelling invertebrates.

Aquatic Mammals

A number of listed mammal species occupy aquatic ecosystems. Listed whales, sea lions, sea otters, polar bears, and seals forage in the open ocean and either occupy open ocean habitat exclusively, or primarily with some aspect of its life cycle spent on the shore (*i.e.,* sea lions basking in the sun on rocks) for purposes other than forage. Exposure in the open ocean could be through residues in the diet, or contact with residues in the water, and exposure through inhalation or dermal interception of spray droplets may occur for species that are on the shore on the day of application. The West Indian manatee, conversely, moves through and forages in both estuarine/marine and freshwater environments and can be exposed through drinking freshwater in addition to contact and dietary exposure.

Dietary exposure to glufosinate-P in the open ocean is likely to be insignificant due to dilution and low potential for bioaccumulation (**Section 8.2.5.1**). Since these species do not forage while on land, dietary exposure while in terrestrial habitats is not expected. Although dermal and inhalation exposure to species that come onto shore may occur, the exposure window would be limited to the day of application, the application would need to occur adjacent to nesting or basking sites, these species spend a relatively short portion of their life on the shore and the terrestrial area of their range is small fraction of their total range which lowers the likelihood of exposure. Furthermore, glufosinate exhibits low acute dermal and inhalation toxicity in mammals (USEPA, 2021). Contact exposure in the aquatic environment is also unlikely to lead to adverse effects due to dilution and low dermal toxicity. The skin of many marine mammals is also much thicker than the terrestrial mammal species evaluated in dermal toxicity studies which further reduces the likelihood of dermal toxicity in these species.

A separate semi-quantitative analysis was conducted for drinking water exposure in the West Indian manatee. When traveling through freshwater, the species occupies flowing medium to large waterbodies. Intake of residues from drinking freshwater is estimated to be at most 0.0041 mg ai/kg-bw/day based on the average daily water consumption of an individual (145 ml/kg-bw/day[42]) and the highest aquatic EEC for the farm pond (28.29 ug ai/L). This value is over three orders of magnitude below the threshold for individual and population effects in mammals indicating a low likelihood of adverse effects from this route of exposure. There are a number of uncertainties in this analysis including use of a dietary endpoint to evaluate drinking water exposure, extrapolating toxicity endpoints from the rat to evaluate a mammal that is orders of magnitude larger, and evaluating exposure from a model waterbody that does not account for flow in the exposure estimates. Given that toxicity is likely to be low across all anticipated routes of exposure, adverse direct effects to individuals and populations of aquatic mammals are not likely.

[42] Physiological Ecology and Bioenergetics Lab, University of Central Florida. https://sciences.ucf.edu/biology/PEBL/current-research/manatee-studies/do-manateesneed-to-drink-fresh-water/

PPHD Effects

Listed mammals have generalist diet relationships with plants, invertebrates, birds, reptiles, terrestrial-phase amphibians, fish, and other mammals and generalist relationship with plants and mammals (*e.g.,* use of other species burrows) for habitat. Several listed mammal species also have obligate relationships to terrestrial plants, mammals, and fish. Based on the generic-taxa based screening-level assessment, the uses of glufosinate-P are likely to have a discernable effect on listed mammal species that have PPHD relationships with plants, mammals, and invertebrates. Based on the generic-taxa based screening level assessment, the labeled uses of glufosinate-P are likely to have a discernable effect on listed mammal species that have PPHD relationships with plants, mammals, and invertebrates.

Listed mammalian species with a generalist or obligate relationship to terrestrial and semi-aquatic plants for food and shelter are further likely to experience adverse effects at both the individual and population level given expected population and community level impacts in those taxa (**Section 8.3.8.1**). The loss of habitat and plant dietary items will have the greatest impact among listed mammalian species that rely primarily or exclusively on herbaceous plants. Listed mammals that have generalist relationship with diverse plant communities consisting of herbaceous and woody plants, or exclusively woody plants and shrubs are less likely to experience large scale loss of diet or habitat. While individual effects cannot be ruled out for these species, the greater resilience of the plant communities on which they rely is likely to limit how many individuals are impacted and lower the likelihood of a species level impact. The Columbia Basin pygmy rabbit is the only mammal with an obligate relationship with terrestrial plants and is dependent on sagebrush, a woody shrub species, for both forage and shelter. The labeled uses of glufosinate-P have the potential to impact the health of the sagebrush, particularly sagebrush occurring near use sites and with new growth, which will affect individual rabbits co-localized with these shrubs; however, because the sagebrush is a woody shrub, the impact of the glufosinate-P on this obligate relationship is lessened. Riparian areas near shorelines may be affected by the labeled glufosinate-P uses which may affect water quality in near shore habitats and the aquatic mammalian species that inhabit those ecosystems. Aquatic mammalian species that are known to inhabit the open ocean exclusively or primarily (*e.g.,* whales, sea otters), however, are unlikely to experience individual nor population-level effects from impacts to riparian communities on the shore given the minimal effect this will have on their habitat.

Other mammalian species with obligate relationships include the Canada lynx and Killer whale which have dietary relationships with the snowshoe hare and salmonid species, and the Black-footed ferret which rely on prairie dogs as a food source and for use of their burrows as shelter. Population-level effects are not likely for mammals (**Sections 8.3.4.1**); therefore, adverse effects related to a decline in these prey/dietary items or loss of shelter are not likely. While population-level effects are also not likely for fish (**Section 8.3.1.1**), the Killer whale relies on in part on threatened and endangered salmonid species. Some but not all populations of the listed salmonid species are predicted to be adversely affected at the population level from the labeled glufosinate-P uses (**Section 8.3.1.3**). Consequently, adverse effects to Killer whale

individuals cannot be discounted. It is, however, unlikely to lead to a population-level effect in this species given that all but one population of threatened and endangered salmonids species are not likely to be adversely affected.

Community-level effects are not likely for aquatic plants (**Section 8.3.8.1**), mammals (**Section 8.3.4.1**), terrestrial invertebrates (**Section 8.3.7.1**), or aquatic invertebrates (**Section 8.3.4.1**); therefore, species that have a generalist relationship with these taxa are unlikely to experience adverse effects related to a decline in these prey/dietary items or loss of aquatic plant habitat.

Effect Determinations and Predictions of Likelihood of Jeopardy

EPA considered a total of 94 mammals in this listed species assessment. An NE determination was made for 24 species, NLAA determination for 42 species, and LAA determination for 28 species. Of the 28 species with LAA determinations, EPA initially predicted that the labeled glufosinate-P uses do not have the potential likelihood of future jeopardy for 26 mammalian species and there is a potential likelihood of future jeopardy for 2 mammals. The rationale for each determination and J prediction is summarized in **Table 43** and discussed in more detail for each species in **Appendix M**.

Table 43. Species effects determination and prediction of potential likelihood of future jeopardy summary for listed mammalian species.

Effects Determination	Predictions of Likelihood of Jeopardy	Number of species	Characteristics of Species for Each Determination
NE	N/A	24	<1% overlap with any of the UDLs, species habitat indicated a low likelihood of exposure path, species found in Guam, American Samoa, or the Marianas Islands which is not in the action area for this active ingredient.
NLAA	N/A	42	Although exposure is anticipated, it is not likely to adversely affect the species because: 1) <1% overlap with any of the UDLs when considering likelihood of adverse direct and PPHD effects to the individual; or 2) >1% overlap with the Other Grain, Vegetable and Ground Fruit UDL only but the Census of Agriculture tool indicates overlap with canola and sweet corn, respectively, is <1%.
LAA	Not Likely J	26	While there is potential for direct or indirect effects, it is not expected to result in a population-level impact because: 1) overlap of the exposure area (considering direct and indirect population-level effects) with the species range is low (<5%) for any individual UDL; **OR** 2) overlap is >5% but the diversity of habitats available to the species including several which are not expected to be impacted, the species is highly mobile and capable of moving in and between habitats to reduce exposure and find new unaffected sources of shelter or food, foraging habits that limit direct exposure, and/or species' habitat is expected to be resilient (*i.e.,* woody plant communities) to glufosinate-P exposure, which reduce the likelihood of a population-scale impacts from direct effects or PPHD effects from reduced prey/dietary item availability and habitat integrity.
LAA	Likelihood of J	2	Population-level impacts are expected because: 1) Exposure area overlap with species range considering direct and PPHD population-level effects is medium to high (>5%) for any individual UDL after consideration of use site refinements **AND** the species is reliant on herbaceous vegetation, and the species has specialized habitat or primary habitat which is expected to be impacted by the labeled uses of glufosinate-P. All species also have medium to high vulnerability.

J=jeopardy; N/A= not applicable; NE=no effect; NLAA=not likely to adversely affect; LAA=likely to adversely affect; PPHD= prey, pollination, habitat, and dispersal; UDL=use data layer

Table 44 summarizes the listed mammal species for which EPA predicted the potential likelihood of future jeopardy from the uses of glufosinate-P. **Table 44** summarizes the listed mammal species for which EPA predicted the potential likelihood of future jeopardy from the labeled uses of glufosinate-P. For all these species, at least one UDL overlaps with >5% of species range after considering use site refinements, they have generalist relationship with herbaceous terrestrial upland or semi-aquatic plants for diet or habitat, and the species is dependent on a specialized habitat or a primary habitat that is likely to be exposed to glufosinate-P. Runoff and spray drift from the use site will have a substantial impact on the upland and semi-aquatic plant communities in the species' terrestrial and wetland habitat and are main contributors to the predicted potential likelihood of future jeopardy. Exposure to plants at the use site will also reduce availability of dietary items and habitat at those locations; however, listed mammal species are not likely to rely exclusively on managed or fallow fields for forage and/or shelter. Direct effects to mammals are not likely to contribute to a species-level impact for any of the listed mammals.

Table 44. Listed mammal species with predicted likelihood of future jeopardy.

Entity ID	**Common Name (Scientific Name)**
52	Preble's meadow jumping mouse (*Zapus hudsonius preblei*)
58	Buena Vista Lake ornate shrew (*Sorex ornatus relictus*)

8.4.5 Birds

Direct Effects

Discernable and adverse effects are not likely to bird individuals, populations, or communities from the labeled uses of glufosinate-P based on the conclusions of the generic taxa-based screening level assessment (**Section 8.2.1.1**). Consequently, direct effects are not likely for listed bird species nor are the labeled uses of glufosinate-P likely to affect listed species through their obligate or generalist relationships with birds.

PPHD Effects

Listed birds have generalist relationships with plants, invertebrates, mammals, birds, reptiles, and amphibians for food and with plants for habitat. Several listed birds also have reported obligate relationships with benthic invertebrates or terrestrial plants.

Based on the generic-taxa based screening level assessment, the labeled uses of glufosinate-P are likely have a discernable effect on listed bird species that have PPHD relationships with plants, mammals, and invertebrates. The labeled uses of glufosinate-P are further likely to adversely affect listed bird species that have generalist or obligate relationships with upland and semi-aquatic plants given the likelihood of adverse effects to plant populations and communities (**Section 8.3.8.1**). The loss of habitat and plant dietary items will have the greatest

impact among listed bird species that rely primarily or exclusively on herbaceous plants. Listed species that have generalist relationship with diverse plant communities consisting of herbaceous and woody plants, or exclusively woody plants and shrubs are less likely to experience large scale loss of diet or habitat. While individual effects cannot be ruled out for these species, the greater resilience of the plant communities on which they rely is likely to limit how many individuals are impacted and lower the likelihood of a species level impact. Community-level effects are not likely for aquatic plants (**Section 8.3.8.1**), mammals (**Section 8.3.4.1**), aquatic invertebrates (**Section 8.3.3.1**), or terrestrial invertebrates (**Section 8.3.7.1**); therefore, species that have a generalist relationship with these taxa are unlikely to experience adverse effects related to a decline in these prey/dietary items or loss of aquatic plant habitat.

A total of 7 bird species have an obligate relationship with plants, all of which are to upland woody dicot or conifer species. The labeled uses of glufosinate-P have the potential to impact the health of the woody plant and tree species, particularly those occurring near use sites and with new growth, which will affect individual species co-localized with these woody plants; however, because glufosinate-P is not likely to adversely affect populations of woody plants or trees, the impact of the glufosinate-P on this obligate relationship is lessened. The only other obligate relationship among listed birds is the Everglade snail kite (*Rostrhamus sociabilis plumbeus*) which has a dietary obligate relationship with apple snails. Since the adverse population-level effects are not likely for aquatic invertebrates (**Section 8.3.3.1**), this obligate relationship is not likely to be adversely affected by the labeled uses of glufosinate-P.

Effect Determinations and Predictions of Potential Likelihood of Future Jeopardy

A total of 98 bird species federally listed as endangered or threatened are considered in this BE. Although 99 bird species were listed as of February 2022, one species, the San Clemente sage sparrow (*Amphispiza belli clementeae*) was delisted due to recovery and thus is not evaluated further in this BE. An NE determination was made for 17 species, NLAA determination for 49 species, and LAA determination for 32 species. Of the 32 species with LAA determinations, EPA predicts that the labeled glufosinate-P uses do not have the potential likelihood of future jeopardy for 31 bird species and EPA predicts there is a potential likelihood of future jeopardy for 1 bird species. The rationale for each determination and J prediction is summarized in **Table 45** and discussed in more detail for each species in **Appendix M**.

Table 45. Species effects determination and prediction of likelihood of future jeopardy summary for listed bird species.

Effects Determination	Predictions of Likely Jeopardy	Number of species	Characteristics of Species for Each Determination
NE	N/A	17	<1% overlap with any of the UDLs, species habitat indicated a low likelihood of exposure path, species found in Guam, the Mariana Islands, or American Samoa which is not in the action area for this active ingredient.
NLAA	N/A	49	Although exposure is anticipated, it is not likely to adversely affect the species because: 1) <1% overlap with any of the UDLs when considering likelihood of adverse direct and indirect effects to the individual; or 2) >1% overlap with the Other Grain, Vegetable and Ground Fruit UDL only but the Census of Agriculture tool indicates low acreage of canola and sweet corn is grown in counties withing the species range.
LAA	Not Likely J	31	While there is potential for direct or indirect effects, it is not expected to result in a population-level impact because: 1) overlap of the exposure area (considering direct and indirect population-level effects) with the species range is low (<5%) for any individual UDL; **OR** 2) overlap is >5% but the species can occupy multiple habitats including several which are not expected to be impacted, is capable of easily moving within and between habitats to reduce exposure and find new unaffected sources of shelter or food, and/or species' habitat is expected to be resilient (*i.e.,* woody plant communities) to glufosinate-P exposure, which reduce the likelihood of a population-scale impacts from indirect effects from reduced prey/dietary item availability and habitat integrity.
LAA	Likelihood of J	1	Population-level impacts are expected because: 1) Exposure area overlap with species range considering direct and indirect population-level effects is medium to high (>5%) for any individual UDL **AND** the species is reliant on herbaceous vegetation for diet and/or shelter, the species has specialized habitat or primary habitat which is expected to be impacted by the labeled uses glufosinate-P, and the species has limited mobility/dispersal capabilities to reduce likelihood of exposure and to find new unaffected sources of shelter or food. All species also have medium to high vulnerability.

J=jeopardy; N/A= not applicable; NE=no effect; NLAA=not likely to adversely affect; LAA=likely to adversely affect; UDL=use data layer

Table 46 summarizes listed bird species for which glufosinate-P is predicted to have a potential likelihood of future jeopardy. For this species, at least one UDL overlaps with >5% of species range after considering use site refinements, they have generalist relationship with herbaceous terrestrial upland or semi-aquatic plants for diet or habitat, and the species is dependent on a specialized habitat or a primary habitat that is likely to be exposed to glufosinate-P. Runoff and spray drift from the use site will have a substantial impact on the upland plant communities in the species' terrestrial habitat and are main contributors to the predicted potential likelihood of future jeopardy. Exposure to plants at the use site will also reduce availability of dietary items and habitat at those locations; however, listed bird species are not likely to rely exclusively on managed or fallow fields for forage and/or shelter. Direct effects are not likely to contribute to a species-level impact for this listed bird species.

Table 46. Listed bird species with predicted potential likelihood of future jeopardy.

Entity ID	Common Name (Scientific Name)
83	Attwater's greater prairie-chicken (*Tympanuchus cupido attwateri*)

8.4.6 Reptiles

Direct Effects

Discernable and adverse effects are not likely to reptile individuals, populations, or communities from the labeled glufosinate-P uses based on the conclusions of the generic taxa-based screening level assessment (**Section 8.2.1.1**). Consequently, direct effects are not likely for listed reptile species nor are the labeled uses of glufosinate-P likely to affect listed species through their obligate or generalist relationships with reptiles.

PPHD Effects

Listed reptiles have a generalist diet relationship with plants, invertebrates, fish, mammals, birds, amphibians, and other reptiles and a generalist relationship with plants and mammals (*i.e.,* use of other species burrows) for habitat. Obligate relationships for listed reptile species involve mammals and aquatic invertebrates.

Based on the generic-taxa based screening level assessment, the labeled uses of glufosinate-P are anticipated have a discernable effect on listed reptile species that have PPHD relationships with plants, aquatic invertebrates, mammals, and terrestrial invertebrates. The labeled uses of glufosinate-P uses are further likely to adversely affect listed reptile species that have generalist or obligate relationships with upland and semi-aquatic plants given the likelihood of adverse effects to plant populations and communities (**Section 8.3.8.1**). The loss of habitat and plant dietary items will have the greatest impact among listed reptile species that rely primarily or exclusively on herbaceous plants. Listed species that have generalist relationship with diverse plant communities consisting of herbaceous and woody plants, or exclusively woody plants and

shrubs are less likely to experience large scale loss of diet or habitat. While individual effects cannot be ruled out for these species, the greater resilience of the plant communities on which they rely is likely to limit how many individuals are impacted and lower the likelihood of a species level impact. Community-level effects are not likely for aquatic plants (**Section 8.3.8.1**), mammals (**Section 8.3.4.1**), aquatic invertebrates (**Section 8.3.3.1**), or terrestrial invertebrates (**Section 8.3.7.1**); therefore, species that have a generalist relationship with these taxa are unlikely to experience adverse effects related to a decline in these prey/dietary items or loss of aquatic plant habitat.

Two listed reptiles, the Louisiana pine snake (*Pituophis ruthveni*) and Eastern Massasauga rattlesnake (*Sistrurus catenatus*), have reported obligate relationships to mammals (Bairds pocket gopher; *Geomys breviceps*) and aquatic invertebrates (crayfish), respectively. Since the adverse population-level effects are not likely for aquatic invertebrates (**Section 8.3.3.1**) or mammals (**Section 8.3.4.1**), these obligate relationships are not likely to be adversely affected by the labeled uses of glufosinate-P.

Effect Determinations and Predictions of Likelihood of Jeopardy

Species determinations were made for 45 reptile species; a NE determination was made for 8 reptiles. An NLAA determination was made for 16 reptile species, and LAA determination for 21 reptile species. Of the 21 species with LAA determinations, EPA initially predicted that the labeled glufosinate-P uses do not have the potential likelihood of future jeopardy for 19 bird species and predicted a potential likelihood of future jeopardy to 2 bird species. The rationale for each determination and J prediction is summarized in **Table 47** and discussed in more detail for each species in **Appendix M**.

Table 47. Species effects determination and predicted potential likelihood of future jeopardy summary for listed reptile species.

Species Determination	Predictions of Likelihood of Future Jeopardy	Number of species	Rationale for the Species Determination
NE	N/A	8	<1% overlap with any of the UDLs.
NLAA	N/A	16	Although exposure is likely, it is not likely to adversely affect the species because) the species primarily inhabits the open ocean where PPHD effects are expected to be limited given large dilution in habitat.
LAA	Not Likely J	19	While there is potential for adverse PPHD effects to individuals, it is not likely to result in a population-level impact because: 1) overlap of the exposure area with the species range is low (<5%) for all UDL; OR 2) Multiple diets and habitats sources available and the species does not have a preference for dietary items or habitats that are likely to be most affected by the labeled uses glufosinate-P.
LAA	Likely J	2	Although direct effects are not likely, PPHD effects are likely to result in population-level impacts because: 1) Exposure area

Species Determination	Predictions of Likelihood of Future Jeopardy	Number of species	Rationale for the Species Determination
			overlap with species range considering PPHD population-level effects is medium to high (>5%) for any individual UDL **AND** the species is reliant on herbaceous vegetation for shelter, the species has specialized habitat or primary habitat which is likely to be impacted by the labeled uses glufosinate-P. All species also have medium to high vulnerability and pesticides are noted in the geographical area.

J=jeopardy; N/A= not applicable; NE=no effect; NLAA=not likely to adversely affect; LAA=likely to adversely affect; PPHD= prey, pollination, habitat, and dispersal; UDL=use data layer

Table 48 summarizes the listed reptile species for which EPA initially predicted that the uses of glufosinate-P are predicted to have a potential likelihood of jeopardy. **Table 48** summarizes the listed reptile species for which EPA initially predicted that the labeled uses of glufosinate-P are predicted to have a potential likelihood of jeopardy. For all these species, at least one UDL overlaps with >5% of species range after considering use site refinements, they have generalist relationship with herbaceous terrestrial upland or semi-aquatic plants for diet or habitat, and the species is dependent on a specialized habitat or its primary habitat for at least one life stage is likely to be exposed to glufosinate-P. Runoff and spray drift from the use site will have a substantial impact on the upland and/or semi-aquatic plant communities in the species' terrestrial and wetland habitat and are main contributors to the predicted potential likelihood of future jeopardy. Exposure to plants at the use site will also reduce availability of dietary items and habitat at those locations; however, these listed reptile species are not likely to rely exclusively on managed or fallow fields for forage and/or shelter. Direct effects to reptiles are not likely to contribute to a species-level impact for any of the listed reptiles.

Table 48. Listed reptile species with predicted potential likelihood of future jeopardy.

Entity ID	Common Name (Scientific Name)
170	Plymouth Redbelly Turtle (*Pseudemys rubriventris bangsi*)
182	Bog turtle (*Glyptemys muhlengergii*)

8.4.7 Terrestrial Invertebrates

Direct Effects

Terrestrial invertebrate species listed as federally endangered or threatened include arachnids, insects, and snails. Several species have both terrestrial and aquatic phases for portions of their life cycle. Listed terrestrial invertebrate, plant, bird, amphibian, reptile, and mammal species

also have obligate or generalist relationships to terrestrial invertebrates for prey, pollination, dispersal, or other symbiotic purposes (*e.g.,* El Segundo blue butterfly)

Direct effects to terrestrial invertebrate species may result from direct spray during application, contact with residues on foliar surfaces or in the soil, and/or consumption of residues in prey and dietary items. Contact exposure and residues in prey and other dietary items are expected to be the main source of direct exposure to glufosinate-P for terrestrial invertebrates. The dietary needs of terrestrial invertebrates are diverse and include plants (*e.g*., grass, broadleaf plants, fruits, pods and seeds), fungi, carrion, and other terrestrial invertebrates. Terrestrial invertebrates with an aquatic phase may also be exposed to residues in the water column, and to a lesser extent, the sediment and dietary items in its aquatic habitat. Given different routes of exposure, different approaches are taken to assess direct effects to terrestrial-phase and aquatic-phase invertebrates and are discussed separately below.

Terrestrial-phase

Table 49 below summarizes the exposure models and endpoints used to evaluate mortality and sublethal effects for terrestrial only invertebrates and the terrestrial phase of invertebrates that also spend a portion of their lifecycle in aquatic ecosystems. EPA used different exposure models and selected different endpoints to assess effects in bees and in non-bee terrestrial invertebrates.

Table 49. Description of Toxicity Endpoints and Exposure Models Used in Evaluating the Direct Effects to Terrestrial-Phase of Terrestrial Invertebrates.

Taxon	Exposure Models	Direct Effects	
		Mortality	Growth/Reproduction
Bees	On-Site: BeeREX v. 1.0 Off-Site: AgDrift™ v. 2.1.1 Individual/Population: Default residues in pollen and nectar estimated in BeeREX	Individual/Population: Adult MATC = 25.7 µg ae/bee/day	Individual/Population: Larval MATC = 3.6 µg ae/larvae/day
Non-Bee Terrestrial Invertebrates	On-Site: T-REX v. 1.5.2 Off-Site: AgDrift™ v. 2.1.1 Individual: Upper-bound residues for reported dietary items Population: Mean residues for reported dietary items	Individual/Population: Considered the more sensitive sublethal effects only	Individual/Population: Larval MATC = 92.9 mg ae/kg-diet

Taxon	Exposure Models	Direct Effects	
		Mortality	Growth/Reproduction

MATC=maximum acceptable toxic concentration representing the geometric mean of the natural log of the no-observed adverse effect concentration (NOAEC) and the lowest observed adverse effect concentration (LOAEC).
Step 1 = May Affect or No Effect (MA/NE) Determination; Step 2 = Likely to Adversely Affect or Not Likely to Adversely Affect (LAA/NLAA) Determination; Step 3 = Likely future Jeopardy/Adverse Modification or Not Likely future Jeopardy/Adverse Modification (J/AM) Determination.

Terrestrial invertebrate toxicity data for glufosinate (**Section 6.2**) are only available for insect species and most of these data reflect toxicity to a single species, the European honey bee (*Apis mellifera*). These data cover contact and dietary toxicity and separate endpoints are established for both routes of exposure. The generic taxa-based screening level assessment (ERA; **Section 7.4**) indicated contact and dietary exposure are a concern for non-bee terrestrial invertebrates and dietary exposure alone is a concern for bee species. Since contact exposure from the uses is not estimated to exceed the level of concern for bee species, contact toxicity is not likely to result in adverse effects to bee individuals, populations, or communities. Since contact exposures from the labeled uses are not estimated to exceed the level of concern for bee species, contact toxicity is not likely to result in adverse effects to bee individuals, populations, or communities. Although acute contact toxicity was identified as an effect of concern for non-bee terrestrial invertebrates, the endpoint used in that analysis is based on an upper-bound estimate of exposure and toxicity, and, consequently, likely overestimates contact exposure relative to what is expected in the environment. While these data suggest acute contact exposure could result is significant mortality to non-bee terrestrial invertebrate species, the actual risk to non-bee terrestrial invertebrates from acute contact exposure is uncertain. Consequently, EPA did not utilize this endpoint for evaluating adverse direct effects to individuals, populations, or communities. Since no contact toxicity data with greater environmental relevance is available for non-bee terrestrial invertebrates, contact toxicity is not evaluated for adverse individual and population-level effects and is an uncertainty in magnitude of effect analysis for these species.

The generic taxa screening level assessment indicated that sublethal effects in bee and non-bee terrestrial invertebrates resulting from chronic dietary exposure are a concern for the labeled uses glufosinate-P whereas acute dietary exposure is not a concern. EPA, therefore, relied on sublethal endpoints for the European honey bee (*Apis mellifera*) to evaluate the likelihood of adverse dietary toxicity in bees and non-bee terrestrial invertebrate individuals. Although the most sensitive endpoint (EC_{10}= 8.38 mg ae/kg-diet for the honey bee; based on reduced food consumption) indicates that adult terrestrial invertebrates foraging at the application site will consume less food, it is uncertain at what dietary exposure level the reduced food consumption in adult bees translates to effects on growth. Furthermore, it is uncertain whether the dietary response in honey bees is reflective of dietary toxicity in non-bee terrestrial invertebrates. EPA, therefore, selected the MATC (92.9 mg ae/kg-diet equivalent to 3.6 µg ae/bee/day) from the chronic larval honey bee study which is based on a 19% decrease in adult emergence at the LOAEL (134 mg ae/kg-diet equivalent to 5.0 µg ae/bee/day) to evaluate individual level effects. Dietary exposure to individuals was estimated in T-REX based on upper-bound residues in grass,

broadleaves, fruit/pods, seeds, and arthropod dietary items. The tall grass residue values were also used as a surrogate for estimating residues in pollen and nectar.

EPA relied on the same endpoints to evaluate adverse effects to bee and non-bee terrestrial invertebrate populations but utilized the T-REX mean residue EECs to evaluate dietary exposure in non-bee terrestrial invertebrates. Similar to mammals, EPA considers the average exposure level to better represent the spatial and temporal variability in exposure amongst individuals within the population. The available data are limited to a small number of species and were not sufficient to evaluate community level impacts; therefore, the conclusions for the population-level assessment were used to evaluate the likelihood of a community level effect.

Upper-bound and mean exposure estimates along with effect analysis results for bee and non-bee terrestrial invertebrate individuals, populations, and communities are summarized in **Table 50** and **Table 51**, respectively. Adverse direct effects are likely for individuals of bee species from the labeled uses on glufosinate-tolerant field corn, canola, cotton, and soybean as well as burndown uses on corn, cotton, soybean, canola, and sweet corn. Similarly, adverse effects to individuals of non-bee terrestrial invertebrates are likely for species that consume short grass containing residues from the labeled uses on glufosinate-tolerant field corn, cotton, canola, and soybean as well as burndown uses on cotton. Individual level adverse effects are not likely for non-bee terrestrial invertebrates that consume other dietary items. These adverse effects are likely to manifest in reduced growth and development. Estimated exposure for bee and non-bee terrestrial invertebrates does not exceed the threshold for adult mortality (MATC = 25.7 µg ai/bee; 1,987 mg ae/kg-diet) indicating that significant mortality in bee and non-bee terrestrial invertebrate individuals is unlikely to result from the labeled uses of glufosinate-P. At the population and community level, adverse effects are likely for bee species from the same labeled uses glufosinate-P likely to adversely affect individuals. The population and community analysis for bees are based on the most highly exposed caste or task within a honey bee colony, assume exposure to default residues in pollen and nectar, and are based on toxicity data for bee individuals. While measured residue data are not available to refine the quantitative analysis, semi-field honey bee studies suggest that the sublethal effects observed in individuals may not result in colony level adverse effects for social bee species in the environment. The semi-field field studies, however, inform on the likelihood of effects to social bees only and do not reflect a low likelihood of population or community level impacts for solitary bees. For non-bee terrestrial invertebrates mean EECs on dietary items fall below the MATC, indicating that adverse effects are not likely for non-bee terrestrial invertebrates at the population or community level.

Table 50. Direct effects summary for listed non-bee terrestrial invertebrates.

Level of Biological Organization→	Individual			Population		
Food Type↓	Upper-bound EEC (mg ae/kg-diet)	Exposure to Effects Ratio (EEC/Toxicity Endpoint)[1]	Use Exceedances	Mean EEC (mg ae/kg-diet)	Exposure to Effects Ratio (EEC/Toxicity Endpoint)[1]	Use Exceedances
Short grass	57.6-153	0.62-**1.65**	GMO: Canola, Field Corn, Cotton, Soybean Non-GMO: Cotton	20.4-54.4	0.22-0.59	None
Tall grass	26.4-70.4	0.28-0.76	None	8.64-23.0	0.09-0.25	
Broadleaf plants	32.4-86.4	0.35-0.93		10.8-28.8	0.12-0.31	
Fruits/pods/seeds	3.60-9.60	0.04-0.10		1.68-4.48	0.02-0.05	
Arthropods	22.6-60.1	0.24-0.65		15.6-41.6	0.17-0.45	

EEC=estimated environmental concentration; GMO=genetically modified organism

[1]Based on the 4-day chronic maximum acceptable toxicant concentration (MATC) of 92.9 mg ae/kg diet for larval honey bees (*Apis mellifera*; MRID 51036685). The same endpoint is used to evaluate adverse effects to the individual and the population.

Table 51. Direct effects summary for listed bees.

Level of Biological Organization	Pollen and Nectar EECs (µg ae/mg)	Adult (Mortality)			Larvae (Adult Emergence)		
		Dose (µg ae/bee) [1]	Exposure to Effects Ratio (EEC/Toxicity Endpoint)[2]	Use Exceedances	Dose (µg ae/bee)[3]	Exposure to Effects Ratio (EEC/Toxicity Endpoint)[4]	Use Exceedances
Individual	0.0202 – 0.0395	5.91 – 11.53	0.23 – 0.45	None	2.50 – 4.88	0.70 – **1.36**	GMO: Soybean, cotton, field corn, canola Non-GMO: Soybean, Cotton, Field Corn, Sweet Corn, Canola
Population/Community							

EEC=estimated environmental concentration; GMO=genetically modified organism

[1]Adult bee dose is based on the total dose estimated for an adult worker bee foraging for nectar in BeeREX v. 1.0. Assumes a single application at the maximum single application rate for each labeled use.

[2]The toxicity endpoint used for the adult magnitude of direct effect calculation is the chronic survival maximum acceptable toxicant concentration (MATC) of 25.7 µg ae/bee/day for adult honey bees (*Apis mellifera*; MRID 51102401) based on 14% decrease in survival at the lowest observed adverse effect level for survival of 37.2 µg ae/bee/day. The same endpoint is used to evaluate adverse effects to the individual and the population.

[3] Larval bee dose is based on the total dose estimated for a 5-day old larval worker bee in BeeREX v. 1.0. Assumes a single application at the maximum single application rate for each labeled use.

[4]The toxicity endpoint used for the larval magnitude of direct effect calculation is the 4-day MATC of 3.6 µg ae/bee/day for larval honey bees (MRID 51036685) based on a 19% reduction in adult emergence at the lowest observed adverse effect level of 5.0 mg ae/bee/day. The same endpoint is used to evaluated adverse effects to the individual and the population.

Aquatic Phase

Direct effects to aquatic phase terrestrial invertebrates are assessed based on the conclusions of the direct effects analysis for aquatic invertebrates (**Section 8.3.3.1**). Based on the low likelihood of adverse effects in aquatic invertebrates, exposure during the aquatic phase of a species' lifecycle is not likely to contribute to adverse effects in the terrestrial invertebrate species.

PPHD Effects

Listed terrestrial invertebrate species have generalist diet relationships with plants, aquatic invertebrates, other terrestrial invertebrates, and terrestrial vertebrates (*i.e.,* carrion) and a generalist relationship with plants for habitat. Several listed terrestrial invertebrate species also have obligate relationships to terrestrial plants and terrestrial invertebrates.

Based on the generic-taxa based screening level assessment, the labeled uses of glufosinate-P are anticipated have a discernable effect on listed terrestrial invertebrate species that have PPHD relationships with plants, aquatic invertebrates, mammals, and terrestrial invertebrates. The labeled uses of glufosinate-P are further likely to adversely affect listed terrestrial invertebrate species that have generalist or obligate relationships with upland and semi-aquatic plants given the likelihood of adverse effects to plant populations and communities (**Section 8.3.8.1**). The loss of habitat and plant dietary items will have the greatest impact among listed terrestrial invertebrate species that rely primarily or exclusively on herbaceous plants. Listed species that have generalist relationship with diverse plant communities consisting of herbaceous and woody plants, or exclusively woody plants and shrubs are less likely to experience large scale loss of diet or habitat. While individual effects cannot be ruled out for these species, the greater resilience of the plant communities on which they rely is likely to limit how many individuals are impacted and lower the likelihood of a species level impact. Community-level effects are not likely for aquatic plants (**Section 8.3.8.1**), mammals (**Section 8.3.4.1**), aquatic invertebrates (**Section 8.3.3.1**), or terrestrial invertebrates (**Section 8.3.7.1**); therefore, species that have a generalist relationship with these taxa are unlikely to experience adverse effects related to a decline in these prey/dietary items or loss of aquatic plant habitat.

A total of 47 terrestrial invertebrate species have an obligate relationship with upland and/or semi-aquatic plants of which 23 rely on herbaceous plants and 24 rely on woody plants or trees. Adverse PPHD effects to individuals and populations are likely for the 23 species that rely on herbaceous plants given the high likelihood of adverse effects to herbaceous plant populations (**Section 8.2.5.2**). For the other 24 species, the labeled uses of glufosinate-P have the potential to impact the health of the woody plant and tree species, particularly those occurring near use sites and with new growth, which will affect individual species co-localized with these woody

plants; however, because glufosinate-P is not likely to adversely affect populations of woody plants or trees, the impact of the glufosinate-P on this obligate relationship is lessened. Other obligate relationships include four lepidopteran species that have a mutualistic relationship with ants and the Delta green ground beetle which has a dietary obligate relationship with springtails. Since adverse population-level effects are not likely for non-bee terrestrial invertebrates (**Section 8.3.7.1**), these obligate relationships are not likely to be adversely affected by the labeled uses glufosinate-P.

Effect Determinations and Predictions of Potential Likelihood of Future Jeopardy

EPA considered a total of 157 listed terrestrial invertebrates in this assessment. An NE determination was made for 72 species. There are NLAA determinations for 23 species, and LAA determinations for 62 species. Of the 62 species with LAA determinations, EPA initially predicted that the labeled glufosinate-P uses do not have a potential likelihood of future jeopardy to 53 terrestrial invertebrate species and predicted a potential likelihood of jeopardy to 9 terrestrial invertebrates. The rationale for each effects determination is summarized in **Table 52** and discussed in more detail in **Appendix M**.

Table 52. Species effects determination and prediction of potential likelihood of future jeopardy summary for listed terrestrial invertebrate species.

Species Determination	Number of species	Rationale for the Species Determination/J Prediction
NE	72	<1% overlap with any of the UDLs or species habitat indicated a low likelihood of exposure path (*e.g.,* species habitat is an interior forest)
NLAA	23	Although exposure is likely, it is not likely to adversely affect the species because: 1) Species is likely extinct; 2) Species is in a karst system in a forest on a cliff.
LAA-Not Likely J	53	While there is potential for adverse direct and/or PPHD effects to individuals, it is not likely to result in a population-level impact because: 1) overlap of the exposure area (considering direct and PPHD population-level effects) with the species range is low (<5%) for any individual UDL; **OR** 2) Multiple diets and habitats sources available and the species does not have a preference for dietary items or habitats that are likely to be most affected by the labeled uses of glufosinate-P.
LAA-Likelihood of J	9	Population-level impacts are expected because: Exposure area overlap with species range considering direct and PPHD population-level effects is medium to high (>5%) for any individual UDL **AND** the species is reliant on herbaceous vegetation for shelter or forage, the species has specialized habitat or primary habitat which is likely to be impacted by the labeled uses of glufosinate-P. All species also have medium to high vulnerability.

J=jeopardy; N/A= not applicable; NE=no effect; NLAA=not likely to adversely affect; LAA=likely to adversely affect; PPHD= prey, pollination, habitat, and dispersal; UDL=use data layer

Table 53 summarizes the listed terrestrial invertebrate species for which glufosinate-P is predicted to have a potential likelihood of future jeopardy. For all these species, at least one UDL overlaps with >5% of species range after considering use site refinements, they have generalist or obligate relationship with herbaceous terrestrial upland or semi-aquatic plants for diet or habitat, and the species is dependent on a specialized habitat or a primary habitat that is likely to be exposed to glufosinate-P. Runoff and spray drift from the use site will have a substantial impact on the upland and semi-aquatic plant communities in the species' terrestrial and wetland habitat and are main contributors to the predicted potential likelihood of future jeopardy. Exposure to plants at the use site will also reduce availability of dietary items and habitat at those locations; however, with few exceptions, listed terrestrial invertebrate species are not likely to rely exclusively on managed or fallow fields for forage and/or shelter. Direct effects to terrestrial invertebrates are not likely to contribute to a species-level impact for any of the listed terrestrial invertebrate species.

Table 53. Listed terrestrial invertebrate species with predicted potential likelihood of future jeopardy.

Entity ID	Common Name (Scientific Name)
389	Chittenango ovate amber snail (*Novisuccinea chittenangoensis*)
420	Karner blue butterfly (*Lyaeides meliss samuelis*)
424	Mitchell's satyr butterfly (*Neonympha mitchellii mitchellii*)
445	Hine's emerald dragonfly (*Somatochlora hineana*)
455	Saint Francis' satry butterfly (*Neonympha mitchellii francisci*)
3412	Dakota skipper (*Hesperia dacite*)
4910	Salt Creek Tiger beetle (*Cicindela nevadica lincolniana*)
10147	Poweshiek skipperling (*Parisma poweshiek*)
10383	Rusty patched bumble bee (*Bombus affinis*)

8.4.8 Plants

Direct Effects

Plant species listed as federally endangered or threatened include lichens, ferns and allies, conifers, cycads, and monocot and dicot flowering plants. All listed plants species occupy dry, upland terrestrial and/or semi-aquatic habitats. Plants in semi-aquatic habitats are emergent species, generally with shoots and leaves extending above the surface of the water and roots inundated or in moist soil following dry down. While several emergent species may also tolerate aquatic habitat where the plant is fully submerged for a period of time, none of the species grow in those habitats exclusively. All listed plant species are vascular except for the lichen species which are a symbiotic relationship of non-vascular green algae or blue-green algae with fungi. There are no currently listed non-vascular aquatic plants species. Direct effects to upland plants may result from direct spray during application at the use site and direct effects to upland, semi-aquatic, and aquatic plants may result from exposure to pesticide that is transported off-site. Since there are no direct to water applications included in this action for this action, direct spray exposure is not likely for semi-aquatic and aquatic plants. Spray drift

and runoff are likely to be the primary mechanisms for off-site transport of glufosinate-P and will be the main sources of exposure to plants that do not establish at the use site. Based on the generic taxa-based screening assessment (ERA; **Section 8.2.1.1**), the labeled uses of glufosinate-P are likely to affect upland and semi-aquatic plants, and aquatic non-vascular plants. Effects to aquatic vascular plants either listed or non-listed are not likely and are therefore, not evaluated further in this listed species assessment.

Upland and Semi-Aquatic Plants

Terrestrial plant toxicity data for glufosinate-P are available for four monocot and six dicot species (**Section 6.2**). **Table 54** below summarizes the exposure models and endpoints used to evaluate effects to plant species individuals, populations, and communities that inform the magnitude of effect analysis for the NLAA/LAA determination and the predictions of potential likelihood of future jeopardy.

Table 54. Description of Toxicity Endpoints and Exposure Models Used in Evaluating the Effects to Plants.

Taxon	Exposure Models	Endpoints for Each Level of Biological Organization	
		Mortality	Growth/Reproduction
Terrestrial/Semi-Aquatic plants – Monocots	On/Off-Site: PAT v. 2.7 Wetland and Other Low-Volume Waterbodies – Peak WPEZ EEC Terrestrial – Peak TPEZ EEC	Not applicable	Individual: NOAEC = 0.046 lbs ae/acre Population: HC_{05} = 0.0417 lb ae/acre Community: HC_{25} = 0.058 lb ae/acre
Terrestrial/Semi-Aquatic plants - Dicots		Not applicable	Individual: NOAEC = 0.023 lbs ae/acre Population: HC_{05} = 0.0417 lb ae/acre Community: HC_{25} = 0.058 lb ae/acre

MATC=maximum acceptable toxic concentration representing the geometric mean of the natural log of the no-observed adverse effect concentration (NOAEC) and the lowest observed adverse effect concentration (LOAEC). HC_x = Hazard Concentration, the exposure concentration expected to affect x% of species from that taxon; PAT = Plant Assessment Tool; WPEZ= Wetland Plant Exposure Zone; TPEZ = Terrestrial Plant Exposure Zone; EEC = Estimated Environmental concentration; ae= acid equivalents.

For this analysis, EPA considered endpoints separately for listed monocots and dicots. Plant toxicity endpoints are not available that directly represent toxicity to ferns and allies, conifers and cycads, and lichens. While aquatic toxicity data are available for cyanobacteria and green algae, they are not representative of a terrestrial exposure pathway, leaving it uncertain as to whether the observed effects are likely to occur in lichen. Since no data are available, the most sensitive terrestrial plant endpoints are used as a surrogate to evaluate effects to fern and allies, conifer and cycad, and lichen species.

The effect analysis for plants used the 1-in-10 year peak TPEZ and WPEZ EECs as a measure of exposure for upland and semi-aquatic plants, respectively. To assess adverse effects to individuals, EPA compared the EECs for monocots to the most sensitive monocot endpoint (*i.e.*,

NOAEC= 0.046 lbs L ae/A) which is based on a growth effect in onions. Likewise, EPA compared the EECs for dicots to the most sensitive dicot endpoint (*i.e.,* NOAEC= 0.023 lbs ae/A) which is based on a growth effect in carrots, to assess adverse effects in dicot individuals. EPA also used the dicot toxicity endpoints to evaluate adverse effects to fern and allies, conifer and cycad, and lichen species individuals since it is the most sensitive toxicity endpoint available. EPA considered the most sensitive monocot and dicot MATC values as an alternative for evaluating effects in individuals; however, the MATC values exceeded the most sensitive IC_{25} values indicating that individual effects could occur at concentrations below the MATC.EPA selected the concentration that is expected to be hazardous to 5% and 25% of plant species (*i.e.,* HC_{05} and HC_{25}) as the endpoint to assess effects to plant populations and communities, respectively. The HC_{05} of 0.0417 lbs ae/A and HC_{25} of 0.058 lbs ae/A are estimated from a species sensitivity distribution (SSD) developed from available terrestrial plant dry weight IC_{25} data (see **Appendix H** and **Section 7.7.1.3** for more details). The SSD represents the sensitivity of 8 crop species to glufosinate using data on the L-glufosinate typical end-use product (TEP), L-glufosinate acid TEP, and racemic glufosinate ammonium TGAI. The sensitivity distribution is assumed to reflect all plant species; therefore, the HC_{05} and HC_{25} indicates an effect level where 95% and 75%, respectively, of plant species exposed will not experience 25% or greater effect to growth. Since the HC_{05} reflects an exposure level that is not expected to elicit population-level effects in most plant species and is similar to the most sensitive endpoint for terrestrial plants, this endpoint is considered protective of population-level effects that occur in a listed species and a single species or small number of species that form obligate relationships. The HC_{25} was selected to evaluate impacts at the community level because the ecological function of plant communities is expected to be diminished where 25% or more of plant species experience adverse growth effects.

An SSD was also developed from plant height data. The HC_{05} and HC_{25} for height are 0.0431 and 0.0739 lbs ae/A. respectively. Since these are not more sensitive compared to the dry weight endpoints, they are used for characterization purposes. Notably, the HC_{05} for dry weight and height are similar and indicate that the most sensitive plant species are likely to experience both a reduction in dry weight and height. The dry weight and height SSDs rely on data from the vegetative vigor studies only. Seedling emergence data were not included because plants generally exhibited much lower sensitivity to pre-emergence exposure in the seedling emergence studies compared to the post-emergence exposure in the vegetative vigor studies.

The distribution of IC_{25} in the dry weight and height SSDs indicate greater sensitivity in dicot species compared to monocot species consistent with the difference observed in the most sensitive endpoints. Dry weight and height endpoints for the monocots oat (*Avena sativa*) and ryegrass (*Lolium perenne*) were excluded from the SSD because they are non-definitive (IC_{25}>0.18 or >0.37 lbs ae/A) but present further evidence of lower sensitivity in monocots. Although there is a visual difference in sensitivity within the distribution, EPA used the HC_{05} as the toxicity threshold for population-level effects in both monocot and dicot species given that few monocot species (*i.e.,* 2) are captured in the SSD. The HC_{25} was also considered to represent an adverse effect in all plant communities regardless of the species composition within the community; however, the relative sensitivity of dicots and monocots as well as

woody species were qualitative considerations in assessing the extent of effects to listed species that rely on diverse plant communities. EPA initially considered including data for the racemic glufosinate ammonium TEP in the SSD. These data demonstrate a similar pattern of increased sensitivity in the dicot species compared to monocots; however, effects on dry weight are observed at levels >3x lower than the L-glufosinate TEP in the same monocot and dicot species after normalizing for L-isomer acid equivalents. The difference in toxicity suggests the racemic glufosinate TEP may overestimate effects in terrestrial plants that could result from the glufosinate-P products included in this registration and these data were thus excluded from the SSD.

The effects analysis for terrestrial species individuals, populations, and communities are summarized in **Table 55**. Detailed results for each PAT and PWC scenario are provided in **Appendix F**. At least one scenario for each labeled use result in EECs in upland and semi-aquatic environments that exceed the toxicity threshold for terrestrial and semi-aquatic plant individuals and populations. Based on the EECs, upland and semi-aquatic plants located in habitat off-site in the path of runoff and/or spray drift are expected to exhibit varying degrees of stunted growth and minimal to severe phytotoxic symptoms. Non-target plant species growing at the application site are also likely to experience a significant reduction in survival. Adverse direct effects to individuals of listed plant species and their populations are, therefore, expected for all labeled glufosinate-P uses, regardless of the whether the species occurs in upland or semi-aquatic habitat. Furthermore, adverse effects are also likely for listed species that have an obligate relationship with upland and semi-aquatic plants based on likely effects in plant populations.

Effects on growth are anticipated in upwards of 99% of plant species depending on the scenario with a majority of scenarios expected to affect at least 25% of plant species and 50% of plant species affected by at least one scenario for each labeled use pattern. Consequently, the labeled uses of glufosinate-P are likely to adversely affect plant communities. Glufosinate-P is, however, not likely to affect all plants within a community equally. In addition to inter-individual variability in sensitivity, the distribution of dry weight and height IC_{25} in the SSDs indicate greater sensitivity in dicot species compared to monocot species. While it is likely that sensitive monocot species are affected at lower concentrations, scenarios for which EECs exceed the IC_{25} for 50% or more plant species (*i.e.,* the HC_{50}) are more likely to affect a wider range of monocots within the plant community. Furthermore, as discussed in **Section 2.5.2**, woody shrub and tree species are expected to be more resilient to exposure compared to herbaceous plants with affects likely limited to direct exposure at use sites and primarily on saplings and new growth. The differences in sensitivity suggest that effects to listed species that have a generalist relationship with upland and/or semi-aquatic plants for habitat or forage will depend on the composition of the plant community. Species that rely on diverse plant communities that include herbaceous and woody species are likely to be more resilient to the effects of glufosinate-P exposure on diet or habitat compared to species that rely on communities of herbaceous plants.

Semi-aquatic plants may be present in a variety of habitats including wetlands, riparian forests, ponds, creeks/streams, and near shore habitat in deeper waterbodies, which will vary the extent of exposure from runoff and spray drift. The type of habitat is, therefore, considered in determining the extent of direct effects to semi-aquatic plant individuals, populations, and communities. The effects analysis for semi-aquatic plants reported in **Table 3.23** is based on exposure in wetlands and indicates impacts to semi-aquatic plant individuals, populations, and communities are anticipated in wetlands with similar characteristics to the WPEZ model (*i.e.,* depression wetland). EPA does not have a model to evaluate effects to semi-aquatic plants in other types of low-volume waterbodies; therefore, the effects analysis for semi-aquatic plants in wetlands is used as an initial measure of potential effects in low-volume waterbodies. Since the exposure to semi-aquatic plant communities in the WPEZ are within 3x of the toxicity threshold (except for one scenario which is driven by high erosion), increased dilution in waterbodies that are larger than the WPEZ and/or have moderate to swift flow rate are likely to reduce the concentration in the pesticide load such that impacts to semi-aquatic plant communities are not likely. However, low-volume waterbodies of similar or smaller size to the WPEZ and with low or no-flow are likely to experience effects to semi-aquatic plant communities, which include riparian forests and shallow water habitat near the shoreline of medium- and large-volume waterbodies. EPA utilized information from Services' documents to distinguish between the two groups of low-volume waterbodies for listed semi-aquatic plants and listed species that rely on semi-aquatic plants for PPHD.

Table 55. Effects analysis for terrestrial and semi-aquatic plant species at each level of biological organization.

Level of Biological Organization →			Individual		Population		Community	
Habitat	**Monocot/Dicot**	**Peak 1-in-10-yr EEC (lbs ae/A)**	**Exposure to Effects Ratio (EEC/Toxicity Endpoint)[2]**	**Use Exceedances**	**Magnitude of Effect (EEC/Toxicity Endpoint)[3]**	**Use Exceedances**	**Exposure to Effects Ratio (EEC/Toxicity Endpoint)[4]**	**Use Exceedances**
Upland	Monocot	0.01 – 0.304	0.25 – **3.57**	GMO: All Uses Non-GMO: All Uses Fallow Fields	0.28 – **3.93**	GMO: All Uses Non-GMO: All Uses Fallow Fields	0.20 – **2.83**	GMO: All Uses Non-GMO: All Uses Fallow Fields
	Dicot[1]		0.50 – **7.13**					
Semi-Aquatic	Monocot	0.0121 – 0.415	0.26 – **6.57**	GMO: All Uses Non-GMO: All Uses Fallow Fields	0.29 – **7.24**	GMO: All Uses Non-GMO: All Uses Fallow Fields	0.21– **5.2**	GMO: All Uses Non-GMO: All Uses Fallow Fields
	Dicot[1]		0.53 – **13.1**					

EEC=estimated environmental concentration; GMO=genetically modified organism

Bolded values exceed the risk to terrestrial plant level of concern (LOC) of 1.0.

[1]Individual and population magnitude of effect for upland and semi-aquatic dicot species is used as a surrogate for lichens, ferns and allies, conifers, and cycads that occupy these habitats since toxicity data specific to non-flowering plant species are not available and the dicot endpoints are the most protective.

[2] Individual magnitude of effect is based on the most sensitive monocot NOAEL (0.046 lbs ae/A in onion) and dicot NOAEL (0.023 lbs ae/A in cucumber).

[3] Population effect analysis is based on the HC_{05} of 0.0417 lbs ae/A estimated from a plant species sensitivity distribution. The HC_{05} is used to assess adverse population effects in all plant species.

[4] Community effect analysis is based on the HC_{25} of 0.058 lbs ae/A estimated from a plant species sensitivity distribution.

Aquatic Plants

Aquatic plant toxicity data for glufosinate-P are available for one vascular species and four non-vascular species (**Section 6.1**). **Table 56** below summarizes the exposure models and endpoints used to evaluate effects to aquatic plant species populations and communities that inform the magnitude of effect analysis for the NLAA/LAA determination and the predictions of potential likelihood of future jeopardy.

Table 56. Description of Toxicity Endpoints and Exposure Models Used in Evaluating the Effects to Aquatic Plants.

Taxon	Exposure Models	Endpoints for Each Level of Biological Organization	
		Mortality	Growth/Reproduction
Aquatic Plants – Non-vascular	On/Off-Site: PAT v. 2.7 and PWC v. 2.001 Wetlands - Peak WPEZ EEC Low-Volume Waterbody (Bins 2 and 5) – Edge of Field Peak 1-in-10-year EECs Medium/Large-Volume (Bins 3, 4, 6, and 7) – Standard Farm Pond 1-in-10-year 1-day average	Not applicable	Population: IC_{50} = 0.026 mg ae/L to assess blue-green algae. IC_{50} = 2.1 mg ae/L to assess population-level effects to other species. Community: Considered all reported non-vascular aquatic plant endpoints to assess community level impacts to other non-vascular aquatic plants.
Aquatic Plants - vascular	Effects to aquatic vascular plants are not likely based on low risk identified in the generic taxon listed species assessment.		

MATC=maximum acceptable toxic concentration representing the geometric mean of the no-observed adverse effect concentration (NOAEC) and the lowest observed adverse effect concentration (LOAEC). HC_x = Hazard Concentration; PAT = Plant Assessment Tool; WPEZ= Wetland Plant Exposure Zone; TPEZ = Terrestrial Plant Exposure Zone; EEC = Estimated Environmental concentration; ae= acid equivalents. PWC = Pesticide in Water Calculator

There are currently no federally listed aquatic non-vascular species and the labeled uses of glufosinate-P are not likely to affect vascular aquatic plants; therefore, the effects analysis for aquatic plants focuses on population and community level effects in non-vascular species to evaluate obligate and generalist relationships, respectively, with listed species. Of the aquatic non-vascular species tested, blue-green algae exhibited orders of magnitude greater sensitivity to glufosinate-P compared to the other species (**Section 2.5.2**). As a result, different population-level thresholds were selected when evaluating adverse effects to blue-green algae (*i.e.,* the blue-green algae IC_{50}) compared to the other aquatic non-vascular species (*i.e.*, the most sensitive IC_{50} of the other three species). For community level effects, EPA considered the toxicity data across the four species collectively, relying on a qualitative analysis of the data rather than developing an SSD given the few numbers of studies available.

The effects analysis for aquatic plant species individuals, populations, and communities are summarized in **Table 57**. Detailed results for each PAT and PWC scenario are provided in **Appendix E**. Adverse effects to aquatic non-vascular plant populations are expected in all waterbodies; however, the concern for aquatic non-vascular plants is driven by effects in blue-green algae alone. All glufosinate-P labeled uses are expected to affect blue-green algae populations in wetlands and low-volume waterbodies, while the use on GMO corn is the only use expected to affect blue-green algae in medium or larger volume waterbodies. Adverse effects are not anticipated for populations of other non-vascular species such as green algae and diatoms given that toxicity in these species is observed at concentrations more than an order of magnitude above the EECs in all waterbodies. Aquatic vascular plant communities are expected to consist of a diverse range of species which may or may not include blue-green algae. A reduction in the biomass of blue green algae because of glufosinate-P exposure will have a minor effect on some plant communities; however, the labeled uses of glufosinate-P not likely to impact the functional integrity of the community, given the comparative lack of sensitivity in other phyla.

Table 57. Effects analysis for non-vascular aquatic plant species at each level of biological organization.

Level of Biological Organization →			Population		Community	
Habitat	**Non-Vascular Species**	**1-in-10-yr EEC (µg ae/L)[1]**	**Exposure to Effects Ratio (EEC/Toxicity Endpoint)[2]**	**Use Exceedances**	**Exposure to Effects Ratio (EEC/Toxicity Endpoint)[2]**	**Use Exceedances**
Wetland	Blue-green algae	6.36-167	0.24-**6.42**	GMO: All Uses Non-GMO: All Uses Fallow Fields	Community level impacts are not anticipated for aquatic non-vascular plants. Blue-green algae is the only species expected to be affected by the labeled uses of glufosinate-P with the other species exhibiting effects only at concentrations more than an order of magnitude above the EECs in all waterbodies.	
	Other Non-vascular Species		<0.01-0.08	None		
Low-volume	Blue-green algae	12.8-135	0.49-**5.0**	GMO: All Uses Non-GMO: All Uses Fallow Fields		
	Other Non-vascular Species		0.01-0.06	None		
Medium to Large Volume	Blue green algae	1.26-28.3	0.11-**1.09**	GMO: Corn		
	Other Non-vascular Species		<0.01-0.01	None		

EEC=estimated environmental concentration; GMO=genetically modified organism

[1] Different 1-in-10-year EECs were selected to compare against the toxicity endpoints based on the waterbody. Exposure in wetlands is based on the peak 1-in-10-year WPEZ EEC. Exposure in low-volume waterbodies is based on the peak edge of field EECs. Exposure in medium to large volume waterbodies is based on the 1-day mean farm pond EECs.

[2] The endpoints relied on for population and community level effects analysis are reported in **Table 56**.

Most of the listed species with a relationship to aquatic non-vascular plants for habitat or diet rely on phyla other than blue-green algae. The habitat requirements for several aquatic animal species mention blue-green algae (*i.e.,* algal mats) as a component; however, there are no reported obligate relationships with blue-green algae among currently listed species suggesting that these species have a generalist relationship with non-vascular aquatic plant communities. Since there are no obligate relationships with blue-green algae, and effects to the populations of other phyla and to non-vascular aquatic plant communities are not likely, the uses of glufosinate-P are not expected to affect obligate or generalist relationships with aquatic non-vascular plants. Since there are no obligate relationships with blue-green algae, and effects to the populations of other phyla and to non-vascular aquatic plant communities are not likely, the labeled uses of glufosinate-P are not expected to affect obligate or generalist relationships with aquatic non-vascular plants.

PPHD Effects

Listed plants may be affected by labeled glufosinate-P uses through impacts to their biotic pollinator or dispersal mechanisms or impacts to the species' habitat. Listed plant species have generalist relationships with terrestrial invertebrates (bees and non-bees), mammals, and birds for pollination and dispersal. Several listed plant species also have reported obligate relationships with terrestrial plants, fungi, birds, bees, and non-bee terrestrial invertebrates. Although listed plants likely rely to some extent on other plants within their community to maintain habitat quality (*e.g.*, temperature regulation), PPHD relationships with other terrestrial plants are not well defined for most plant species. Consequently, EPA assumed that a plant species did not rely on other terrestrial plants unless an obligate relationship is specified.

Based on the taxa-based screening-level assessment, the uses for glufosinate-P are expected to have a discernable effect on relationships with other upland terrestrial and semi-aquatic plants, terrestrial invertebrates (bees and non-bees), and mammals. Based on the taxa-based screening-level assessment, the labeled uses for glufosinate-P are expected to have a discernable effect on relationships with other upland terrestrial and semi-aquatic plants, terrestrial invertebrates (bees and non-bees), and mammals. The uses of glufosinate-P ammonium are further likely to adversely affect listed plant species with an obligate relationship to terrestrial upland plants and semi-aquatic plants at both at the individual and population level based on likely population effects in these taxa (**Section 8.3.8.1**). The labeled uses of glufosinate-P ammonium are further likely to adversely affect listed plant species with an obligate relationship to terrestrial upland plants and semi-aquatic plants at both at the individual and population level based on likely population effects in these taxa (**Section 8.3.8.1**). Listed plants with generalist or obligate relationship with bees for pollination and/or dispersal are also likely to experience adverse effects on reproduction. Although the effects analysis for terrestrial invertebrates (**Section 8.3.7.1**) indicates adverse effects are likely in bee populations, these adverse effects are limited to bees that forage at the treated use-site, not all uses sites will be treated at the same time, a species' bee pollinators will not forage exclusively at treated use site, and most listed plants will not establish in large numbers at the use sites. Consequently, adverse effects to bee species are expected to affect reproduction in individual

plants that rely on them for pollinator/dispersal, but it is not expected to manifest in a population-level effect in listed plant species. Adverse PPHD effects are not likely for generalist relationships with non-bee terrestrial invertebrates (**Section 8.3.7.1**) and mammals (**Section 8.3.4.1**) based on the low likelihood of community level effects in these taxa.

Effect Determinations and Predictions of Likelihood of Future Jeopardy

EPA considered a total of 938 listed plant species in this listed species assessment. An NE determination was made for 533 species, NLAA determination for 175 species, and LAA determination for 230 species. Of the 230 species with LAA determinations, EPA initially predicted that the labeled glufosinate-P uses do not have a potential likelihood of future jeopardy for 195 plant species and predicted there is a potential likelihood of future jeopardy for 35 plant species. The rationale for the effects determinations and J prediction is summarized in **Table 58** and discussed in more detail for each species in **Appendix M**.

Table 58. Species effects determination and prediction of the potential likelihood of future jeopardy summary for listed plant species.

Effects Determination	Predictions of Likelihood of Future Jeopardy	Number of species	Rationale for the Species Determinations and J Predictions
NE	N/A	533	<1% overlap with any of the UDLs when considering likelihood of an effect to the species **OR** species found in Guam or American Samoa which is not in the action area for this active ingredient.
NLAA	N/A	175	<1% overlap with any of the UDLs when considering likelihood of adverse direct and PPHD effects to the individual **OR** >1% overlap with the Other Grain, Vegetable and Ground Fruit UDL only but the Census of Agriculture tool indicates overlap with canola and sweet corn, respectively, is <1%.
LAA	Not Likely J	195	While there is potential for direct and, for several plants, PPHD effects, it is not likely to result in a species-level impact because 1) overlap of the exposure area (considering direct and PPHD population-level effects) with the species range is low (<5%) for any individual UDL; **OR** 2) >5% overlap with the Other Grain, Vegetable and Ground Fruit UDL only but the Census of Agriculture tool indicates overlap with canola and sweet corn, respectively, is <5%; **OR** 3) >5% overlap after considering use site refinements but the species is either a woody plant or tree which are likely to be more resilient to exposure limiting the number of individuals impacted; OR magnitude of effect is high but overlap is <10% and species has low vulnerability to all stressors suggesting that the adverse effects are not likely to jeopardize the species existence.

Effects Determination	Predictions of Likelihood of Future Jeopardy	Number of species	Rationale for the Species Determinations and J Predictions
LAA	Likelihood of J	35	Species-level impacts are likely because direct effects to the listed plant species are likely, the exposure area overlap with species range considering direct and PPHD population-level effects is medium to high (>5%) for any individual UDL for species with medium to high vulnerability, and >10% for species with low vulnerability, and the species is an herbaceous plant/shrub.

J=jeopardy; N/A= not applicable; NE=no effect; NLAA=not likely to adversely affect; LAA=likely to adversely affect; PPHD= prey, pollination, habitat, and dispersal; UDL=use data layer

The listed plant species for which EPA predicted that the labeled uses of glufosinate-P have a potential likelihood of future jeopardy are summarized in **Table 59** below. All species occur in upland and/or semi-aquatic habitat and at least one UDL overlaps with >5% of the species range after considering use site refinements. Direct effects to these listed plants, whether from direct exposure to species that can establish at use sites, off-site exposure from runoff and spray drift, or a combination, are the main contributors to the predicted species-level impacts from the labeled uses of glufosinate-P. Only one species, the Spring Creek bladderpod (*Lesquerella perforata*), is likely to establish on agricultural fields where glufosinate-P is labeled for use. Listed plant species that rely on bees for pollination and/or dispersal are also likely to experience some effects to reproductive success; however, the direct effects to the plant species are likely to have a much larger impact on the overall health of the species' population.

Table 59. Listed plant species with predicted potential likelihood of future jeopardy.

Entity ID	Common Name (Scientific Name)
513	Star cactus (*Astrophytum asterias*)
568	Spring Creek bladderpod (*Lesquerella perforata*)
620	Northern wild monkshood (*Aconitum noveboracense*)
624	South Texas ambrosia (*Ambrosia cheiranthifolia*)
636	Mead's milkweed (*Asclepias meadii*)
642	Jesup's milk-vetch (*Astragalus robbinsii var. jesupii*)
651	Texas poppy-mallow (*Callirhoe scabriuscula*)
655	Small-anthered bittercress (*Cardamine micranthera*)
734	Dwarf-flowered heartleaf (*Hexastylis nanifora*)
739	Slender rush-pea (*Hoffmannseggia tenella*)
750	Lyrate bladderpod (*Lesquerella lyrata*)
763	Walker's manioc (*Manihot walkerae*)
819	Green pitcher-plant (*Sarracenia oreophila*)
823	Northeastern bulrush (*Scirpus ancistrochaetus*)
835	Short's goldenrod (*Solidago shortii*)
852	Cooley's meadowrue (*Thalictrum cooleyi*)
859	Solano grass (*Tuctoria mucronata*)
891	Decurrent false aster (*Boltonia decurrens*)

Entity ID	Common Name (Scientific Name)
930	Clay-loving wild buckwheat (*Eriogonum pelinophilum*)
935	Minnesota dwarf trout lily (*Erythronium proullans*)
945	Schweinitz's sunflower (*Helianthus schweinitzii*)
946	Swamp pink (*Helonias bullata*)
957	Prairie bush-clover (*Lespedeza leptostachya*)
967	Rough-leaved loosestrife (*Lysimachia asperulaefolia*)
976	Canby's dropwort (*Oxypolis canbyi*)
977	Fassett's locoweed (*Oxytropis campestris var. chartacea*)
984	Eastern prairie fringed orchid (*Plantanthera leucophaea*)
991	Harperella (*Ptilmnium nodosum*)
1059	Lakeside daisy (*Hymenoxys herbacea*)
1077	Texas ayenia (*Ayenia limitaris*)
1080	Western prairie fringed orchid (*Platanthera praeclara*)
1150	Leedy's roseroot (*Rhodiola integrifolia ssp. Leedyi*)
1189	Golden sedge (*Carex lutea*)
1710	Fleshy-fruit gladecress (*Leavenworthia crassa*)
1881	Whorled sunflower (*Helianthus verticillatus*)

8.5 Final Effects Determinations and Predictions of Potential Likelihood of Future Adverse Modification for Designated Critical Habitat

This section presents the rationale supporting the glufosinate-P final effects determinations and predictions of the potential likelihood of future adverse modification made for the 826 critical habitats designated as final as of February 16, 2022[43]. Since the same considerations apply for all species with CH, the critical habitat determinations and predictions of the potential likelihood of future adverse modification for each taxon are discussed collectively.

One fish species with designated CH, the Snail darter, was delisted due to recovery after February 2022 and thus did not receive a determination. An NE determination was made for 476 CH, NLAA determination for 152 CH, and LAA determination for 197 CH. Of the 197 critical habitats with LAA determinations, EPA predicts that the labeled glufosinate-P uses do not present a potential likelihood of future adverse modification (*i.e.,* LAA- Not Likely AM) for 159 CH and predicts the potential likelihood of adverse modification (*i.e.,* LAA-Likely AM) for 38 CH. The rationale for each effects determination and prediction of the potential likelihood of future adverse modification is summarized in **Table 60** and discussed in more detail in **Appendix N**. The species with CH that are predicted to have a potential likelihood of future adverse modification are listed in **Table 61**.

[43] This count of endangered and threatened species reflects separate species in addition to listed distinct population segments (DPS) or evolutionarily significant units (ESUs) as of 2022.

Table 60. Effects determination and predictions of potential likelihood of future adverse modification of designated critical habitat.

Effects Determination	Predictions of Likelihood of Future Adverse Modification	Number of Critical Habitats	Characteristics of Species for Each Determination
NE	N/A	476	<1% overlap with any of the UDLs when considering the exposure area in which an effect to the CH is likely **OR** the species occurs in Guam, the Mariana Islands, or American Samoa which is not in the action area for this active ingredient.
NLAA	N/A	152	The critical habitat does not include PBFs and SMCs that are likely to be affected by the uses **OR** adverse effects to the critical habitat PBFs and SMCs are likely but the CH has a <1% overlap with any of the UDLs or >1% overlap with the Other Grain, Vegetable and Ground Fruit UDL only but the CoA tool indicates overlap with canola and sweet corn, respectively, is <1%. The critical habitat does not include PBFs and SMCs that are likely to be affected by the labeled uses **OR** adverse effects to the critical habitat PBFs and SMCs are likely but the CH has a <1% overlap with any of the UDLs or >1% overlap with the Other Grain, Vegetable and Ground Fruit UDL only but the CoA tool indicates overlap with canola and sweet corn, respectively, is <1%.
LAA	Not Likely AM	159	While adverse effects to the PBFs with the CH are likely, it is not likely to result in adverse modification because overlap of the exposure area with the critical habitat is low (<5%) for any individual UDL or >5% overlap with the Other Grain, Vegetable and Ground Fruit UDL only but the CoA tool indicates overlap with canola and sweet corn, respectively, is <5% **OR** overlap is >5% but the only PBF affected is water quality and there is no mention of upland or semi-aquatic plant communities as an essential PBF.
LAA	Likelihood of AM	38	Adverse modification of the species' critical habitat is likely because: Exposure area overlap with CH is medium to high (>5%) for any individual UDL **AND** adverse effects are likely to PBFs or SMCs related to habitat quality (using direct effects as a surrogate) and/or the health of plant communities in the habitat.

LAA=likely to adversely affect; N/A=not applicable; NE=no effect; NLAA=not likely to adversely affect; PBF = physical and biological factor; SMC = special management considerations; UDL = use data layer; CoA = Census of Agriculture

Table 61. Listed species with designated critical Habitat (CH) that have a predicted potential likelihood of future adverse modification.

Entity ID	Common Name (Scientific Name)
58	Buena Vista Lake ornate shrew (*Sorex ornatus relictus*)

Entity ID	Common Name (Scientific Name)
67	Whooping crane (*Grus americana*)
4296	Streaked Horned lark (*Eremophila alpestris strigata*)
170	Plymouth Redbelly turtle (*Pseudemys rubriventris bangsi*)
212	Maryland darter (*Etheostoma sellare*)
239	Slackwater darter (*Etheostoma boschungi*)
311	Topeka shiner (*Notropis topeka*)
2514, 8241	Chinook salmon (*Oncorhynchus tshawytscha*)
3069	Trispot darter (*Etheostoma trisella*)
3525	Rush darter (*Etheostoma phytophilum*)
3596	Sharpnose shiner (*Notropis oxyrhynchus*)
4112, 9432	Steelhead (*Oncorhynchus mykiss*)
7332	Spring pygmy sunfish (*Elassoma alabamae*)
7670	Smalleye shiner (*Notropis buccula*)
9378	Llanero Coqui (*Eleutherodactylus juanariveroi*)
9943	Reticulated flatwoods salamander (*Ambystoma bishopi*)
490	Conservancy fairy shrimp (*Branchinecta conservatio*)
10757	Slenderclaw crayfish (*Cambarus cracens*)
445	Hine's emerald dragonfly (*Somatochlora hineana*)
450	Fender's blue butterfly (*Icaricia icarioides fenderi*)
3412	Dakota skipper (*Hesperia dacotae*)
4910	Salt Creek Tiger beetle (*Cicindela nevadica lincolniana*)
5067	Bartram's hairstreak butterfly (*Strymon acis bartrami*)
7495	Taylor's Checkerspot (*Euphydryas editha taylori*)
10147	Poweshiek skipperling (*Oarisma poweshiek*)
527	Hoover's spurge (*Chamaesyce hooveri*)
558	Pecos sunflower (*Helianthus paradoxus*)
580	Colusa grass (*Neostapfia colusana*)
584	Lau 'ehu (*Panicum nihauense*)
859	Solano grass (*Tuctoria mucronata*)
870	Texas wild rice (*Zizania texana*)
1069	No common name (*Schiedea spergulina var. leiopoda*)
1881	Whorled sunflower (*Helianthus verticillatus*)
4420	Florida Brickell-bush (*Brickellia mosieri*)
7167	Kentucky glade cress (*Leavenworthia exigua laciniata*)
7206	Carter's small-flowered flax (*Linum carteri carteri*)

8.6 Revised Aerial Spray Drift Analysis

Since the publication of the draft ecological risk assessment, EPA re-examined some of the input parameters for AgDRIFT™ by considering comments made by NAAA as well as other sources of information and developed updated recommendations on the use of Tier III aerial modeling in AgDRIFT™ with input parameters that reflect current, common aerial application

practices.[44] This section describes updates to the Tier III aerial modeling and the effects on the estimated offsite transport distances for population/community level effects to terrestrial plants. The analysis only considered effects to terrestrial plants, as they were the only taxa for which population- or community-level impacts from spray drift were determined to be likely off-field.

Table 62 summarizes the previously modeled and updated AgDRIFT™ parameters. EPA selected a medium spray droplet size distribution based on the label instructions and standard aerial application practices. The rationale for the other updated input parameters can be found in the mitigation support document. **Table 63** provides the spray drift distances to no effect for population- and community-level effects to terrestrial plants based on aerial and ground applications. The updated aerial spray drift analysis reduced the off-site distance to population-level effects from 46 to 36 ft and the distance to community-level effects from 30 to 13 ft. Since the revised spray drift analysis still identified effects to plants within 30 m of the treated field, this analysis did not alter the overlap analysis conclusions or the predicted potential likelihood of future J/AM identified in the preceding sections.

Table 62. Comparison between previous and current recommended input parameters in Tier III AgDRIFT™.

Parameter Group and Parameter		Previous Default Input Parameter	Current Recommended Default Input Parameter
Aircraft > Aircraft	Aircraft Type	Air Tractor AT-401	Air Tractor AT-802A
Aircraft > Nozzles and Droplet Size Distribution (DSD)	Drop Size Distribution	Fine to Medium	Medium*
	Generate Regular Distribution	Extent:76.32% Nozzle Spacing: 0.912 ft	Extent**: 75% Nozzle Spacing: 1 ft
Aircraft	Boom Height	10 ft.	10 ft.
	Flight Lines	20	15
Swath	Swath Width Definition	Fixed Width	Fixed Width
	Swath Width	60	80
	Swath Width Displacement as Fraction of Swath Width	0.3722	0.5
	Half Boom Effect	No entry	No entry
Atmospheric Stability	Stability	Night/Overcast Cloud Cover	Day/Slight Solar Insolation
Advanced Settings	Height for Wind Speed Measurement	6.56 ft	10 ft
Terrain	Surface Roughness	0.0246 ft	0.0246 ft

* Droplet Size Distribution (DSD) selected based on label instructions. For L-glufosinate, the labeled DSD is medium or coarser. The EPA used a medium DSD in the updated modeling to generate a conservative estimate of the spray drift distances based on the smallest allowable droplet size.

[44] Described in *Ecological Mitigation Support Document to Support Endangered Species Strategies Version 1.0* (also referred to as the "mitigation support document").

Parameter Group and Parameter	Previous Default Input Parameter	Current Recommended Default Input Parameter

** Extent defines the length of the spray boom relative to the airplane wingspan

Table 63. Spray Drift Distances Based on Highest Application Rate Used to Establish the Exposure Area for Evaluating Adverse Effects to Listed Species Populations and Communities of Plants

Taxa	Population/ Community Adverse Effects Endpoint	Use/Use Site	Highest App Rate[1]	Fraction of Applied to No Effect	Application Method	Boom Height	Distance from the Field Edge to No Effect (ft)[3]	
							2024 BE	Revised Aerial Inputs
Terrestrial Plants	HC_{05} = 0.0417 lbs ae/A (Population)	GMO/Non-GMO-Soybean, Field Corn, Canola, Cotton	0.359	0.116	Ground	Low	3	3
						High	7	7
					Aerial	NA	46	36
	HC_{25} = 0.058 lbs ae/A (Community)		0.359	0.162	Ground	Low	3	3
						High	3	3
					Aerial	NA	30	13

BE= Biological Evaluation; GMO=Genetically modified Organism; HC_{xx} = XX centile hazard concentration; NA= not applicable.

[1] Spray drift distance for terrestrial plants is based on the maximum single application rate which is reported in this column.

[2] Calculated as the ratio of the associated adverse effects endpoint to the highest app rate.

[3] Distance from field edge at which exposure no longer exceeds the endpoint. The distance was estimated assuming ground application with low (20 inches above the ground) or high (50 inches above the ground) boom height and ASAE fine to medium/coarse droplet size distribution and aerial application with nozzles that produce ASAE medium droplet size distribution with the updated Tier 3 input parameter described in **Table 62**.

8.7 Mitigations to Avoid the Predicted Potential Likelihood of future Jeopardy/Adverse Modification and Reduce Incidental Take of Listed Species

The effects determination and Biological Evaluation for the labeled uses of glufosinate-P makes LAA determinations for 637 species and 197 critical habitats. For these species, they are either listed plants that are directly affected or listed animals that rely upon plants for forage/prey and/or habitat. For the 197 CHs, EPA based the LAA determinations on effects on essential principle biological features related to habitat quality for the listed species, plants, forage and/or habitat, and water quality. For the LAA species, EPA predicts a potential likelihood of future jeopardy for 60 species and for the CH, EPA predicts potential likelihood of future adverse modification of 38 CHs from the use of glufosinate-P. Predictions of the potential likelihood of future J/AM are primarily for listed plants, listed animal species that are highly dependent on plants for forage and/or habitat, and CHs with essential PBFs related to plants. All listed species and CH for which EPA predicts to have a potential likelihood of future J/AM have medium to high overlap with at least one agricultural UDL within the likely exposure area,

a medium to high magnitude of effect, and most of the species are classified as having medium to high vulnerability.

EPA has developed a strategy discussed in the document entitled *Herbicide Strategy to Reduce Exposure of Federally Listed Endangered and Threatened Species and Designated Critical Habitats from the Use of Conventional Agricultural Herbicides to Reduce Exposure of Federally Listed Endangered and Threatened Species and Designated Critical Habitats from the Use of Conventional Agricultural Herbicides*[45] (referred to as the Herbicide Strategy). The Herbicide Strategy focuses on identifying early protections for listed species and designated critical habitat from the use of conventional herbicides with agricultural uses in the CONUS to reduce the potential for population-level impacts on listed species. The mitigations to address predictions of potential likelihood of future J/AM were informed by the strategy document, and reflect measures that can be readily implemented by growers and are structured to provide flexibility for growers to choose mitigation measures that work best for their situation. For additional information on the mitigation measures to reduce spray drift and/or runoff/erosion from treatment sites, EPA refers the reader to the document entitled *Ecological Mitigation Support Document to Support Endangered Species Strategies* (Version 1; https://www.regulations.gov/document/EPA-HQ-OPP-2023-0365-1133) and the document *Application of EPA's Runoff and Erosion and Spray Drift Mitigations through Scenarios that Represent Crop Production Systems in Support of Endangered Species Strategies* (https://www.regulations.gov/document/EPA-HQ-OPP-2023-0365-1139). The measures discussed in these documents and the mitigation discussed below include geographically explicit measures as well as more broadly applied restrictions that ensure greater consistency across mitigation measures. The mitigations were identified as necessary to minimize exposure and the likelihood of future J/AM and to minimize take from the final registration of glufosinate-P.

Based on the effects determination described in **Section 8.4**, glufosinate-P is predicted to have a potential likelihood of future J/AM without mitigation. The recently finalized Herbicide Strategy informed the mitigations identified to address the predicted potential likelihood of future J/AM. Without mitigation, exposure at the use site and from off-site transport are both likely to contribute to incidental take and adverse effects to plant individuals and CH. While many of the animal species with LAA determinations may occupy, move through, or forage at use sites, it is unlikely that any of the species would regularly use these sites thus limiting the number of individuals affected. Likewise, it is unlikely that most of the plants with LAA determinations will establish at managed agricultural use sites except for the Spring Creek Bladderpod. Consequently, off-site transport from spray drift and runoff are the main drivers of

[45] Herbicide Strategy to Reduce Exposure of Federally Listed Endangered and Threatened Species and Designated Critical Habitats from the Use of Conventional Agricultural Herbicides. Office of Pesticide Programs, Office of Chemical Safety and Pollution Prevention, U.S. Environmental Protection Agency, Washington, DC. August 20, 2024. https://www.regulations.gov/document/EPA-HQ-OPP-2023-0365-1137

exposure for listed species that are predicted to be jeopardized by the final labeled uses; however, mitigation measures are included to avoid the potential likelihood of future J/AM.

The focus of the mitigation measures is on reducing spray drift, runoff, and erosion (which are identified the primary exposure pathways) from off-site transport in terrestrial, wetland, and/or aquatic habitats. Although the Services ultimately determine whether J/AM is likely through the consultation process, EPA believes that the mitigation measures outlined below will be sufficient to avoid J/AM and will streamline the consultation process while putting protections in place in advance of the completion of consultation and the issuance and implementation of any Biological Opinions.

In additional to minimization measures, EPA is also utilizing avoidance measures for listed species which are considered particularly vulnerable. EPA has identified species that are particularly vulnerable based on a review of USFWS and NMFS documents (*e.g.*, 5-yr reviews; BiOps) in which the Services have identified either high or medium vulnerability for species to all relevant stressors and where pesticides may be a potential stressor as well. These species generally have smaller ranges relative to other listed species and the ranges of these species or their designated critical habitat overlap with those of other listed species. Therefore, protections for the vulnerable species would benefit other listed species that are located in the same area. EPA identified additional geographically specific mitigation measures (*i.e.*, pesticide use limitation areas; PULA) for two vulnerable species – Whorled Sunflower and Springcreek Bladderpod. The product labeling directs the user to EPA's Bulletins Live! Two (BLT) website to access these measures through Endangered Species Protection Bulletins.

EPA considered the Herbicide Strategy to inform mitigations to address predictions of J/AM. Similar to the strategy, EPA considered the overall impact of the pesticide referred to as the magnitude of difference (MOD) (*i.e.*, the ratio of estimated environmental concentrations to the population- and community-level toxicity threshold value). EPA uses the MOD for a chemical to determine the extent of mitigation required. EPA identified three mitigation points as the level of mitigation needed to avoid the potential likelihood for future J/AM from runoff and erosion for uses of glufosinate-P given that the MODs are between 1 and 10.

Spray Drift Mitigations

To reduce exposure from the labeled uses of glufosinate-P, EPA is relying on a combination of measures to minimize or avoid exposure. To reduce exposure from spray drift, mitigation measures include spray drift buffers and wind speed restrictions.

Table 68 summarizes spray drift wind-directional spray drift buffer distances to reduce exposure from aerial and ground applications of glufosinate-P. These buffer distances are consistent with the revised aerial spray drift analysis in this assessment (**Section 8.6**) and the final Herbicide Strategy.

Table 68 Aerial and Ground Spray Drift Buffer distances based on Spray Droplet Size Distribution.

Application Method	Droplet Size Distribution (DSD)	Minimum Buffer Distance
Aerial	medium	50 ft
Ground	medium or coarser	10 ft

Wind Speed Restrictions
When the wind speed is between 11-15 miles per hour, the boom length must be 65% or less of the wingspan for fixed wing aircraft and 75% or less of the rotor diameter for helicopters. Otherwise, the boom length must be 75% or less of the wingspan for fixed-wing aircraft and 90% or less of the rotor diameter for helicopters.

The applicator can reduce the width of the spray drift buffers by implementing a variety of mitigations, described below. The following spray drift mitigation language will appear on the pesticide label:

LABEL SPRAY DRIFT MITIGATION LANGUAGE: The following language must be added to label for Bulletins Live! Two.

Endangered Species Requirements - Before using this product, you must obtain any applicable Endangered Species Protection Bulletins (Bulletins) within six months prior to or on the day of application. To obtain Bulletins, go to Bulletins Live! Two (BLT) at https://www.epa.gov/pesticides/bulletins. When using this product, you must follow all directions and restrictions contained in any applicable Bulletin(s) for the area where you are applying the product, including any restrictions on application timing if applicable. It is a violation of Federal law to use this product in a manner inconsistent with its labeling, including this labeling instruction to follow all directions and restrictions contained in any applicable Bulletin(s). For general questions or technical help, call 1-844-447-3813, or email ESPP@epa.gov.

MITIGATION FOR SPRAY DRIFT EXPOSURE
Aerial and Ground Spray Drift Buffer distances based on Spray Droplet Size Distribution.

Application Method	Droplet Size Distribution (DSD)	Minimum Buffer Distance
Aerial	medium	50 ft
Ground	medium or coarser	10 ft

Aerial Wind Speed Restrictions
When the wind speed is between 11-15 miles per hour, the boom length must be 65% or less of the wingspan for fixed wing aircraft and 75% or less of the rotor diameter for helicopters. Otherwise, the boom length must be 75% or less of the wingspan for fixed-wing aircraft and 90% or less of the rotor diameter for helicopters.
The following language needs to be added on the label:

Mandatory Spray Drift Mitigation
For Aerial and Ground Boom Applications:

- Do not apply when wind speeds exceed 15 miles per hour at the application site.

• Select nozzle and pressure that deliver medium or coarser spray droplets as indicated in nozzle manufacturer's catalogues and in accordance with American Society of Agricultural & Biological Engineers standards 572.1 and 641 (ASABE S572 and S641).

- During application, the Sustained Wind Speed, as defined by the National Weather Service (standard averaging period of 2 minutes) must register between 3 and 15 miles per hour.
- Wind speed must be measured at the release height or higher, in an area free from obstructions such as trees, buildings, and farm equipment.

• Do not apply during temperature inversions.

For Aerial Application:

- When applying to crops via aerial application equipment, the spray boom must be mounted on the aircraft to minimize drift caused by wing tip or rotor blade vortices.
- Wind speed and direction must be measured on location using a windsock, an anemometer (including systems to measure wind speed or velocity on an aircraft), or an aircraft smoke system.
- When the wind speed is between 11-15 miles per hour, the boom length must be 65% or less of the wingspan for fixed wing aircraft and 75% or less of the rotor diameter for helicopters. Otherwise, the boom length must be 75% or less of the wingspan for fixed-wing aircraft and 90% or less of the rotor diameter for helicopters.
- When the wind speed is between 11-15 miles per hour, applicators must use a minimum of ¾ swath displacement upwind at the downwind edge of the field. Otherwise, applicators must use a minimum of ½ swath displacement upwind at the downwind edge of the field

• Do not release spray at a height greater than 10 ft above the crop canopy, unless a greater application height is required for pilot safety.

For Ground Boom Application:

• Spray at the appropriate boom height based on nozzle selection and nozzle spacing, but do not exceed a boom height of 24 inches above target pest or crop canopy. Set boom to lowest effective height over the target pest or crop canopy based on equipment manufacturer's directions.

• Wind speed and direction must be measured on location using a windsock or anemometer (including systems to measure wind speed or velocity using application equipment).

Mandatory Spray Drift Buffers
For aerial and ground applications, maintain a downwind buffer between the last spray row and the protection area as follows:

Application Method	Droplet Size Distribution (DSD)	Minimum Buffer Distance
Aerial	medium	50 ft
Ground	medium or coarser	10 ft

• Protection areas include all areas with the following exceptions which can be included in the buffer footage, provided that people are not present within the application exclusion zone during the application, and they will not be contacted by the pesticide, either directly or through drift (see 40 CFR 170.405(a) and 40 CFR 170.505(a)):

- Agricultural fields, including untreated portions of the treated field.
- Roads, paved or gravel surfaces, mowed grassy areas adjacent to field, and areas of bare ground from recent plowing or grading that are contiguous with the treated area.
- Buildings and their perimeters, silos, or other man-made structures with walls and/or roof.
- Areas maintained as a mitigation measure for runoff/erosion or drift control, such as vegetative filter strips (VFS), field borders, hedgerows, Conservation Reserve Program lands (CRP), and other mitigation measures identified by EPA on the mitigation menu.[1]
- Managed wetlands including constructed wetlands on the farm.
- On-farm contained irrigation water resources that are not connected to adjacent water bodies, including on-farm irrigation canals and ditches, water conveyances, managed irrigation/runoff retention basins, and tailwater collection ponds.

[1] *Growers must ensure that pesticide use does not cause degradation of the CRP habitat.*

Aerial Spray Drift Buffer Reduction Options:

- A 20% (*i.e.*, 10-foot) reduction in the required wind-directional buffer distance can be made if the applicator selects a nozzle and pressure that deliver coarse or coarser droplets in accordance with ASABE s572.
- A 35% (i.e., 18-foot) reduction can be made if the applicator selects a nozzle and pressure that delivers coarse droplets and uses an oil emulsion drift reducing adjuvant that constitutes 2.5% of the volume of the finished spray tank mix.
  A reduction in the required wind-directional buffer distance can be made if a windbreak or shelterbelt (*e.g.*, trees or riparian hedgerows) between the application site and non-managed area is present and meets the criteria listed in the **'Windbreak-Shelterbelt Criteria'** section of this label. The reduction is 50% (*i.e.*, 25 feet) if the windbreak or shelterbelt meets the basic windbreak-shelterbelt criteria and is 75% (*i.e.*, 38 feet) if the windbreak or shelterbelt meets the advanced windbreak-shelterbelt criteria.
- The percent reduction in wind-directional buffer distances may be added if you use one droplet size buffer reduction option (coarse or coarse with an oil emulsion

drift reducing adjuvant that constitutes 2.5% of the volume of the finished spray tank mix) and one windbreak-shelterbelt option (basic or advanced). The maximum buffer reduction that can be achieved by a combination of buffer reduction options is 100% (i.e., no drift buffer).

Ground Boom Spray Drift Buffer Reduction Options:
Any of the following options can reduce the ground buffer distance to 0 feet:

- Use of an oil emulsion drift reducing adjuvant that constitutes 2.5% of the volume of the finished spray tank mix.
- Application is made using an over-the-top hooded sprayer, as a layby application, or is made below the crop canopy using drop nozzles.
- Use of a row-middle hooded sprayer.
- If a windbreak or shelterbelt (*e.g.*, trees or riparian hedgerows) between the application site and non-managed area is present and meets the criteria listed in the **'Windbreak-Shelterbelt Criteria'** section of this label.

Windbreak-Shelterbelt Criteria
Both basic and advanced windbreaks or shelterbelts (*e.g.*, trees or riparian hedgerows) between the application site and non-managed area must be present and meet the following criteria for 50% and 75% wind-directional buffer distance reductions, respectively:

- The windbreak or shelterbelt must be downwind between the pesticide application and the non-managed area.
- The windbreak or shelterbelt must run the full length of the treated area with no significant breaks in the vegetation.
- The windbreak or shelterbelt foliage must be sufficiently dense such that the non-managed area is not visible from the upwind side at the time of application.
- The windbreak or shelterbelt must be planted according to local/regional/federal conservation program standards; however, no state or federally listed noxious or invasive trees or shrubs should be planted.
- The windbreak or shelterbelt must be maintained such that their functionality is not compromised.
- For basic windbreaks (50% reduction)
    - The height of the trees in the windbreak or shelterbelt must be at the same height or above the release height of the application.
    - The windbreak must have a minimum of one row of trees and/or shrubs or a 4-foot-wide strip of non-woody vegetation.
    - A semi-permeable manmade structure, curtain, or netting that is raised prior to application can be used instead of a windbreak or shelterbelt. This structure must be downwind between the pesticide application and the non-managed area, cover the entire distance of field adjacent to non-managed area, and at the same height or higher as the release height of the application.

- For advanced windbreak-shelterbelt (75% reduction)
  - The height of the trees in the windbreak or shelterbelt must be at a height that is at least twice as high as the release height of the application.
  - The windbreak or shelterbelt must have a minimum of two or more rows of trees and/or shrubs with a mixture of vegetation types (*e.g.*, trees, shrubs, herbs), or that have 8 or more feet of depth for herbaceous (non-woody) vegetation.
  - A semi-permeable manmade structure, curtain, or netting that is raised prior to application can be used instead of a windbreak or shelterbelt. This structure must be downwind between the pesticide application and the non-managed area, cover the entire distance of field adjacent to non-managed area, and at a height that is at least twice as high as the release height of the application.
- ***SEE "ADDITIONAL SPRAY DRIFT INFORMATION" section below for more details.***

ADDITIONAL SPRAY DRIFT INFORMATION:

This section is intended to provide additional information for applicators to assist in implementing the mandatory spray drift mitigations above. THE APPLICATOR IS RESPONSIBLE FOR AVOIDING OFF-SITE SPRAY DRIFT. Be aware of nearby non-target sites and environmental conditions.

Importance of droplet size

An effective way to reduce spray drift is to apply large droplets. Consider the largest droplets that provide target pest control. While applying larger droplets will reduce spray drift, the potential for drift will be greater if applications are made improperly or under unfavorable environmental conditions.

Controlling Droplet Size – Ground boom

• Volume – Increasing the spray volume so that larger droplets are produced will reduce spray drift. Consider using the highest practical spray volume for the application. If a greater spray volume is needed, consider using a nozzle with a higher flow rate.
• Pressure – Using the lowest spray pressure recommended for the nozzle will produce the target spray volume and droplet size.
• Spray Nozzle – Consider using a spray nozzle that is designed for the intended application, as well as using nozzles designed to reduce drift.

Controlling Droplet Size – Aircraft

• Adjust Nozzles – Applicators should follow nozzle manufacturers' recommendations for setting up nozzles. Generally, to reduce fine droplets, nozzles should be oriented parallel with the airflow in flight.

Release height – Ground Boom

For ground equipment, the boom should remain level with the crop and have minimal bounce. Automated boom height controllers are recommended with large booms to better

maintain optimum nozzle to canopy height. Excessive boom height will increase the potential for spray drift.

Release height – Aircraft
Higher release heights increase the potential for spray drift.

Hooded (or shielded) sprayers
Shielding the boom or individual nozzles can reduce spray drift. Consider using hooded sprayers. Applicators should verify that the shields are not interfering with the uniform deposition of the spray on the target area.

Temperature and humidity
When making applications in hot and dry conditions, consider using larger droplets to reduce effects of evaporation.

Temperature inversions
Drift potential is high during a temperature inversion. Temperature inversions are characterized by increasing temperature with altitude and are common on nights with limited cloud cover and light to no wind. The presence of an inversion can be indicated by ground fog or by the movement of smoke from a ground source or an aircraft smoke generator. Smoke that layers and moves laterally in a concentrated cloud (under low wind conditions) indicates an inversion, while smoke that moves upward and rapidly dissipates indicates good vertical air mixing. Avoid applications during temperature inversions.

Wind
Drift potential generally increases with wind speed.
Applicators need to be familiar with local wind patterns and terrain that could affect spray drift.

Measuring wind speed and wind direction

- Applicators should check and acquire the predicted wind speed and direction for the application site within 12 hours prior to conducting applications to determine the time periods wind speed is likely to fall outside the applicable thresholds.
- Applicators should reassess wind speed and direction at the application site every 15 minutes while applications are in progress.
- Measuring wind speed and direction can be done by:
    - Relying on equipment on the application equipment that measures wind speed (e.g., aerial equipment).
    - Using a tower anemometer with telemetry or handheld anemometer. Users should read user manual on how to calibrate, operate and interpret the output from an anemometer. Ground applicators should stop every 15 minutes to take a reading with a tower anemometer with telemetry or handheld anemometer. Some anemometers may have software that would allow users to view wind measurements in real time while

making an application, and, those cases, applicators would not have to stop to take measurements.

- Using a windsock. Wind can be estimated with a windsock using the strips on a windsock. The applicator should consult the user manual for the windsock on wind speed estimation and direction of wind. Applicators should look at the sock at least every 15 minutes to estimate wind speed and direction. The windsock should be pointed in the opposite direction of the windbreak and the non-managed area.
- Using an aircraft smoke system. Laying down several puffs of smoke along different lines using an aircraft smoke system can provide an accurate view of what the wind speed and direction for the application.
- Checking behind the spray rig at least every 15 minutes to see if the spray has changed direction from when the application started.

Runoff/Erosion Mitigations

To inform the mitigations identified to address runoff/erosion risks, EPA considered the Herbicide Strategy framework. EPA determined the MODs for glufosinate-P placed this pesticide in the low category; therefore, EPA identified that three mitigation points are needed to avoid to avoid the potential likelihood for future J/AM to listed species from runoff and erosion. The three mitigation points determined to be necessary to address effects to listed species is listed on the product labeling and directs the user to the mitigation menu website (https://www.epa.gov/pesticides/mitigation-menu). This menu identifies mitigation measures that can be employed to achieve the three mitigation points necessary to reduce exposure from runoff and erosion through restrictions associated with application parameters, field characteristics, in-field versus adjacent area measures, and systems which capture/control runoff.

The following language will be included on the label to specify the label runoff/erosion mitigation measures required.

LABEL RUNOFF/EROSION MITIGATION LANGUAGE

MANDATORY RUNOFF MITIGATION:

- DO NOT apply Glufosinate-P-Ammonium when soils are saturated or above field capacity.
- DO NOT apply Glufosinate-P-Ammonium during rain.
- You must achieve a minimum of three points for the crop uses listed on this label unless otherwise stipulated belowbelow.

Applicators must access and search Bulletins Live! Two (BLT) at https://www.epa.gov/pesticides/bulletins within six months of the application to determine whether the application site falls within a Pesticide Use Limitation Area (PULA) that has a Bulletin in BLT. If you are located inside a PULA, follow the instructions in the bulletin.

If the application site is located outside a PULA, runoff/erosion mitigation is required for this product unless certain field/application parameters are present at the time of application (i.e., subsurface or tile drains with controlled outlet, perimeter berm systems, irrigation tailwater return systems, spot treatment, etc). Access EPA's Mitigation Menu Website at www.epa.gov/pesticides/mitigation-menu for a full list of field/application parameters to evaluate whether your field is subject to runoff/erosion mitigation.

If the application does not meet the specified field/application parameters, a minimum of three points for the crop uses listed on this label must be achieved. The applicator must choose among the mitigation and/or mitigation relief measures on EPA's Mitigation Menu Website to meet or exceed these points before applying this product. The website includes the full menu of [runoff/erosion mitigation and mitigation relief measures. The following are examples:

- Location in a very low, low, or medium runoff vulnerability county
- Field slope
- Soil incorporation
- Conservation tillage
- Vegetative strips
- Cover crop or continuous ground cover
- Irrigation water management
- Mulching
- Grassed waterway
- Vegetated ditch
- Constructed and natural wetlands
- Water retention systems
- Following recommendations from a runoff/erosion specialist or participating in a qualifying conservation program (see the www.epa.gov/pesticides/mitigation-menu for minimum elements).

To achieve mitigation points for the application, the mitigation and mitigation relief measures must be:

- Employed in accordance with the instructions and descriptions on EPA's Mitigation Menu Website.
- In place during the application unless a different timing (such as before or after application) is specifically provided in the measure's description on EPA's Mitigation Menu Website.

EPA may periodically update the Mitigation Menu Website, for example, by adding new mitigation measures or updating a mitigation measure description.

When tank mixing, the most restrictive of the products' label or bulletin requirements must be followed (e.g., use prohibition, timing restriction, application method restriction, sandy soil application restriction)."

Avoidance Mitigations to Address Vulnerable Species

In some situations, minimization efforts (*i.e*., mitigations to reduce runoff/erosion and spray drift) may not be sufficient and avoidance measures are needed for species which are identified as particularly vulnerable. **Table 69** lists vulnerable species which EPA is predicting potential likelihood of future jeopardy or adverse modification of designated critical habitat for which avoidance measure are necessary. These avoidance measures were informed by the FWS Enlist BiOp (USFWS, 2023). Before using this product, you must obtain any applicable Endangered Species Protection Bulletins (Bulletins) within six months prior to or on the day of application. To obtain Bulletins, go to Bulletins Live! Two (BLT) at https://www.epa.gov/pesticides/bulletins. To avoid exposure to the Spring Creek bladderpod, EPA is prohibiting spray applications in specific areas of Wilson County, TN between September 15 and May 15 (*i.e*., the same mitigations as those used for ENLIST (USFWS, 2023). Consistent with the FWS BiOp conducted for pesticides with similar environmental fate properties and application methods, the EPA is prohibiting applications within 60 m of the Whorled Sunflower designated critical habitat to avoid exposure to the species from agricultural uses.

Table 69. Glufosinate-P jeopardy species that are on the vulnerable species list

Species		Taxon	PULA area	PULA description	Mitigation
Scientific name	**Common name**				
Helianthus verticillatus	Whorled Sunflower	Plant	Critical habitat	Designated critical habitat buffered by 60 m	Do not apply glufosinate-P within the use limitation area
Lesquerella perforata	Spring Creek bladderpod		Species range	HUC12 watersheds covering Spring Creek, Cedar Creek, and Barton's Creek	Do not apply glufosinate-P within the use limitation area between September 15 and May 15.

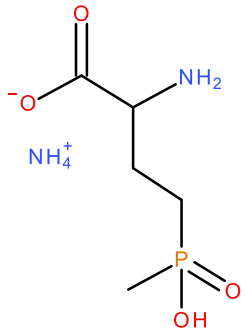
LABEL MITIGATION LANGUAGE: The following language is included on the label for Bulletins Live! Two:

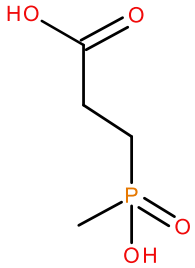
Endangered Species Requirements - Before using this product, you must obtain any applicable Endangered Species Protection Bulletins (Bulletins) within six months prior to or on the day of application. To obtain Bulletins, go to Bulletins Live! Two (BLT) at https://www.epa.gov/pesticides/bulletins. When using this product, you must follow all directions and restrictions contained in any applicable Bulletin(s) for the area where you are applying the product, including any restrictions on application timing if applicable. It is a violation of Federal law to use this product in a manner inconsistent with its labeling, including this labeling instruction to follow all directions and restrictions contained in any applicable Bulletin(s). For general questions or technical help, call 1-844-447-3813, or email ESPP@epa.gov.

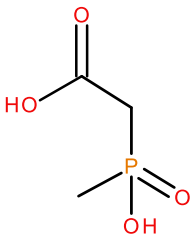
Appendix A. Residues of Concern Knowledgebase Subcommittee (ROCKS) Table

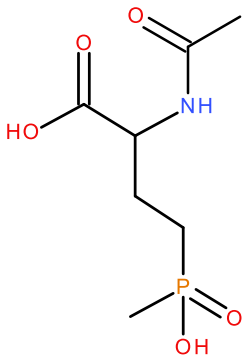
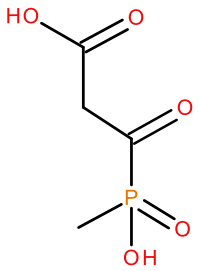
The ROCKS table contains information on the nature and quantity of the degradates formed in the environmental fate studies for glufosinate. The table has been updated to include information from the new hydrolysis, aqueous photolysis, and aerobic soil metabolism studies conducted on L-glufosinate acid and L-glufosinate ammonium salt, denoted by LH and LA, respectively, in the Master Record Identification (MRID) number column. These new data indicate that L-glufosinate is comparably persistent to racemic glufosinate to hydrolysis, photolysis, and aerobic soil metabolism.

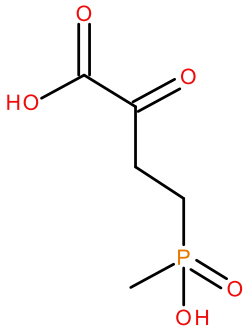
Table A-1. Maximum Amount of Glufosinate and Glufosinate Degradates in Environmental Fate Studies.

Compound	Maximum % of Applied	% of Applied at Study Termination	Study Type[1]	MRID
Glufosinate[1] **CAS No.: 77182-82-2** **Molecular Formula:** **$C_5H_{15}N_2O_4P$** 	Not applicable	98.4% (Day 30)	Hydrolysis (pH 5)	40345656
		100% (Day 30)	Hydrolysis (pH 7)	40345656
		103% (Day 30)	Hydrolysis (pH 9)	40345656
		99.3% (Day 29)	Hydrolysis (pH 4)	51036698[LH]
		98.8% (Day 29)	Hydrolysis (pH 5)	51036698[LH]
		101.9% (Day 29)	Hydrolysis (pH 7)	51036698[LH]
		100.4% (Day 29)	Hydrolysis (pH 9)	51036698[LH]
		96.4% (Day 8)	Aqueous Photolysis (pH 5)	41323115
		99.1% (Day 8)	Aqueous Photolysis (pH 7)	41323115
		98% (Day 9)	Aqueous Photolysis (pH 9)	41323115
		92.9% (Day 12.3)	Aqueous Photolysis (pH 5)	51036699[LH]
		97.8% (Day 12.3)	Aqueous Photolysis (pH 7)	51036699[LH]
		84.5% (Day 12.3)	Aqueous Photolysis (pH 9)	51036699[LH]
		76.7 (Day 12.3)	Aqueous Photolysis (Lake Water)	51036699[LH]
		6.1% (Day 30)		41920102
		0.8% (Day 60, sandy loam)	Soil Photolysis	41323119
		0.5% (Day 60, silt loam)	Aerobic Soil Metabolism	41323119
		1.2% (Day 60, loamy sand)	Aerobic Soil Metabolism	41323119
		1.9% (Day 120, sandy loam)	Aerobic Soil Metabolism	40345659[A]
		4.0% (Day 95, sandy loam)	Aerobic Soil Metabolism	40345659[A]
		4.4% (Day 95, silt loam)	Aerobic Soil Metabolism	40345659[A]
		<LOD (Day 152, loam)	Aerobic Soil Metabolism	50982320[LA]
		<LOD (Day 152, loamy sand)	Aerobic Soil Metabolism	50982320[LA]
		0.0 (Day 152, silt loam)	Aerobic Soil Metabolism	50982320[LA]
		<LOD (Day 152, loamy sand)	Aerobic Soil Metabolism	50982320[LA]
		<LOD (Day 121, loam)	Aerobic Soil Metabolism	51036701[LH]
		<LOD (Day 121, loamy sand)	Aerobic Soil Metabolism	51036701[LH]
		<LOD (Day 121, silt loam)	Aerobic Soil Metabolism	51036701[LH]
		<LOD (Day 121, sandy loam)	Aerobic Soil Metabolism	51036701[LH]
		13.8% (Day 60, silt loam)	Aerobic Soil Metabolism	40501014
		27.4% (Day 94, silt loam)	Anaerobic Soil Metabolism	40345660
		27.0% (Day 94, sand)	Aerobic Aquatic Metabolism	40345660
		0.0% (Day 130, loam)	Aerobic Aquatic Metabolism	45204402/01
		32.6% (Day 130, sand, 1ppm)	Aerobic Aquatic Metabolism	45204402/01
		0.0% (Day 130, sand, 0.1 ppm)	Aerobic Aquatic Metabolism	45204402/01
		72.7% (Day 125)	Aerobic Aquatic Metabolism	47923714
		0.021 ppm (Day 327)	Anaerobic Aquatic Metabolism	43110402
		0.01 ppm (Day 602)	Terrestrial Field Dissipation	43766915
		< 0.01ppm (Day 591)	Terrestrial Field Dissipation	43766916

Compound	Maximum % of Applied	% of Applied at Study Termination	Study Type[1]	MRID
		<0.01ppm (Day 336) <0.002ppm (Day 28, CA, water) <0.004 ppm (Day 270, LA, soil) <0.003 ppm (Day 42, LA, water)	Terrestrial Field Dissipation Terrestrial Field Dissipation Aquatic Field Dissipation Aquatic Field Dissipation Aquatic Field Dissipation	47542601 45204403 44204403 44204403
3-methylphosphinico-propionic acid **MPP (HOE 061517)** **Molecular Formula: $C_4H_9O_4P$** **CAS No.: 15090-23-0**  	1.2% (Day 12.3) 2.8% (Day 12.3) **11.5%** (Day 12.3) **16.5 %** (Day 12.3) **60.4**% (Day 30) **47.7**% (Day 7, sandy loam) **25.8**% (Day 14, silt loam) **36.5**% (Day 7, loamy sand) **42.5**% (Day 64, sandy loam) **55.4**% (Day 64, sandy loam) **41.7**% (Day 64, silt loam) **30.5%** (Day 7 loam) **27.9%** (Day 2 loamy sand) **23.7%** (Day 4, silt loam) **25.7%** (Day 4, loamy sand) **43.7%** (Day 28, loam) **36.8%** (Day 28, loamy sand) **24.9%** (Day 14, silt loam) **29.3%** (Day 7, sandy loam) **42.2**% (Day 60, silt loam) **16.5**% (Day 64, silt loam) **56.5**% (Day 64, sand) **48.4**% (Day 91, loam) **30.5**% (Day 50, sand, 1 ppm) **79.8**% (Day 14, sand, 0.1 ppm) 0.172 ppm (Day 192) 0.21 ppm (Day 42) 0.15 ppm (Day 14) 0.10 ppm (Day 28)	1.2% (Day 12.3) 2.8% (Day 12.3) 11.5% (Day 12.3) 16.5 % (Day 12.3) **60.4**% (Day 30) 3.8% (Day 60, sandy loam) 6.6% (Day 60, silt loam) 4.5% (Day 60, loamy sand) **34.3**% (Day 120, sandy loam) **51.7**% (Day 95, sandy loam) **40.6**% (Day 95, silt loam) 0.64% (Day 152 loam) 1.23% (Day 152, loamy sand) 0.88% (Day 152 silt loam) 1.07% (Day 152 loamy sand **30.4%** (Day 121, loam) 7.04% (Day 121, loamy sand) 1.28% (Day 121, silt loam) 1.76% (Day 121, sandy loam) **42.2**% (Day 60, silt loam) **16.3**% (Day 94, silt loam) **36.5**% (Day 94, sand) **45.3**% (Day 130, loam) **29.7**% (Day 130, sand, 1 ppm) **67.3**% (Day 130, sand, 0.1 ppm) 0.024 ppm (Day 327) 0.02 ppm (Day 602) < 0.01 ppm (Day 591) < 0.01 ppm (Day 336)	Aqueous Photolysis (pH 5) Aqueous Photolysis (pH 7) Aqueous Photolysis (pH 9) Aqueous Photolysis (Lake Water) Soil Photolysis Aerobic Soil Metabolism Aerobic Soil Metabolism Aerobic Soil Metabolism Aerobic Soil Metabolism Aerobic Soil Metabolism Aerobic Soil Metabolism Aerobic Soil Metabolism Aerobic Soil Metabolism Aerobic Soil Metabolism Aerobic Soil Metabolism Aerobic Soil Metabolism Aerobic Soil Metabolism Aerobic Soil Metabolism Aerobic Soil Metabolism Aerobic Soil Metabolism Aerobic Soil Metabolism Anaerobic Soil Metabolism Aerobic Aquatic Metabolism Aerobic Aquatic Metabolism Aerobic Aquatic Metabolism Aerobic Aquatic Metabolism Aerobic Aquatic Metabolism Terrestrial Field Dissipation Terrestrial Field Dissipation Terrestrial Field Dissipation Terrestrial Field Dissipation	51036699[LH] 51036699[LH] 51036699[LH] 51036699[LH] 41920102 41323119 41323119 41323119 40345659[A] 40345659[A] 40345659[A] 50982320[LA] 50982320[LA] 50982320[LA] 50982320[LA] 51036701[LH] 51036701[LH] 51036701[LH] 51036701[LH] 40501014 40345660 40345660 45204402/01 45204402/01 45204402/01 43110402 43766915 43766916 47542601
2-methylphosphinico-acetic acid **MPA (HOE 064619)** **Chemical Formula: $C_3H_7O_4P$**	8.5% (Day 16) **28.2**% (Day 14, sandy loam) 3.1% (Day 20, silt loam) **10.7**% (Day 20, loamy sand) 6.6% (Day 98, sandy loam)	6.3% (Day 30) 5.0% (Day 60, sandy loam) 2.1% (Day 60, silt loam) 3.8% (Day 60, loamy sand) 3.3% (Day 120, sandy loam)	Soil Photolysis Aerobic Soil Metabolism Aerobic Soil Metabolism Aerobic Soil Metabolism Aerobic Soil Metabolism	41920102 41323119 41323119 41323119 40345659[A]

Compound	Maximum % of Applied	% of Applied at Study Termination	Study Type[1]	MRID
	**10.3**% (Day 95, sandy loam) **18.5**% (Day 95, silt loam) **18.0** (Day 30, loam) **11.4** (Day 30, loamy sand) 5.17 (Day 0, silt loam) 2.65 (Day 4, loamy sand) **18.1%** (Day 121, loam) **11.2%** (Day 65, loamy sand) **18.9%** (Day 28, silt loam) **12.6%** (Day 28, sandy loam) 5.8% (Day 60, silt loam) **18.4**% (Day 94, silt loam) **19.1**% (Day 94, sand) **19.9**% (Day 50, loam) **15.5**% (Day 130, sand, 1 ppm) 6.8% (Day 130, sand, 0.1 ppm) 0.055 ppm (Day 184) 0.11 ppm (Day 296) 0.10 ppm (Day 45) 0.05 ppm (Day 65)	**10.3**% (Day 95, sandy loam) **18.5**% (Day 95, silt loam) <LOD (Day 152, loam) <LOD (Day 152, loamy sand) <LOD (Day 152, silt loam) <LOD (Day 152, loamy sand) **18.1%** (Day 121, loam) **10.5%** (Day 121, loamy sand) <LOD (Day 121, silt loam) <LOD (Day 121, sandy loam) 5.8% (Day 60, silt loam) **18.4**% (Day 94, silt loam) **19.1**% (Day 94, sand) **15.5**% (Day 130, loam) **15.5**% (Day 130, sand, 1 ppm) 6.8% (Day 130, sand, 0.1 ppm) <0.02 ppm (Day 327) 0.04 ppm (Day 602) <0.01 ppm (Day 591) <0.01 ppm (Day 336)	Aerobic Soil Metabolism Aerobic Soil Metabolism Aerobic Soil Metabolism Aerobic Soil Metabolism Aerobic Soil Metabolism Aerobic Soil Metabolism Aerobic Soil Metabolism Aerobic Soil Metabolism Aerobic Soil Metabolism Aerobic Soil Metabolism Anaerobic Soil Metabolism Aerobic Aquatic Metabolism Aerobic Aquatic Metabolism Aerobic Aquatic Metabolism Aerobic Aquatic Metabolism Aerobic Aquatic Metabolism Terrestrial Field Dissipation Terrestrial Field Dissipation Terrestrial Field Dissipation Terrestrial Field Dissipation	40345659[A] 40345659[A] 50982320[LA] 50982320[LA] 50982320[LA] 50982320[LA] 51036701[LH] 51036701[LH] 51036701[LH] 51036701[LH] 40501014 40345660 40345660 45204402/01 45204402/01 45204402/01 43110402 43766915 43766916 47542601
L-2-acetamido-4-methylphosphinico-butanoic acid **NAG** **(HOE 085355/HOE 099730)** **Formula: $C_7H_{14}NO_5P$**	**17.7**% (Day 4) **32.6%** (Day 61, loam) 5.59% (Day 30, loamy sand) 3.07% (Day 2, silt loam) 4.29% (day 1, loamy sand) 4.74% (Day 65, loam) 5.14% (Day 7, loamy sand) 3.82% (Day 77, silt loam) 6.77% (day 14, sandy loam) 8.2% (Day 7, loam) 4.3% (Day 50, sand, 1 ppm) 9.9% (Day 1, sand, 0.1 ppm)	0.0% (Day 30) **22.4%** (Day 152, loam) 1.34% (Day 152, loamy sand) 0.83% (Day 152, silt loam) 1.54% Day 152, loamy sand) <LOD (Day 121, loam) <LOD (Day 121, loamy sand) <LOD (Day 121, silt loam) <LOD (Day 121, sandy loam) 0.0% (Day 130, loam) 2.1% (Day 130, sand, 1 ppm) 0.0% (Day 130, sand, 0.1 ppm)	Soil Photolysis Aerobic Soil Metabolism Aerobic Soil Metabolism Aerobic Soil Metabolism Aerobic Soil Metabolism Aerobic Soil Metabolism Aerobic Soil Metabolism Aerobic Soil Metabolism Aerobic Soil Metabolism Aerobic Aquatic Metabolism Aerobic Aquatic Metabolism Aerobic Aquatic Metabolism	41920102 50982320[LA] 50982320[LA] 50982320[LA] 50982320[LA] 51036701[LH] 51036701[LH] 51036701[LH] 51036701[LH] 45204402/01 45204402/01 45204402/01

Compound	Maximum % of Applied	% of Applied at Study Termination	Study Type[1]	MRID
				
3-[hydroxy(methyl) phosphoryl]-3-oxo-propanoic acid **HOE 086486** **Chemical Formula: $C_4H_7O_5P$** 	5.1% (Day 120, sandy loam) 5.9% (Day 32, sandy loam) 3.7% (Day 95, silt loam) 5.7% (Day 60, silt loam) 2.7% (Day 64, silt loam) 5.0% (Day 94, sand) **12.5%** (Day 50, loam) 3.7% (Day 130, sand, 1 ppm) 5.9% (Day 3, sand, 0.1 ppm)	5.1% (Day 120, sandy loam) 5.4% (Day 95, sandy loam) 3.7% (Day 95, silt loam) 5.7% (Day 60, silt loam) 0.6% (Day 94, silt loam) 5.0% (Day 94, sand) 6.8% (Day 130, loam) 3.7% (Day 130, sand, 1 ppm) 1.4% (Day 130, sand, 0.1 ppm)	Aerobic Soil Metabolism Aerobic Soil Metabolism Aerobic Soil Metabolism Anaerobic Soil Metabolism Aerobic Aquatic Metabolism Aerobic Aquatic Metabolism Aerobic Aquatic Metabolism Aerobic Aquatic Metabolism Aerobic Aquatic Metabolism	40345659[A] 40345659[A] 40345659[A] 40501014 40345660 40345660 45204402/01 45204402/01 45204402/01
4-[hydroxy(methyl) phosphoryl]-2-oxo-butanoic acid **HOE 065594** **Chemical Formula: $C_5H_9O_5P$**	5.7% (Day 8, silt loam)	<1.0% (Day 95, silt loam)	Aerobic Soil Metabolism	40345659A

Compound	Maximum % of Applied	% of Applied at Study Termination	Study Type[1]	MRID
				
M-1 No structural information available.	2.3% (Day 0, loam) 2.4% (Day 0, sand, 1 ppm) 2.0% (Day 0, sand, 0.1 ppm)	0.2% (Day 130, loam) 0.0% (Day 130, sand, 1 ppm) 0.0% (Day 130, sand, 0.1 ppm)	Aerobic Aquatic Metabolism Aerobic Aquatic Metabolism Aerobic Aquatic Metabolism	45204402/01 45204402/01 45204402/01
M-2 No structural information available.	3.5% (Day 0, loam) 3.3% (Day 3, sand, 1 ppm) 4.7% (Day 0, sand, 0.1 ppm)	0.0% (Day 130, loam) 0.0% (Day 130, sand, 1 ppm) 0.0% (Day 130, sand, 0.1 ppm)	Aerobic Aquatic Metabolism Aerobic Aquatic Metabolism Aerobic Aquatic Metabolism	45204402/01 45204402/01 45204402/01
M-3 No structural information available.	1.3% (Day 50, loam) 2.0% (Day 130, sand, 1 ppm) 2.6% (Day 7, sand, 0.1 ppm)	0.0% (Day 130, loam) 2.0% (Day 130, sand, 1 ppm) 0.0% (Day 130, sand, 0.1 ppm)	Aerobic Aquatic Metabolism Aerobic Aquatic Metabolism Aerobic Aquatic Metabolism	45204402/01 45204402/01 45204402/01
M-4 No structural information available.	0.1% (Day 21, sand, 1 ppm) 0.3% (Day 3, sand, 0.1 ppm)	0.0% (Day 130, sand, 1 ppm) 0.3% (Day 130, sand, 0.1 ppm)	Aerobic Aquatic Metabolism Aerobic Aquatic Metabolism	45204402/01 45204402/01
M-5 No structural information available.	0.2% (Day 77, loam) 0.3% (Day 7, sand, 1 ppm)	0.0% (Day 130, loam) 0.0% (Day 130, sand, 1 ppm)	Aerobic Aquatic Metabolism Aerobic Aquatic Metabolism	45204402/01 45204402/01
M-7 No structural information available.	8.5% (Day 77, loam) 4.8% (Day 91, sand, 1 ppm) 9.3% (Day 21, sand, 0.1 ppm)	7.9% (Day 130, loam) 4.6% (Day 130, sand, 1 ppm) 8.7% (Day 130, sand, 0.1 ppm)	Aerobic Aquatic Metabolism Aerobic Aquatic Metabolism Aerobic Aquatic Metabolism	45204402/01 45204402/01 45204402/01

[1] Unless otherwise specified, the study was conducted on racemic (D- and L-isomer mixture) glufosinate ammonium salt.
[LA] Indicates the study was conducted on L-glufosinate ammonium salt
[LH] Indicates the study was conducted on L-glufosinate free acid.

Appendix B. Aquatic Modeling Parameters and Output

Surface water aquatic modeling was simulated using the Pesticide in Water Calculator (PWC; version 2.001) for use patterns to terrestrial areas. Chemical input parameters used in modeling are presented in **Table 9** and were calculated for parent based on information described in **Section 3.4.** Input parameters were selected in accordance with EFED's guidance documents (USEPA, 2009b; USEPA, 2010b; USEPA, 2012c; USEPA, 2013a; USEPA, 2013b; USEPA, 2014a; USEPA, 2014b; USEPA and Health Canada, 2012). All of the physical chemical and degradation rate data is bridged[46] between the racemic and L-glufosinate studies. Details and justifications of the model input assumptions used in this assessment are provided below. Complete modeling results are given in **Tables B-5** and **B-6**

Spray Drift Assumptions for All Uses

Application efficiency, spray drift, and application method parameters used in ecological modeling are given in **Table B-1.** Applications can be made via ground or aerial equipment, unless otherwise specified. Label indicates a minimum boom height of 24-inches above the crop canopy. Based on the height of potential cover crops, EFED assumed a high boom height (50 inches above the ground) for all ground applications.

Table B-1. Spray Drift and Application Method Parameters for Aquatic Modeling.

Application Type	Application Efficiency	Spray Drift Fraction	Application Method
Aerial, medium to coarse DSD	0.95	0.089	Above Crop
Ground, fine to medium-coarse DSD, High boom	0.99	0.017	

DSD = droplet size distribution

Water Body Parameters and Modeling Settings

Exposure to non-target plants was assessed using the Pesticide in Water Calculator (PWC; version 3.0) external batch model and Plant Assessment Tool (PAT; version 2.0) batch mode Python script (version 2.2.1.1) run with Python version 3.9.7 (64-bit). Detailed instruction can be found in the *Plant Assessment Tool (PAT) Version 1.0. User's Guide and Technical Manual for Estimating Pesticide Exposure to Terrestrial, Wetland, and Aquatic Plants in EPA's Listed Species Biological Evaluations* (USEPA 2020). Application pattern summary, PWC and PAT batch mode files input files, and modeling results for the TPEZ, WPEZ, and APEZ are attached to this assessment. The water body parameters and PWC options used in modeling the standard farm pond and wetland exposure are given in **Table B-2**. Edge of field concentrations were calculated using the PWC edge of field calculator version 2.2.1.

46 Bridging refers to the use of an existing dataset to describe the environmental fate and toxicological effects of another chemical for which there is little or no existing data.

Table B-2. Water Body and Pesticide in Water Calculator (PWC; version 3.0) Parameters.

Parameter	Standard Farm Pond	Wetland
User Defined Surface Water Body option	Not Applicable	Varying Volume and Flowthrough
Field Area (m^2)	100,000	100,000
Water Body Area (m^2)	10,000	10,000
Initial Depth (m)	2	0.15
Maximum Depth (m)	2	0.15
Hydraulic Length (m)	356.8	356.8
Benthic Depth (m)	0.05	0.15
Precipitation (under More Options Tab)	Not selected	Selected

Application Timing and Rate Assumptions

Application parameters for aerial and ground applications are given in the attached L-Glufosinate Application Parameters.xlsx spreadsheet. PWC and PAT modeling results are given in the attached L-Glufosinate Modeling Results.xlsx spreadsheet. An example PWC output summary is provided below. Unless specified, application timings are given relative to the emergence date in the listed PWC scenarios and were chosen based on the minimum retreatment interval between the pre-emergence burndown application and the post-emergence in-season applications allowed on the glufosinate labels unless otherwise specified. Application rates were based on the maximum labeled rate for each use pattern. For crops where there were two options for combinations of burndown and in-season applications that could be made in a single growing season, EFED modeled both potential combinations at the maximum label rates to characterize the effect of these different application patterns on the EEC values. While some uses allow for 3 in-season applications (*e.g.*, seed propagation), EFED did not model those uses, as the burndown plus in-season application combinations are expected to be protective of potential exposure due to the higher expected runoff from pre-emergence applications. The different application patterns are described in the Use Site column of **Tables 3-1** and **3-2**. EFED modeled both a single burndown applications and burndown plus in-season application to characterize the difference in ecological exposure from applications to glufosinate sensitive and glufosinate tolerant crops. A complete list of the application rate and pattern assumptions are given below.

Application Timing and Rate Assumptions, by Crop

Canola

1. Recommended Time of Application
   - Label information on application timing:
     - Apply to small and actively growing weeds, targeting less than 3-inch weeds in height.

    - For post-emergence applications, apply from cotyledon up to early bolt stage of glufosinate-resistant canola.
- Burndown applications are recommended to be made preplant or pre-emergence to the crop on the label. Emergence typically takes 4-10 days depending on the soil and weather conditions (Kandel *et al.*, 2019). Used 6-day pre-emergence of canola to represent pre-emergence application.

2. Application Rates and Timing

- Conventional Canola – Burndown
    - 1 burndown pre-emergence application of 0.36 lbs ae/A (0.403 kg/ha, apply 6 days before emergence), 0.36 lbs ae/A/year.

- Glufosinate-resistant Canola - Burndown and Crop Post-Emergence
    - 1 burndown pre-emergence application of 0.25 lbs ae/A (0.28 kg/ha; apply 6 days pre-emergence) followed by 2 crop post-emergence applications of 0.24 lbs ae/A (0.27 kg/ha) 7-day RTI, 0.73 lbs ae/A/year
    - 1 burndown pre-emergence application of 0.36 lbs ae/A (0.403 kg/ha; apply 6 days pre-emergence) followed by 2 post-emergence applications of 0.18 lbs ae/A (0.20 kg/ha; apply 1 day and 8 days post-emergence) 7-day RTI, 0.73 lbs ae/A/year.

Cotton

1. Recommended Time of Application
- May be applied post emergence of cotton up to two (Scenario 1) or three (Scenario 2) times. Used 1- and 11-days since emergence as per the label RTI of 10-days.
- Label information on application timing:
    - Apply to small and actively growing weeds, targeting less than 3-inch weeds in height.
    - Apply from emergence up to early bloom.

2. Application Rates and Timing
    - Conventional and Glufosinate-resistant Cotton
        - Scenario 1 – 1 burndown application 0.36 lbs ae/A (0.403 kg/ha) (apply 9 days pre-emergence) and 1 post-emergence application 0.24 lbs ae/A (0.27 kg/ha) (1-day after emergence), 10-day RTI, 0.60 lbs ae/A/year
        - Scenario 2 - 1 burndown application 0.24 lbs ae/A (0.27 kg/ha) (apply 9 days pre-emergence) and 2 post-emergence applications of 0.24 lbs ae/A (0.27 kg/ha; 1 days after emergence) and 0.24 lbs ae/A (0.146 kg/ha; 11 days after emergence), 10-day RTI, 0.73 lbs ae/A/year

Corn

1. Recommended Time of Application
- May be applied as a burndown herbicide for glufosinate-resistant and conventional corn

- May be applied post emergence of glufosinate-resistant corn up to two times. Used 1- and 8-days post-emergence as per the label RTI of 7-days. Label information on application timing:
    - Apply to small and actively growing weeds, targeting less than 3-inch weeds in height.
    - Apply from emergence through V6 stage of growth.

2. Application Rates and Timing
    - Glufosinate-resistant Corn
        - 1 burndown application of 0.36 lbs ae/A (0.403 kg/ha; apply 6 days pre-emergence) followed by 1 post-emergence application 0.36 lbs ae/A (0.403 kg/ha, apply 1-day post-emergence), 7-day RTI, 0.73 lbs ae/A/year
    - Conventional Corn
        - 1 burndown application of 0.36 lbs ae/A (0.403 kg/ha, -6)

Sweet Corn

1. Recommended Time of Application
    - May be applied as a burndown herbicide for glufosinate-resistant and conventional sweet corn.
    - May be applied post-emergence to glufosinate-resistant sweet corn up to two times. Used after 1 to 8-days after emergence. RTI of 7-days.
    - If used for burndown application to glufosinate-resistant sweet corn, it may not be applied post-emergence.
2. Application Rates and Timing
        - Glufosinate Resistant Sweet Corn
            - 1 burndown application of 0.18 lbs ae/A (0.20 kg/ha, apply 6 days pre-emergence). If used as a burndown herbicide on glufosinate-resistant sweet corn, then no post-emergence applications can be made.
            - 2 post-emergence applications of 0.18 lbs ae/A (0.20 kg/ha, apply 1 to 8 days post-emergence, 0.36 lbs ae/A/year (0.40 kg/ha/year).
        - Conventional Sweet Corn
            - 1 burndown application of 0.36 lbs ae/A (0.40 kg/ha, apply 6 days pre-emergence).

Soybean

1. Recommended Time of Application
    - May be applied post-emergence of soybean up to two times. Used 1- and 6-days post-emergence RTI of 5-days.
    - Apply to small and actively growing weeds, targeting less than 3-inch weeds in height.
    - Apply from emergence up to bloom or R1 growth stage.
2. Application Rates and Timing
    - Conventional soybean
        - 1 burndown application of 0.36 lbs ae/A (0.403 kg/ha, apply 4 days pre-emergence)

- Glufosinate-resistant Soybean:
    - 1 burndown application of 0.36 lbs ae/A (0.403 kg/ha, apply 4 days pre-emergence) followed by 1 post-emergence application 0.36 lbs ae/A (0.403 kg/ha, apply 1-day post-emergence), 5-day RTI, 0.73 lbs ae/A/year
    - 1 post-emergence application of 0.36 lbs ae/A (0.403 kg/ha, apply 1 day after emergence) followed by 1 post-emergence application 0.36 lbs ae/A (0.403 kg/ha, apply 6-day post-emergence), 5-day RTI, 0.73 lbs ae/A/year

Below is an example output summary file from a single PWC modeling simulation.

Summary of Water Modeling of L-Glufosinate New Jersey (NJ) Nursery 3x0.67 and the USEPA Standard Pond

Estimated Environmental Concentrations for L-Glufosinate NJ Nursery 3x0.67 are presented in **Table B3** for the USEPA standard pond with the NJnurserySTD_V2 field scenario. A graphical presentation of the year-to-year acute values is presented in **Figure B1**. These values were generated with the Pesticide Water Calculator (PWC), Version 2.001. Critical input values for the model are summarized in **Tables B4** and B**5**.

This model estimates that about 1.7% of L-Glufosinate NJ Nursery 3x0.67 applied to the field eventually reaches the water body. The main mechanism of transport from the field to the water body is by spray drift (53.6% of the total transport), followed by runoff (46%) and erosion (0.37%).

In the water body, pesticide dissipates with an effective water column half-life of 397.0 days. (This value does not include dissipation by transport to the benthic region; it includes only processes that result in removal of pesticide from the complete system.) The main source of dissipation in the water column is metabolism (effective average half-life = 397 days) followed by volatilization (8.119316E+12 days).

In the benthic region, pesticide dissipation is negligible (1724.9 days). The main source of dissipation in the benthic region is metabolism (effective average half-life = 1724.9 days). The vast majority of the pesticide in the benthic region (96.98%) is sorbed to sediment rather than in the pore water.

Table B3. Estimated Environmental Concentrations (ppb) for L-Glufosinate NJ Nursery 3x0.67.

1-day Avg (1-in-10 yr)	44.41
4-day Avg (1-in-10 yr)	44.08
21-day Avg (1-in-10 yr)	42.90
60-day Avg (1-in-10 yr)	40.99
365-day Avg (1-in-10 yr)	33.24
Entire Simulation Mean	26.53

Table B4. Summary of Model Inputs for L-Glufosinate NJ Nursery 3x0.67.

Scenario	NJnurserySTD_V2
Cropped Area Fraction	1

K_{oc} (ml/g)	297
Water Half-Life (days) @ 20 °C	267
Benthic Half-Life (days) @ 20 °C	1160
Photolysis Half-Life (days) @ 40 °Lat	0
Hydrolysis Half-Life (days)	0
Soil Half-Life (days) @ 20 °C	12.4
Foliar Half-Life (days)	0
Molecular Weight	181.1
Vapor Pressure (torr)	1.15E-10
Solubility (mg/l)	1.37E6
Henry's Constant	8.18E-16

Table B5. Application Schedule for L-Glufosinate NJ Nursery 3x0.67.

Date (Days Since Emergence)	Type	Amount (kg/ha)	Eff.	Drift
1	Above Crop (Foliar)	0.75	0.95	0.089
15	Above Crop (Foliar)	0.75	0.95	0.089
29	Above Crop (Foliar)	0.75	0.95	0.089

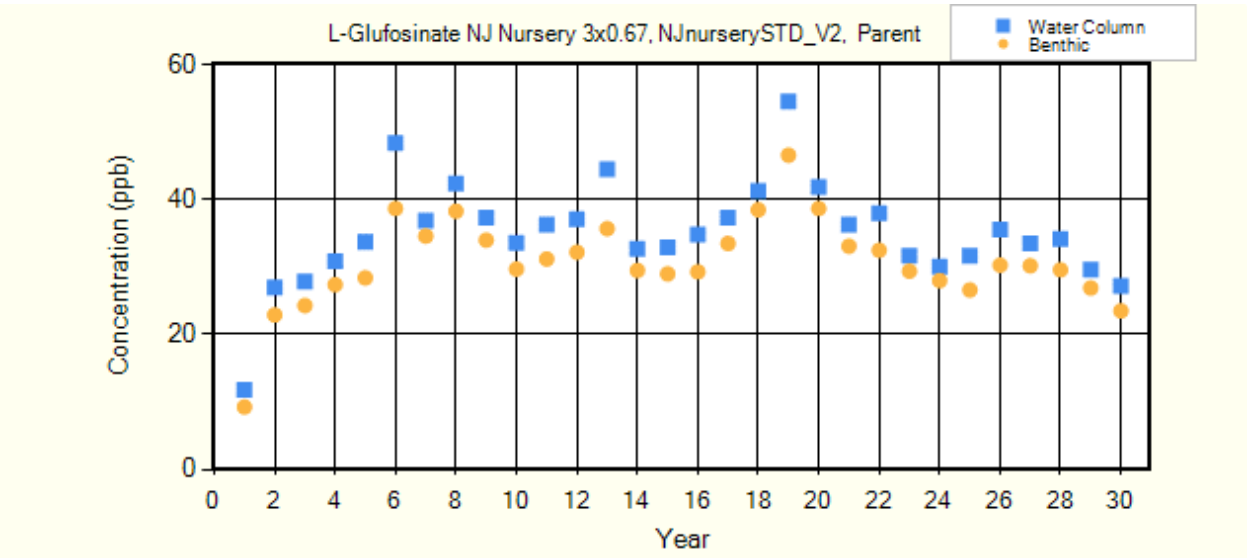


Figure B1. Yearly Highest 1-day Average Concentrations.

Appendix C. Summary of Newly Submitted Effect Study Results and Conclusions

Table C-1. Summary of Effects Studies Submitted for Racemic Glufosinate Ammonium.

Guideline/Study Title (Species, if applicable)	Classification (MRID)	Test Material (TGAI or TEP)	Study Results (reported in acid equivalents)[1]	Notes
Non-guideline Laboratory and semi-field non-target arthropod study Various species	Unacceptable (51787603)	TEP	N/A	Study classified unacceptable due to limited information on the test material.
Non-guideline Field non-target arthropod study Various species	Supplemental (51787604)	TEP	Transient effects on arthropod populations and communities in an apple orchard.	Study tested up to 0.61 lbs ae/A (~0.31 lbs L-isomer ae/A). Reliable for qualitative use only
Non-guideline Field non-target arthropod study Various species	Supplemental (51787605)	TEP		
Non-guideline Field non-target arthropod study Various species	Supplemental (51787606)	TEP	No adverse effects on arthropod populations or communities in an actively managed maize field.	Study tested up to 0.65 lbs ae/A (~0.32 lbs L-isomer ae/A). Reliable for qualitative use only

MRID=master record identification (number); TEP = Typical End-use Product;

Non-guideline – Laboratory and Semi-Field Non-Target Arthropod Study (MRID 51787603)

Laboratory study

In a laboratory study of the racemic glufosinate ammonium formulated end-use product (TEP) Basta™ (purity not specified) the European ground beetle *Bembidion lampros* was the most sensitive species tested with a 72-hr dermal contact LD_{50} of 2.27 µg ai/beetle. The TEP dissolved in methanol was applied (0.5 µL) to the integument of the test species at nominal concentrations of up to 50 µg/µL for the ground beetle and up to 200 µg/µL for other species tested. Controls were treated with methanol alone. The number of organisms tested per treatment group ranged from 15 to 45. The reference toxicant dimethoate (89.5% ai) dissolved in butanone was used as a positive control. While *B. lampros* was the most sensitive species tested with the glufosinate ammonium TEP, the rove beetle *Tachyporus hypnorum* and the hoverfly *Metasyrphus corollae* were the most sensitive to dimethoate with LD_{50} values of 0.017 and 0.018 µg ai/species, respectively.

Semi-field study

In a semi-field study of the same formulation, the racemic glufosinate ammonium product was applied as a spray at a rates of 1.5, 3, 6, 12, 18, 24, and 30 L TEP/ 400 L water/ha to fallow soil,

3 L TEP/400 L water/ha to peas and kale, and 7.5 L TEP/ 400 L water/ha to rye. None of the coleopteran or dipteran species tested in in fallow soil exhibited mortality of 50% or greater *(i.e.*, LD_{50}> highest soil concentration). Only the two spider species of the order Araneae were affected, with the money spider Erigone atra being the most sensitive of the two (LD_{50} of 3.6 L/ha). There was no statistically significant effect to any of the beetle species or the single spider species that were tested in peas, kale, or rye gras during the 72-hour exposure period. Given that neither the density of the product nor the purity of the product was reported, the reviewer could not verify that the maximum rate tested in this study is equivalent to the maximum rate permitted on currently registered labels of racemic glufosinate. Furthermore, the reviewer is unable to verify that the product used is equivalent to products registered in the US. Given the limited information on the test material, this study is classified as unacceptable.

Non-guideline –Field Non-Target Arthropod Study (MRID 51787604)

Based on an evaluation of nearly 1.5 million arthropods sampled in the ground vegetation of an apple orchard in southwest Germany, two applications below the orchard canopy (one month re-treatment interval) of the racemic glufosinate ammonium formulated end-use product Glufosinate-ammonium SL 150 (ai: 13.3% glufosinate-ammonium) - at a rate of 0.75 kg ai/ha per application (0.67 lb ai/A) to one third of the ground area along strips below the apple trees. Treatments consisted of either a single application of glufosinate ammonium (T1) or two successive treatments (1 month re-treatment interval) (T2). A water control treatment and a toxic reference chemical treatment (dimethoate, 400 g/L EC formulation) were run in parallel. Both univariate and multivariate analyses demonstrated adverse effects in plots treated with the dimethoate. Results indicate that treatment with the formulated glufosinate-ammonium product led to statistically significant effects on the arthropod community sampled with pitfalls, suction, and weed extraction methods inside the treated areas under the trees. Recovery of the arthropod community to pre-treatment levels occurred within two to four months of the first application in both T1 and T2. When sampled in untreated areas between tree rows adjacent to treated areas, only minor and transient adverse effects were observed for part of the arthropod community in the pitfall dataset. Other sampling methods did not reveal adverse effects on arthropod communities residing in untreated areas next to the weed strips that received one (T1) or two applications (T2).

According to the study authors, approximately 45% of all species examined at the population level were adversely affected by two applications of the glufosinate-ammonium formulated product. At the application site, at least one species from each arthropod order exhibited a clear, adverse decline in population size from 1 or 2 applications. Most populations recovered within two to four months after the first application. For all taxa, within-season recovery was observed except for the collembolan species *Sphaeridia pumulis* (Symphypleona) that recovered within one year after the first application (in T2).

Several species of mites were initially affected by two applications of the glufosinate-ammonium formulated product, but not by one application (*i.e*., predatory mites belonging to the taxon Gamasina, including mites within the families Phytoseiidae, Stigmaeidae,

Tarsonemidae and Tydeoidea). Except for Tydeoidea, none of the mites were affected by the glufosinate ammonium in areas adjacent to the treated weed strips. For arthropod taxa other than mites, adverse treatment-related effects were similar following one or two applications of glufosinate-ammonium. Few taxa that were adversely affected by glufosinate ammonium in the treated weed strips were also reduced compared to the control in test item plots when sampled directly adjacent to the treated areas. Magnitude and/or duration of adverse effects in the untreated areas adjacent to treated areas were lower/shorter than in the treated areas.

The relevance of the results to US registrations is uncertain given that the study was conducted with a formulation that is not registered in the US. While this formulation is similar to a US registered formulation, it contains a lower percent active ingredient and there are differences in the inert components. It is unclear how these differences would affect the toxicity of this formulation compared to the US formulation. Additionally, the concentration of the spray application was not analytically confirmed by the study authors; therefore, it is uncertain if the reported nominal concentration reflects the actual exposure level to the arthropod community at the field site.

This study is scientifically sound but is classified as supplemental because the test solutions were not verified analytically and there is an uncertainty surrounding the relevance of the results to US registrations and limited effects observed in plots treated with the insecticide reference item. The results may be used qualitatively for risk assessment.

Non-guideline –Field Non-Target Arthropod Study (MRID 51787605)

A field study was conducted in an apple orchard in southwest France to test the short and long-term within season effects of the racemic glufosinate ammonium formulated end-use product Glufosinate-ammonium SL 150 (13.6% glufosinate-ammonium active ingredient; ai) applications on the weed-, litter-, and soil-dwelling non-target arthropod fauna. Sixteen plots were arranged in a randomized block design. One plot was established per replicate, and four replicates in total were established for the control, each treatment, and the reference group. The glufosinate ammonium was applied at nominal application rates of 0 (control) and 0.75 kg ai/ha (0.67 lb ai/A). One application of the treatment was designated as treatment 1 (T1) and two applications of the treatment was designated as treatment 2 (T2). Nominal application volumes were 300 L/ha (32 gal/A) of treated surface for all treatments. The test item was applied on May 4, 2013, for the control, treatment 1, treatment 2, and the reference (dimethoate) group. A second application was applied on June 4, 2013, only for the control, glufosinate treatment 2, and the dimethoate group. For applications applied on May 4, the actual application rate ranged from 0.6813 to 0.8405 kg ai/ha (0.61 – 0.75 lb ai/A), and for applications applied on June 4, the actual application rate ranged from 0.7247 to 0.7932 kg ai/ha (0.65 – 0.71 lb ai/A) across all replicates. The average application rates deviated <4% from target rates. The control group consisted of tap water or well water. For the reference group, dimethoate was applied at a nominal rate of 280 g ai/ha (0.25 lb ai/A).

Different trapping systems were installed prior to test initiation, based on population dynamics and species composition. Soil- and surface-dwelling arthropods were collected using pitfall traps. Small, low, and highly mobile weed inhabiting and soil-dwelling arthropods were collected using suction sampling. Mites and other low mobile small plant inhabiting arthropods were collected by weed sampling; vegetative coverage was determined for these samples to determine mite densities per square meter surface. The species were identified to the appropriate taxonomic level. Two "sub-habitats" were evaluated: the area under the tree canopy ("row") and from the central corridor between the rows ("path").

One application of glufosinate ammonium induced moderate and transient adverse community effects to arthropods sampled with pitfall traps and suction in the treated weed strip under the trees, but differences compared to the control were not statistically significant ($p<0.05$) at any individual sampling event. Significant effects after one application of glufosinate ammonium were detected in six (6.5%) of 92 taxa sampled directly in the treated weed strip (juvenile and male mites of the infraorder Gamasina, spiders of the genera *Pardosa* and *Pachygnatha*, a carabid beetle of the genus *Harpalus,* a dipteran of the family Cecidomyiidae, and a parasitic wasp of the family Braconidae). Recovery of all affected taxa occurred within two months after treatment.

Two applications of the test item with a one-month interval led to initial moderate, transient but significant adverse effects on the arthropod community sampled with pitfalls and suction in the rows but not in the central corridor path. Full recovery of the arthropod community occurred within the season, confirmed by samples taken the following spring. In the treated weed strip, 16 of 92 taxa were affected by two treatment applications. Most taxa recovered within two months after the first application (Diptera, Homoptera, and Hymenoptera taxa). The spiders *Oxyptilla, Pachygnatha,* and some *Pardosa* species recovered within four months after the first application. Within season recovery was observed for the spider *Phrurolinthus festivus* and the collembolan taxon *Brachystomella parvula*. Adverse effects were not observed for any taxa the next season.

Spider taxa were adversely affected in untreated areas of the orchard next to treated weed strips. The number of taxa affects and magnitude/duration of adverse effects in the untreated path were less than in the treated rows. Hymenoptera and Diptera had the highest proportions of taxa adversely affected by the test item treatment (*ca.* 15% after one application, and 30 to 40% after two applications), but adverse effects lasted longer for spider taxa. Both univariate and multivariate analyses demonstrated that approximately 10-50% of all arthropods examined were adversely affected by the reference item treatment. Different responses were observed for different arthropod taxa in different sub-habitats. The arthropod community sampled with pitfalls under the trees ("row") was adversely affected, but the response was not significant on any of the sampling moments. Minor and transient adverse community effects were found for mites collected from weed samples. Generally, responses of the mite community towards the reference item treatment were not statistically significant on any sampling moment.

The relevance of the results to US registrations is uncertain given that the study was conducted with a formulation that is not registered in the US. While this formulation is similar to a US registered formulation, it contains a lower percent active ingredient and there are differences in the inert components. It is unclear how these differences would affect the toxicity of this formulation compared to the US formulation. Additionally, the concentration of the spray application was not analytically confirmed by the study authors and there were limited effects on arthropod taxa at sites treated with the reference item; therefore, it is uncertain if the reported nominal concentration reflects the actual exposure level to the arthropod community at the field site and whether the study design could adequately identify population level changes in some of the arthropod species evaluated as well as overall community level effects.

This study is scientifically sound but is classified as supplemental because the test solutions were not verified analytically and there is an uncertainty surrounding the relevance of the results to US registrations and limited effects observed in plots treated with the insecticide reference item. The results may be used qualitatively for risk assessment.

Non-guideline –Field Non-Target Arthropod Study (MRID 51787606)

A field study was conducted at a test site in Nauberg, Germany to test the effects of racemic glufosinate ammonium formulated end-use product Liberty™ (ai: 18.1% glufosinate-ammonium) on non-target terrestrial arthropods. The test site was seeded with a glufosinate-tolerant variety of maize (Anjou 285 Liberty™) approximately one month prior to test initiation. Sixteen plots were arranged in a randomized block design. One plot was established per replicate, and four replicates in total were established for the control, each glufosinate ammonium treatment, and the reference group. The nominal application rates were 0 (control), 0.16, and 4.0 L/ha (*i.e.,* 32 and 792 g ai/ha representing 0.03 and 0.71 lb ai/A, respectively). The 792 g/ha (0.71 lb ai/A) rate was labeled as T1 and represents the maximum rate (the worst-case scenario of application). Treatment T2 (*i.e*., 32 g ai/ha; 0.03 lb ai/A) is intended to represent a 4% drift rate and was chosen to simulate effects in off-crop scenarios. There were two applications for each treatment. For both applications of T1 (792 g ai/ha; 0.71 lb ai/acre), the actual rates ranged from 786 to 836 g/ha (0.70 to 0.75 lb ai/A). For both applications of T2 (32 g/ha; 0.03 lb ai/A), the actual rates ranged from 32 to 34 g ai/ha (~0.03 lbs ai/A) across replicates. The control was treated with water, and the reference group was tested using Fastac™ 10 EC (*alpha*-cypermethrin; 10.9% ai).

Different arthropod trapping systems were installed prior to test initiation, based on population dynamics and species composition. Crop-dwelling arthropods were collected using yellow water traps. Epigaeic (*i.e*., ground-dwelling species which cannot burrow, swim or fly) arthropods were collected using pitfall traps and photoeclectors (*i.e*., sampling device fitted with a light source to attract insects). Collected species were sorted and the number of individuals per relevant family was recorded. The species were identified to the appropriate taxonomic level. Weed coverage was determined for each plot (species, density, and % coverage) and the growth stage was also recorded.

According to the study authors, there were no effects on aphids (crop-dwelling species), Collembola, Diptera, Syrphids, Hymenoptera, ballooning spiders, or epigaeic species. There were some exceptions for the epigaeic species where significant effects were determined (*e.g.*, the dwarf spider *Erigone atra*), but the abundance of the species was so low that the statistical effects should be interpreted with caution. The major weed species present (*i.e.*, couch grass; *Agropyron repens*) was notably affected by the highest application rate of glufosinate ammonium, but there did not appear to be any effects on crop-dwelling aphid species.

This study is scientifically sound but is classified as supplemental because the test solutions were not verified analytically, the number of arthropod species evaluated for population level trends was limited due to overall low abundance among the species observed at the use site, and there is an uncertainty as to how the application of other pesticides to the use site in the months and years prior to the test initiation affected the observations and study results. The results may be used qualitatively for risk assessment.

Table C-1. Summary of Effects Studies Submitted for L-Glufosinate Ammonium.

Guideline/Study Title (Species, if applicable)	Classification (MRID)	Test Material (TGAI or TEP)	Study Results (reported in acid equivalents)[1]	Notes
850.1035 Acute Estuarine/Marine Invertebrate Mysid Shrimp (*Americamysis bahia*)	Acceptable (50982321)	TGAI	96-hr LC_{50} = 8.3 mg ae/L	Moderately toxic on an acute exposure basis.
850.1075 Acute Freshwater Fish Rainbow Trout (*Oncorhynchus mykiss*)	Acceptable (50982322)	TEP	96-hr LC_{50} = 3.3 mg ae/L	Moderately toxic on an acute exposure basis.
850.4100 Seedling Emergence (Various Species[2])	Acceptable (50982323)	TEP	<u>Monocotyledonous Plants</u> EC_{25} >0.59 lb ae/A NOAEC = 0.59 lb ae/A <u>Dicotyledonous Plants</u> EC_{25} >0.63 lb ae/A NOAEC = 0.63 lb ae/A	
850.4150 Vegetative Vigor (Various Species[2])	Acceptable (50982324)	TEP	<u>Monocotyledonous Plants</u> EC_{25} = 0.112 lb ae/A NOAEC = 0.029 lb ae/A <u>Dicotyledonous Plants</u> EC_{25} = 0.099 lb ae/A NOAEC = 0.029 lb ae/A	The most sensitive endpoint is dry weight for both monocotyledonous and dicotyledonous plants.
850.4550 Aquatic Plant Toxicity Cyanobacterium (*Anabaena flos-aquae*)	Acceptable (50982326)	TGAI	IC_{50} = 0.032 mg ae/L NOAEC = 0.0058 mg ae/L	The most sensitive endpoint is reduced yield.
870.1100 Acute Oral Toxicity Norway Rat (*Rattus norvegicus*)	Acceptable (50982307)	TGAI	LD_{50} = 954 mg ae/kg bw	Slightly toxic on an acute exposure basis.

Guideline/Study Title (Species, if applicable)	Classification (MRID)	Test Material (TGAI or TEP)	Study Results (reported in acid equivalents)[1]	Notes
OECD TG 239 Honey Bee Chronic Larval Toxicity (*Apis mellifera*)	Acceptable (50982325)	TGAI	<u>Acute</u> 8-day LD_{50} > 12 µg ae/larva[3] <u>Chronic</u> NOAEL = 2.6 µg ae/larva/day LOAEL = 5.0 µg ae/larva/day	The chronic endpoint is based on 19% reduction in adult emergence at the LOAEL

EC_{25}=concentration resulting in 25% effect; LC_{50}=concentration lethal to 50% of the organisms tested; NOAEC=no-observed adverse effect concentration; LOAEC=lowest observed adverse effect concentration; MRID=master record identification (number); OECD TG = Organization of Economic Co-operation and Development Test Guideline; TGAI = Technical Grade Active Ingredient; TEP = Typical End-use Product; ae = acid equivalents

[1]The DERs for these studies report endpoints in terms of active ingredient; however, for the purposes of comparing to other glufosinate active ingredients in this assessment, the L-glufosinate ammonium endpoints are reported in acid equivalents in this table.

[2]The terrestrial plant studies evaluated the most sensitive monocotyledonous species [onion (*Allium cepa*) in both studies] and dicotyledonous species [lettuce (*Lactuca sativa*) and carrot (*Daucus carota*) in the seedling emergence and vegetative vigor studies, respectively] identified in the racemic glufosinate ammonium terrestrial studies per the recommendation in the stereoisomer guidance.

[3]Estimated based on the chronic (repeat-dose) 8-day larval mortality data and dose level administered on the first day of dosing (*i.e.,* study Day 3; MRID 50982325)

850.1035 - Acute Estuarine/Marine Invertebrate Study (MRID 50982321)

In a 96-hr acute toxicity study, mysid shrimp (*Americamysis bahia)* were exposed to chirally enriched L-glufosinate ammonium (82.45% active ingredient; ai) at nominal concentrations of 0 (negative control) 0.39, 0.78, 1.6, 3.1, 6.3, 13, 25, and 50 mg ai/L under static conditions. The mean-measured concentrations were <0.050 (<MDL, negative control), 0.39, 0.83, 1.6, 3.0, 6.0, 12, 26, and 46 mg ai/L.

Sublethal effects, namely lethargy and mysids at the bottom of the exposure vessel, were observed in all test levels except for the negative control and mean-measured 0.39 and 0.83 mg ai/L treatment groups. The 96-hr LC_{50} value was 9.1 mg ai/L.

Based on the results of this study, L-glufosinate ammonium is classified as moderately toxic to *A. bahia* on an acute exposure basis in accordance with the classification system of the U.S. EPA. This study is scientifically sound and is classified as acceptable.

850.1075-Acute Freshwater Fish Study (MRID 50982322)

In a 96-hr acute toxicity study, Rainbow Trout, *Oncorhynchus mykiss*, were exposed to the chirally enriched L-glufosinate ammonium formulated end-use product L-Glufosinate Ammonium 280 g/L SC (ai: 24.79% active ingredient; ai**)** at nominal concentrations of 0 (negative control), 0.62, 1.2, 2.5, 5.0, and 9.9 mg ai/L corresponding to nominal formulation concentrations of 0 (negative control), 2.5, 5.0, 10, 20, and 40 mg form/L under static conditions. Mean-measured concentrations of <0.10 (<MDL, negative control), 0.63, 1.3, 2.5, 5.2, and 10 mg ai/L were used for analysis and reporting.

No sublethal effects were observed in any L-glufosinate ammonium test concentration. The 96-hr LC_{50} value was 3.6 mg ai/L.

Based on the results of this study, the formulated end-use product L-Glufosinate Ammonium 280 g/L SC is classified as moderately toxic to *O. mykiss* on an acute exposure basis in accordance with the classification system of the U.S. EPA.

This study is scientifically sound and is classified as acceptable.

850.4100 - Seedling Emergence (MRID 50982323)

The effect of chirally enriched L-glufosinate ammonium formulated end-use product L-Glufosinate Ammonium 280 g/L SC (24.79% active ingredient; ai) on the seedling emergence of a monocotyledonous (monocot) crop (onion, *Allium cepa*) and a dicotyledonous (dicot) crop (lettuce, *Lactuca sativa*) was studied. Nominal concentrations of L-glufosinate ammonium ranged from 0.0010 to 0.76 lb ai/A and measured concentrations ranged from 0.0011 to 0.69 lb ai/A (91-106% nominal) and 0.0093 to 0.64 lb ai/A (80-112% of nominal) in onions and lettuce, respectively. The growth medium used in the seedling emergence test was a mixture of loamy sand and washed silica sand (sand; pH not reported; organic matter 1.4%). On Day 14, the emergence and surviving plants per pot were recorded and cut at soil level for measuring the plant height and dry weight.

Negative control seedling emergence ranged from 88-100% and control survival post-emergence was 100% for both species. Reduced plant emergence, plant length, and plant weight relative to controls was observed in L-glufosinate ammonium treatment groups for both species and there was a significant ($p<0.05$) effect on lettuce emergence at the 0.0092 lb ai/A. Reductions in emergence and growth parameters did not exhibit a concentration-response nor did the magnitude of effect exceed 19% inhibition within the application rates tested. Given the lack of a concentration response, the reviewer considered the observed responses to be equivocal evidence of a treatment-related effect, but not robust evidence of an adverse response to treatment. Consequently, the EC_{25}/IC_{25} is greater than the highest test concentration and the NOAEC is equal to the highest test concentration for all parameters assessed in both species.

The only phytotoxic symptoms noted in the emerged plants in the treatment groups was necrosis. No phytotoxic symptoms were observed in lettuce, and necrosis was observed in the 0.082 lb ai/A onion treatment group only. There was no concentration-dependent phytotoxic response.

This study is scientifically sound and is classified acceptable.

850.4150 - Vegetative Vigor (MRID 50982324)

The effect of chirally enriched L-glufosinate ammonium formulated end-use product L-glufosinate ammonium 280 g/L SC (24.79% active ingredient; ai) on the vegetative of monocotyledonous (monocot) crop (onion, *Allium cepa)*; and dicotyledonous (dicot) crop (carrot, *Daucus carota*) was studied. Nominal concentrations of L-glufosinate ammonium ranged from 0.0010 to 0.76 lb ai/A and measured concentrations ranged from 0.0093 to 0.64 lb ai/A (80-112% of nominal).

The growth medium used in the vegetative vigor test was a mixture of sandy loam and sand (sand; pH not reported; percent organic matter 1.4%). On Day 21, the surviving plants per pot were recorded and cut at soil level for measuring the plant height and dry weight.

Negative control survival was 100% in both species tested. A concentration-dependent response in survival was observed in both species at the upper end of the treatment rates tested and carrots were more sensitive to the spray formulation compared to onions. Onion and carrot survival ranged from 48-100% and 15-100%, respectively, across the range of application rates tested. Similar to survival, a concentration-dependent response in seedling height and dry weight was observed in both species, though in the case of onion dry weight the concentration response is more evident at the upper end of the application rate range. Onion seedling height and dry weight was inhibited -1 to 56% and 8-74%, respectively, in the L-glufosinate treatment groups relative to controls. Likewise, carrot shoot height and dry weight was inhibited -1 to 39% and 5-68%, respectively, in the treatment groups relative to controls. In general, the magnitude of the effect on dry weight was greater than that observed for shoot height across treatment groups in both species.

In the vegetative vigor test, both the plant height and the plant dry weight were affected by L-glufosinate ammonium treatment. The most sensitive endpoint for onions is dry weight, with NOAEC and IC_{25} values of 0.032 and 0.123 lb ai/A, respectively. Likewise, the most sensitive endpoint for carrots is dry weight, with NOAEC and IC_{25} values of 0.032 and 0.108 lb ai/A, respectively. Reviewer confidence in the height and weight regression estimates for carrots are impacted by reduced survival at higher concentrations. Both carrot growth endpoints exhibit a concentration response; however, only the carrot weight data provide a reliable representation of the concentration response curve (*i.e.,* >50% inhibition was observed in the concentration range tested). Therefore, confidence in the carrot weight regression estimate is only minimally impacted by reduced survival. The reviewer is less confident in the carrot height regression estimates because the range of responses at the concentration levels tested capture only a small portion of the dose response curve. The remaining endpoints for both onion and carrots exceeded 50% inhibition across the concentration range tested and thus the regression estimates are considered reliable. The reduction in onion survival did not impact confidence in the onion growth regression estimates.

The following phytotoxic symptoms were noted: necrosis and chlorosis. Both carrot and onion showed severe phytotoxicity. Treatment-related phytotoxicity exhibited a dose-dependent response in both species.

This study is scientifically sound and is classified as acceptable.

Non-guideline – Chronic Larval Honey Bee Oral Toxicity (MRID 50982325)

Individual synchronized newly hatched honey bee (*Apis mellifera*) larvae were exposed *in vitro* to chirally enriched L-glufosinate ammonium (82.45% active ingredient; ai) on Days 3 (D3) through Day 6 (D6) of the study at the nominal dietary concentrations of 0, 20, 39, 78, 160, 310, and 630 mg ai/kg diet, representing nominal daily doses of 0, 0.78, 1.6, 3.3, 6.3, 13, and 25 µg ai/larva/day. Mean-measured dietary concentrations were 0, 16.8, 34.0, 70.5, 147, 285, and 571 mg ai/kg diet, representing mean-measured daily doses of 0, 0.65, 1.3, 2.8, 5.5, 11, and 22 µg ai/larva/day.

Dimethoate was tested as a reference toxicant at a nominal dose of 7.39 µg ai/larva. Control and L-glufosinate ammonium treatment groups consisted of 48 larvae sourced from three separate colonies (16 larvae/colony), placed within 48-well cell culture plates. Each individual bee (well) was a replicate.

Emergence was the only affected measurement endpoint in this study. The maximum effect was 69% reduction in adult bee emergence, and there was a clear dose response. The NOAEC and EC_{50} are 70.5 and 405 mg ai/kg diet, respectively (corresponding to a NOAEL and ED_{50} of 2.8 and 16 µg ai/larva/day, respectively). At the LOAEC of 147 mg ai/kg diet (LOAEL=5.5 µg ai/larva/day) there was a 19% reduction in adult emergence.

This study is scientifically sound and is classified as acceptable.

850.4550 – Cyanobacteria Toxicity (MRID 50982326)

In a 96-hour toxicity study, cultures of *Anabaena flos-aquae* were exposed to chirally enriched L-glufosinate ammonium (82.45% active ingredient; ai) under static conditions. The nominal concentrations were 0 (negative control), 6.3, 13, 25, 50, and 100 µg ai/L. The L-glufosinate ammonium was stable under the testing conditions, with 96-hour concentrations ranging from percent 86 to 102% of initial-measured concentrations. The reviewer used the mean-measured concentrations for analysis and reporting, which were <1.0 (<MDL, negative control), 6.3, 13, 26, 52, and 97 µg ai/L.

The percent growth inhibition in cell density in the L-glufosinate ammonium-treated algal cultures as compared to the control ranged from 7 to 98%. Yield, growth rate, and area under the curve were significantly ($p<0.05$) affected (*i.e.*, reduced) in the L-glufosinate ammonium treatments. The most sensitive endpoint was reduced yield, with NOAEC and IC_{50} values of 6.3 and 35 µg ai/L, respectively. Cells appeared to be healthy and normal in appearance.

There were notable increases in pH in in the control and mean-measured 6.3, 13, and 26 µg ai/L treatment groups from 7.4-7.5 at test initiation to 9.0-9.1 at test termination. The pH remained essentially unchanged in the two highest test levels, starting at 7.4 at test initiation and being 7.3-7.4 at test termination.

This study is scientifically sound and is classified as acceptable.

Table C-2. Summary of Effects Studies Submitted for L-glufosinate Acid.

Guideline/Study Title (Species, if applicable)	Classification (MRID)	Test Material (TGAI or TEP)	Study Results (reported in acid equivalents)	Notes
850.2100 Avian Acute Oral Japanese Quail (*Coturnix coturnix japonica*)	Unacceptable (51036676)	TGAI	Not estimated	
850.2200 Avian Acute Dietary Japanese Quail (*Coturnix coturnix japonica*)	Unacceptable (51036677)	TGAI	Not estimated	
850.1075 Acute Freshwater Fish Rainbow Trout (*Oncorhynchus mykiss*)	Supplemental For Quantitative Use (51036678)	TGAI	96-hr LC_{50} > 92.9 mg ae/L	Practically non-toxic on an acute exposure basis.
850.1075 Acute Freshwater Fish Common Carp (*Cyprinus carpio*)	Acceptable (51036679)	TGAI	96-hr LC_{50} > 103 mg ae/L	Practically non-toxic on an acute exposure basis.
850.1075 Acute Freshwater Fish Common Carp (*Cyprinus carpio*)	Supplemental For Qualitative Use (51036680)	TEP	96-hr LC_{50} = 3.77 mg ae/L	Moderately toxic on an acute exposure basis.
850.1010 Acute Freshwater Invertebrate Waterflea (*Daphnia magna*)	Acceptable (51036681)	TGAI	48-hr EC_{50} > 103 mg ae/L	Practically non-toxic on an acute basis.
850.1010 Acute Freshwater Invertebrate Waterflea (*Daphnia magna*)	Supplemental For Qualitative Use (51036682)	TEP	48-hr EC_{50} = 2.72 mg ae/L	Moderately toxic on an acute basis.

Guideline/Study Title (Species, if applicable)	Classification (MRID)	Test Material (TGAI or TEP)	Study Results (reported in acid equivalents)	Notes
850.1035 Acute Estuarine/Marine Invertebrate Mysid Shrimp (*Americamysis bahia*)	Acceptable (51036684)	TGAI	96-hr LC_{50} = 7.9 mg ae/L	Moderately toxic on an acute exposure basis.
850.1350 Life-cycle Estuarine/Marine Invertebrate Mysid Shrimp (*Americamysis bahia*)	Supplemental For Quantitative Use (51036685)	TGAI	NOAEC = 0.067 mg ae/L MATC = 0.108 mg ae/L LOAEC = 0.173 mg ae/L	The most sensitive endpoints are growth (↓21-22% in body weight and ↓8-9% in length across both sexes) and reproduction (↓30% in the number of offspring/female).
OECD TG 213 Honey Bee Acute Oral Adult Toxicity (*Apis mellifera*)	Supplemental For Quantitative Use (51036686)	TGAI	48-hr LD_{50} > 97.7 µg ae/bee	Practically non-toxic on an acute basis
850.3020 Honey Bee Acute Contact Adult Toxicity (*Apis mellifera*)	Supplemental For Quantitative Use (51036687)	TGAI	48-hr LD_{50} > 96.3 µg ae/bee	Practically non-toxic on an acute basis.
OECD TG 239 Honey Bee Chronic Larval Toxicity (*Apis mellifera*)	Acceptable (51036689)	TGAI	<u>Acute</u> 8-day LD_{50} > 18 µg ae/larva[2] <u>Chronic</u> NOAEL = 6.5 µg ae/larva/day LOAEL = 14 µg ae/larva/day	The most sensitive chronic endpoint is adult emergence (79% reduction at the LOAEL)
850.3100 Earthworm Toxicity (*Eisenia fetida*)	Unacceptable (51036690)	TGAI	Not estimated.	
850.4100 Seedling Emergence (Various Species[1])	Supplemental For Quantitative Use (51036692)	EP	<u>Monocotyledonous Plants (onion)</u> EC_{25} > 0.52 lb ae/A NOAEC = 0.27 lb ae/A <u>Dicotyledonous Plants (lettuce)</u> EC_{25} = 0.176 lb ae/A NOAEC = 0.14 lb ae/A	The most sensitive endpoint is shoot height for monocotyledonous plants and survival for dicotyledonous plants.

Guideline/Study Title (Species, if applicable)	Classification (MRID)	Test Material (TGAI or TEP)	Study Results (reported in acid equivalents)	Notes
850.4150 Vegetative Vigor (Various Species[1])	Acceptable (51036693)	EP	<u>Monocotyledonous Plants (onion)</u> EC_{25} = 0.263 lb ae/A NOAEC = 0.14 lb ae/A <u>Dicotyledonous Plants (cucumber)</u> EC_{25} = 0.0266 lb ae/A NOAEC = 0.016 lb ae/A	The most sensitive endpoint is dry weight for both monocotyledonous and dicotyledonous plants.
850.4400 Aquatic Vascular Plant Toxicity Duckweed (*Lemna gibba*)	Acceptable (51036694)	TGAI	IC_{50} = 0.59 mg ae/L NOAEC = 0.25 mg ae/L LOAEC = 0.60 mg ae/L	The most sensitive endpoint is final biomass (50% decrease at the LOAEC)
850.4500 Aquatic Non-Vascular Plant Toxicity Green Alga (*Raphidocelis subcapitata*)	Supplemental For Qualitative Use (51036696)	TEP	IC_{50} = 0.70 mg ae/L NOAEC = 0.058 mg ae/L LOAEC = 0.18 mg ae/L	The most sensitive endpoint is yield (10% decrease at the LOAEC)
850.4550 Aquatic Non-Vascular Plant Toxicity Cyanobacterium (*Anabaena flos-aquae*)	Acceptable (51036697)	TGAI	IC_{50} = 0.026 mg ae/L NOAEC = 0.018 mg ae/L LOAEC = 0.045 mg ae/L	The most sensitive endpoint is yield (93% decrease at the LOAEC)
870.1100 Acute Oral Toxicity Mammals Norway Rat (*Rattus norvegicus*)	Acceptable (51036631)	TGAI	> 300 mg ae/kg bw > LD_{50} < 2,000 mg ae/kg bw	Moderately to slightly toxic on an acute exposure basis.
870.3800 Reproduction and Fertility Effects Mammals Norway Rat (*Rattus norvegicus*)	Acceptable/Guideline (51036662)	TGAI	NOAEL = 7 mg ae/kg bw/day LOAEL = 61 mg ae/kg bw/day	The most sensitive endpoint is a decrease in live pups born (40-43%) in both generations
Non-guideline Non-target arthorpod toxicity Predaceous mite (*Phytoseiulus persimilis*)	Supplemental For Qualitative Use (51631401)	TGAI	NOAEC < 22.4 µg ae/cm^2 LOAEC = 22.4 µg ae/cm^2	Most sensitive endpoint is mortality (100% at the LOAEC)
Non-guideline Non-target arthorpod toxicity Parasitic wasp (*Aphidius shopalosiphi*)	Supplemental For Qualitative Use (51631402)	TGAI	LR_{50} = 0.044 lbs ae/A NOAEC = 0.0112 lbs ae/A	Most sensitive endpoint is mortality (60% at the LOAEC)

Guideline/Study Title (Species, if applicable)	Classification (MRID)	Test Material (TGAI or TEP)	Study Results (reported in acid equivalents)	Notes
Non-guideline Non-target arthorpod toxicity Parasitic wasp (*Aphidius colemani*)	Supplemental For Qualitative Use (51631403)	TGAI	NOAEC < 22.4 µg ae/cm^2 LOAEC = 22.4 µg ae/cm^2	Most sensitive endpoint is mortality (100% at the LOAEC)
Non-guideline Non-target arthorpod toxicity Flower bug (*Orius strigicollis*)	Supplemental For Qualitative Use (51631404)	TGAI	NOAEC < 22.4 µg ae/cm^2 LOAEC = 22.4 µg ae/cm^2	Most sensitive endpoint is mortality (20% at the LOAEC)

EC_{50}=concentration resulting in 50% effect; IC_{50}=concentration resulting in 50% inhibition; LC_{50}=concentration lethal to 50% of the organisms tested; LD_{50}=lethal dose to 50% of the organisms tested; LR_{50}=application rate resulting in 50% mortality; NOAEC=no-observed adverse effect concentration; NOAEL=no-observed adverse effect level; LOAEC=lowest observed adverse effect concentration; LOAEL=lowest observed adverse effect level; MRID=master record identification (number); OECD TG = Organization of Economic Co-operation and Development Test Guideline; TGAI = Technical Grade Active Ingredient; TEP = Typical End-use Product; ai = active ingredient

[1] One monocot species [onion (*Allium cepa*)] and three dicot species [cucumber (*Cucumis sativa*), lettuce (*Latuca sativa*), and carrot (*Daucus carota*)] were tested.

[2]Estimated based on the 8-day larval mortality data and dose level administered on the first day of dosing (*i.e.,* study Day 3) from the chronic larval study (MRID 51036689)

850.2100 – Acute Oral Avian Toxicity (MRID 51036676)

The acute oral toxicity of chirally enriched technical grade L-glufosinate acid (Glufosinate-P; AH-01; 93.93% active ingredient; ai) to 17-week old Japanese quail (*Coturnix coturnix japonica*) was assessed over 14 days. The glufosinate acid was administered to the birds via oral gavage at nominal concentrations of 0 (negative control), 125, 250, 500, 1000, and 2000 mg ai/kg bw.

Body weight reductions were observed for male birds only during the first 7 days of the study in the nominal 1000 mg ai/kg bw treatment group. Food consumption was most notably reduced compared to the control group during the Day 0 to 3 period in the nominal 1000 mg ai/kg bw dose group. Sublethal effects, including loss of coordination (balance disorder), writhing, and decreased activity were observed in the nominal 1000 and 2000 mg ai/kg bw treatment groups.

After 14 days, no mortality was observed in the control or the nominal 125, 250, and 500 mg ai/kg bw treatment groups. Mortality reached 40% and 90% in the nominal 1000 and 2000 mg ai/kg bw treatment groups, respectively. There is uncertainty surrounding the exposure in control and L-glufosinate treatment groups in this study because controls and test solutions were not verified analytically. L-glufosinate is not expected to dissipate in distilled water and dosing solutions prepared correctly should approximate nominal concentrations; however, poor recovery from test media in other studies conducted by the performing laboratory introduced uncertainty in evaluating the concentration response. Consequently, the results of this study cannot be used qualitatively or quantitatively for risk assessment.

This study is not scientifically sound and is classified as unacceptable.

850.2200 – Subacute Dietary Avian Toxicity (MRID 51036677)

The subacute dietary toxicity of chirally enriched L-glufosinate acid (Glufosinate-P; AH-01) technical grade active ingredient (93.93% active ingredient; ai) to young adult Japanese quail (*Coturnix coturnix japonica*) was assessed over 8 days. The L-glufosinate acid was administered to the birds for 5 days in the diet at nominal concentrations of 0 (negative control), 312.5, 625, 1250, 2500, and 5000 mg ai/kg diet, followed by a 3-day recovery period with untreated feed. The recoveries of the L-glufosinate in the avian diet after preparation ranged from 14.3 to 31.4% of nominal. The study author applied a correction factor of 3.4 to these concentrations (based on recovery during the method validation), yielding recoveries ranging from 49 to 107% of nominal. Although there was consistency observed in the recovery results from which the corrective factor was derived, the low recovery suggests the analytical method was inadequate for evaluating concentration in the diet. Furthermore, there are additional uncertainties related to the exposure analysis including lack of analytical verification of the stability and homogeneity of L-glufosinate acid in the test diets that diminish confidence in the reliability of the corrective factor and the reported measured concentrations. Absence of the treatment item in the control was also not analytically verified.

By Day 8, there was no mortality in the control group and two lowest L-glufosinate test levels. Mortality reached 10, 10, and 30% in the nominal 1250, 2500, and 5000 mg ai/kg diet treatment groups, respectively.

Body weights were statistically ($p<0.05$) different (reduced) in all L-glufosinate-treated groups as compared to the control for the 5-day exposure period, but no effects were found for the 3-day recovery period. Mean food consumption was reduced in all L-glufosinate exposure levels as compared to the control for the entirety of the study.

Behavioral abnormalities (balance disorder) were only observed in the nominal 5000 mg ai/kg diet treatment group. Balance disorder was not defined by the study authors and is assumed to represent loss of coordination. Gross necropsies on the birds that died during the study showed “weak general condition”; however, “weak general condition” was also observed during necropsy of the surviving control animals and in the nominal 312.5, 1250, 2500, and 5000 mg ai/kg diet treated animals. The term “weak general condition” was not defined by the study authors as to what specific anatomical features represented such a condition. The incidence of this finding in glufosinate-treated birds exceeded the frequency in controls and exhibited a concentration response at mean-measured concentrations >2500 mg ai/kg diet.

This study is not scientifically sound and is classified as unacceptable.

850.1075 – Acute Freshwater Fish Toxicity (MRID 51036678)

In a 96-hr acute toxicity limit test, Rainbow Trout (*Oncorhynchus mykiss*) were exposed to technical grade L-glufosinate acid (Glufosinate-P (AH-01); 93.93% active ingredient; ai) at nominal concentrations of 0 (negative control) and 100 mg ai/L under static conditions. The glufosinate was stable under the test conditions and therefore mean-measured concentrations were used for analysis and reporting. The mean-measured concentration of the single glufosinate exposure level was 92.90 mg ai/L.

No sublethal effects or mortality were observed in the control or in the single limit concentration during the test. The 96-h LC_{50} value was empirically estimated to be >92.90 mg ai/L.

Based on the results of this study, technical grade L-glufosinate acid would be classified as practically non-toxic to *O. mykiss* on an acute exposure basis in accordance with the classification system of the U.S. EPA.

This study is scientifically sound and is classified as supplemental. These data can be used quantitatively. The study can be upgraded if additional data are provided on measured glufosinate residues in control samples along with additional information on the quality of water used in the study.

850.1075 – Acute Freshwater Fish Toxicity (MRID 51036679)

In a 96-hr acute toxicity limit test, Common Carp (*Cyprinus carpio*) were exposed to the chirally enriched technical grade L-glufosinate acid (L-Glufosinate-P (AH-01); 93.89% active ingredient; ai) at nominal concentrations of 0 (negative control) and 100 mg ai/L under static-renewal conditions. The L-glufosinate acid was stable under the static-renewal test conditions, so the mean-measured concentrations were used for analysis and reporting. The mean-measured concentrations were <10.0 (<Limit of Detection [LOD], control) and 103 mg ai/L.

No sublethal effects nor mortality were observed in the control or in the single L-glufosinate acid treatment level during the exposure. The 96-hr LC_{50} value was empirically determined to be >103 mg ai/L.

Based on the results of this study, technical grade L-glufosinate acid would be classified as practically nontoxic to *C. carpio* on an acute exposure basis in accordance with the classification system of the U.S. EPA.

This study is scientifically sound and is classified as acceptable.

850.1075 – Acute Freshwater Fish Toxicity (MRID 51036680)

In a 96-hr acute toxicity study, Common Carp (*Cyprinus carpio*) were exposed to the L-glufosinate acid formulated end-use product (AH-01 Liquid; 11.5% active ingredient; ai) at nominal concentrations of 0 (negative control), 1.14, 2.52, 3.52, 4.93, and 6.90 mg ai/L under static-renewal test conditions. The corresponding formulation concentrations were 9.94, 21.9, 30.6, 42.9, and 60.0 mg form/L. Analytical verification was not performed for the test solutions. Therefore, the nominal concentrations based on the active ingredient were used for analysis and reporting.

Sublethal effects such as fish being at the surface, loss of equilibrium, lethargy, and reduced activity were observed in the second highest L-glufosinate acid treatment after 24 hours of exposure, but the effects were not quantified. No sublethal effects were detected in the control or three lowest L-glufosinate treatment concentrations. Sublethal effects were present in the highest level-glufosinate treatment at 3 hours after exposure, but mortality reached 100% by 24 hours.

Mortality reached a maximum of 100% in the 4.93, and 6.90 mg ai/L test levels. The 96-hour LC_{50} was 3.77 mg ai/L, based on the reviewer's results and the nominal concentrations based on the active ingredient content of the formulation. Analytical verification of the control and exposure solutions was not performed during the study; therefore, the reviewer could not confirm that the control group was not contaminated with L-glufosinate, that the exposure in each treatment group approximated the reported nominal concentrations, nor that the L-glufosinate acid was stable under the test conditions. While L-glufosinate acid dosing solutions prepared correctly should approximate nominal concentrations for the TGAI, it is uncertain if this remains true for formulations. It is, therefore, uncertain whether the nominal concentrations of L-glufosinate reported in this TEP study reflect the actual concentration in solution. Consequently, the results from this study may only be used qualitatively.

Based on the results of this study, the active ingredient L-glufosinate acid would be classified as moderately toxic to *Cyprinus carpio* in accordance with the classification system of the U.S. EPA.

This study is scientifically sound and is classified as supplemental. The results of this study may be used qualitatively only.

850.1010 – Acute Freshwater Invertebrate Toxicity (MRID 51036681)

In a 48-hour acute toxicity, *Daphnia magna* were exposed to the chirally enriched technical grade L-Glufosinate Acid (AH-01; 93.89% active ingredient; ai) at nominal concentrations of 0 (negative control) and 100 mg ai/L under static conditions. The L-glufosinate acid was stable under the static test conditions, so the mean-measured concentrations were used for analysis and reporting. The mean-measured concentrations were <10.0 (<LOD, negative control) and 103 mg ai/L.

No sublethal effects or mortality were observed during the limit test. The 48-hour EC_{50} was empirically estimated as >103 mg ai/L, based on the mean-measured concentration used in the study.

Based on the results of this study, technical grade L-glufosinate acid (AH-01) would be classified as practically non-toxic to *D. magna* on an acute exposure basis in accordance with the classification system of the U.S. EPA.

This study is scientifically sound and is classified as acceptable.

850.1010 – Acute Freshwater Invertebrate Toxicity (MRID 51036682)

In a 48-hour acute toxicity study, *Daphnia magna* were exposed to the chirally enriched L-glufosinate acid formulated end-use product AH-01 Liquid (11.5% active ingredient**)** at nominal concentrations of 0 (control), 9.53, 17.1, 30.9, 55.6, and 100 mg form/L (equivalent to 1.10, 1.97, 3.55, 6.39, and 11.5 mg ai/L) under static conditions.

Immobilization and sublethal effects were observed daily during the test. Sublethal effects, specifically lethargy and reduced activity, were observed in the nominal 1.97 and 3.55 mg ai/L test levels at test termination. After 48 hours of exposure, 95 to 100% of the daphnids were immobilized in the three highest L-glufosinate acide treatments, while no immobilizations occurred in the control or two lowest L-glufosinate treatments. The 48-hour EC_{50} was 2.72 mg ai/L, based on the nominal concentrations and the reviewer's results.

Analytical verification of the control and exposure solutions was not performed during the study and, therefore, the reviewer could not confirm that the control group was not contaminated with L-glufosinate, that the exposure in each treatment groups approximated the reported nominal concentrations, nor that the L-glufosinate acid solutions were stable under the test conditions. While L-glufosinate acid dosing solutions prepared correctly should approximate nominal concentrations for the TGAI, it is uncertain if this remains true for formulations. It is, therefore, uncertain whether the nominal concentrations of L-glufosinate reported in this TEP study reflect the actual concentration in solution. Consequently, the results from this study may only be used qualitatively.

Based on the results of this study, the active ingredient L-glufosinate acid would be classified as moderately toxic to *Daphnia magna* in accordance with the classification system of the U.S. EPA.

This study is scientifically sound and is classified as supplemental. The results of this study may be used qualitatively only.

***850.1035 – Acute Estuarine/Marine Invertebrate Toxicity* (MRID 51036684)**

In a 96-hr acute toxicity study, marine invertebrate mysid shrimp (*Americamysis bahia*), were exposed to the chirally enriched technical grade L-glufosinate acid (91.14% active ingredient; ai) at nominal concentrations of 0 (negative control), 0.13, 0.42, 1.4, 4.6, 15, and 50 mg ai/L under static conditions. The mean-measured concentrations were <0.00125 (<LOQ, negative control), 0.12, 0.38, 1.3, 4.2, 14, and 46 mg ai/L. These were used for data analysis and reporting.

No sublethal effects or mortalities were observed in the control and two lowest L-glufosinate treatment levels throughout the duration of the test. Low mortality (5%) occurred in the third lowest test level, with no accompanying sublethal effects. After 24 hours of exposure and persisting to 96 hours of exposure, surviving mysids exposed to the three highest treatment levels of L-glufosinate were lethargic and exhibited erratic swimming. By 96 hours mortality ranged from 40 to 80% in these same test levels. The 96-hour LC50 was 7.9 mg ai/L based on the mean-measured concentrations.

Based on the results of this study, technical grade L-glufosinate acid would be classified as moderately toxic to the mysid shrimp, in accordance with the classification system of the U.S. EPA. This study is scientifically sound and is classified as acceptable.

***850.1350 – Chronic Estuarine/Marine Invertebrate Toxicity (*MRID 51036685)**

The 28-day chronic toxicity of chirally enriched technical grade L-glufosinate acid (Glufosinate-P; 94.14% active ingredient; ai) to estuarine/marine mysid shrimp (*Americamysis bahia*) was studied under flow-through conditions. Mysids were exposed to nominal concentrations of 0 (negative control), 1.8, 4.6, 12, 29, 72 and 180 µg ai/L corresponding to mean-measured concentrations of <1.25 (<LOQ, control), 1.7, 4.3, 11, 29, 67, and 173 µg ai/L.

The endpoints G_1 female and male dry weight, G_1 female and male length, and number of G_2 offspring/ G_1 female were affected (reduced) by exposure to L-glufosinate acid at the highest concentration tested. These are also the most sensitive endpoints in the study resulting in a no-observed-adverse-effects concentration (NOAEC) of 67 µg ai/L, a maximum acceptable tolerated concentration (MATC; the geometric mean of the NOAEC and LOAEC) of 108 µg ai/L, and a lowest observed adverse effect concentration (LOAEC) of 173 µg ai/L, respectively. At the LOAEC of 173 µg ai/L, mysids exhibited statistically significant decreases in male and female body weight (↓21-22%), male and female length (↓8-9%), and number of offspring/female (↓30%).

This study is scientifically sound but is classified as supplemental due to larger than recommended spacing between concentrations and uncertainty in the G_2 survival assessment. These deviations/deficiencies did not affect reviewer confidence in the reported results and the study may be used quantitatively.

Non-guideline – Acute Honey Bee Oral Toxicity (MRID 51036686)

The acute oral toxicity of technical grade L-glufosinate acid (93% active ingredient; ai) to adult honey bees, *Apis mellifera*, was evaluated in a 48-hour limit test at nominal doses of 0 (negative control) and 100 µg ai/bee. The reviewer-calculated measured dose was 97.7 µg ai/bee.

No sublethal effects or mortality were detected in the negative control or in the single L-glufosinate acid treatment throughout the 48-hr study period. Based on these data, L-glufosinate acid would be classified as practically non-toxic to adult bees on an acute oral exposure basis.

This study is scientifically sound but is classified as supplemental due to exposure uncertainties for the control group and for not reporting information on the age of the bees. Although the reviewer could not confirm that there was no L-glufosinate acid in the negative control group or even determine whether the negative control group was an adequate comparator for the treatment group, given the lack of mortality or notable sublethal effects in the treatment group, this deficiency did not impact interpretation of the study results. The results may be used quantitatively for risk assessment.

850.3020 – Acute Honey Bee Contact Toxicity (MRID 51036687)

The acute contact toxicity of technical grade L-glufosinate acid (93% active ingredient; ai) to adult honey bees, *Apis mellifera*, was evaluated in a 48-hour limit test at nominal doses of 0 (negative and solvent [Triton® X-100 0.05%] control) and 100 µg ai/bee corresponding to a measured dose of 96.3 µg ai/bee.

There were no sublethal effects or mortality observed in either control group or in the single treatment group tested. Therefore, the LD_{50} was empirically determined to be greater than the limit dose tested.

This study is scientifically sound but classified supplemental due to the lack of concentration analysis on the negative and solvent controls and for not reporting information on the age of the adult bees. Although the reviewer could not confirm that there was no L-glufosinate acid in either control solution or determine whether the negative control group was an adequate comparator for the L-glufosinate treatment group, given the lack of mortality or notable sublethal effects in the controls or L-glufosinate treatment group, this deficiency did not impact interpretation of the data. The results may be used quantitatively for risk assessment.

Non-guideline – Chronic Larval Honey Bee Oral Toxicity (MRID 51036689)

Individual synchronized honey bee (*Apis mellifera*) larvae (3-day old larvae) were exposed *in vitro* to technical grade chirally enriched L-glufosinate acid (94.14% active ingredient; ai) on Day

3 (D3) through Day 6 (D6) of the study at the nominal dietary concentrations of 0, 39, 78, 160, 310, and 630 mg ai/kg diet representing nominal daily doses of 0, 1.6, 3.3, 6.3, 13, and 25 µg ai/larva/day. Mean-measured dietary concentrations were < Limit of Quantification (LOQ), 43, 94, 186, 375, and 721 mg ai/kg diet, representing mean-measured daily doses of <LOQ, 1.5, 3.3, 6.5, 14, and 26 µg ai/larva/day.

Dimethoate (purity of 99.56%) was used as a reference toxicant at a nominal concentration of 0.0528 mg ai/mL (corresponding to 7.39 µg ai/larva). Each bee within a particular treatment was considered a replicate (*i.e*., 48 bees per L-glufosinate acid treatment, dimethoate treatment, and negative control).

By Day 20, all bees either emerged or died. Adult emergence was the most sensitive measurement endpoint. Biologically significant decreases in adult emergence were observed at dose levels $\geq$14 µg ai/larva/day, with a maximum effect of 74% at the highest dose tested (26 µg ai/larva/day). The adult emergence NOAEC and EC_{50} were 186 and 282 mg ai/kg diet, respectively (corresponding to a NOAEL and ED_{50} of 6.5 and 10 µg ai/larva/day, respectively). Pupal (*i.e.,* Day 15 mortality) and larval mortality (*i.e.,* Day 8 mortality) were also impacted by treatment, resulting in mortality of up to 31% and 38%, respectively, at the highest dose tested (26 µg ai/larva/day). This study is scientifically sound and classified acceptable**.**

850.3100 – Acute Earthworm Toxicity (MRID 51036690)

In an acute toxicity study, earthworms (*Eisenia fetida*) were exposed to technical grade chirally enriched L-glufosinate acid (Glufosinate-P, 93.93% active ingredient; ai) at nominal concentrations of 0 (negative control), 62.5, 125, 250, 500, and 1000 mg ai/kg dry weight (dw) soil.

A single mortality was observed in the nominal 125 mg ai/kg dw soil treatment group during the exposure period. No mortalities were recorded in the other L-glufosinate acid treatment groups or the control. Due to a maximum mortality of 3%, the NOAEC and LC_{50} values were empirically determined to be 1000 and >1000 mg ai/kg dw soil, respectively. Based on the study author's results, there were no significant effects on percent body weight change. No behavioral abnormalities were observed.

This study is not scientifically sound and is classified as unacceptable. Given that the soil was not allowed to equilibrate with the test material prior to exposure and the test soils were not analytically verified for homogeneity or L-glufosinate acid concentration, the reviewer was not confident the reported nominal concentrations reflected the actual soil concentrations. Issues with L-glufosinate recovery from exposure media in the acute dietary avian study (MRID 51036677) conducted by the same laboratory, further diminish reviewer confidence in the results of this study.

850.4100 - Seedling Emergence (MRID 51036692)

The effect of the L-glufosinate sodium salt (10.38% w/w% active ingredient; ai) on the seedling emergence of one monocot crop (onion, *Allium cepa*) and three dicot crops (cucumber, *Cucumis sativa*; carrot, *Daucus carota*; and lettuce, *Lactuca sativa*) was studied. Nominal treatment rates ranged from 0.0088 to 0.56 lb ai/A for all species. The test concentrations were analytically confirmed at all glufosinate treatment levels.

The growth medium used in the seedling emergence test was a mixture of kaolinite clay, industrial quartz sand and peat, with limestone added to buffer the pH (loamy sand; pH 6.6; percent organic carbon 0.97%). On Day 21 for onion, cucumber, and lettuce and Day 28 for carrot, the surviving plants per pot were recorded and cut at soil level for measuring the plant height and dry weight.

Negative control seedling emergence ranged from 75 to 95% for cucumber, lettuce, and onion, and was 58% for carrot. When compared to the negative control, there were no significant inhibitions in emergence found for any of the species tested. Carrot emergence did not meet the validity requirements for a seedling emergence study; therefore, data for carrot survival, shoot height, and shoot dry weight are considered unreliable and not discussed further.

Survival was based on the number of seeds planted. Negative control survival ranged from 75 to 95% for cucumber, lettuce, and onion. Inhibition of plant survival in the glufosinate treatment groups ranged from -17 to 14% in onions, -3 to 11% in cucumber, and -13% to 63% in lettuce compared to the negative control. Significant inhibitions in survival were found in lettuce only. When compared to the negative control, inhibition in lettuce was significant at measured 0.28 lb ai/A and higher.

Inhibition of shoot height in the treatment groups ranged from -3-20% in onions, -2 to 29% in cucumber, and -19% to 34% in lettuce compared to the negative control. Significant ($p<0.05$) inhibition in shoot height was noted in cucumber. When compared to the negative control, inhibition in cucumber height was significant at measured rates >0.28 lb ai/A. Although the statistical analysis indicated onion height was significantly ($p<0.05$) inhibited at measured 0.034 lb ai/A, the relevance of this finding is uncertain as there was no consistent concentration response at higher treatment levels and higher treatment levels were not significantly inhibited compared to the negative control. Large variability in the shoot height response, particularly in the measured 0.27 and 0.52 lb ai/A treatment groups, further confounded interpretation of the inhibition observed; however, there was a general trend toward decreased shoot height with increasing concentration and the mean inhibition (20%) at measured 0.52 lb ai/A, was considered by the reviewer to be of a magnitude that represented an adverse response to the glufosinate treatment.

Inhibition of shoot dry weight in the glufosinate treatment groups ranged from 1-25% in onions, -25 to 17% in cucumber, and -34% to 37% in lettuce compared to the negative control. Significant ($p<0.05$) inhibition in shoot dry weight was observed in cucumber only. When

compared to the negative control, inhibition in cucumber dry weight was significant ($p<0.05$) at measured 0.52 lb ai/A, the highest test concentration.

Only one monocot species (*i.e.,* onion) was tested. The most sensitive measurement endpoint for onion was height, with NOAEC of 0.27 lb ai/A. Given that inhibition for all onion endpoints did not exceed 25%, the reviewer did not consider these data appropriate for estimating IC_{25} values from a regression analysis. Empirically, the IC_{25} for all onion endpoints including shoot height is estimated to be >0.52 lb ai/A. The reviewer noted that onion dry weight was inhibited in all glufosinate treatment groups compared to controls and reached a maximum inhibition of 25% in the measured 0.034 lb ai/A treatment group; however, the response did not exhibit a clear relationship with concentration (*i.e.,* inhibition at the highest concentration was 19%) and none of the findings were statistically significant, thus it is uncertain whether the inhibition observed at the lower treatment levels are entirely treatment-related. The reviewer was more confident in the shoot height data; therefore, the endpoints were established based on that parameter. The most sensitive dicot species was lettuce, based on survival, with NOAEC and IC_{25} values of 0.14 and 0.176 lb ai/A, respectively.

The following phytotoxic symptoms were noted for all test species: chlorosis, necrosis, and leaf curling. All species showed moderate levels of phytotoxic symptoms. Onion and lettuce phytotoxic symptoms exhibited a dose-dependent response. Phytotoxic symptoms were observed in control plants, but these symptoms were slight in severity and were not considered to be related to the treatment.

This study is scientifically sound but is classified as supplemental because control carrot emergence did not meet the guideline requirements for an acceptable test and the study authors did not test up to highest labeled application rate which lead to some uncertainty in establishing the most sensitive endpoints for the only monocot species tested.

850.4150 – Vegetative Vigor (MRID 51036693)

The effect of the L-glufosinate sodium salt (10.38 % (w/w%) active ingredient) on the vegetative vigor of one monocotyledonous (monocot) (onion, *Allium cepa*) and three dicotyledonous (dicot) plants (cucumber, *Cucumis sativa*; carrot, *Daucus carota*; and lettuce, *Lactuca sativa*) was studied. Nominal treatment concentrations ranged from 0.00055 to 0.070 lb ai/A for cucumber, 0.0011 to 0.14 lb ai/A for carrot and lettuce, and 0.0044 to 0.56 lb ai/A for onion. The L-glufosinate sodium test concentrations were analytically confirmed at all treatment levels.

The growth medium used in the vegetative vigor test was a mixture of kaolinite clay, industrial quartz sand and peat, with limestone added to buffer the pH (loamy sand; pH 6.6; percent organic carbon 0.97%). On Day 21, the surviving plants per pot were recorded and cut at soil level for measuring the plant height and dry weight.

Negative control survival was 100% in all species tested. When compared to the negative control, significant ($p<0.05$) inhibitions were found in cucumber, lettuce, and onion. Inhibition in cucumber survival was significant ($p<0.05$) at measured 0.067 lb ai/A, inhibition in lettuce survival was significant ($p<0.05$) at measured 0.14 lb ai/A, and inhibition in onion survival was significant ($p<0.05$) at measured 0.54 lb ai/A, the highest L-glufosinate sodium test concentrations for these species.

Significant ($p<0.05$) inhibitions in seedling height were found in all species tested. When compared to the negative control, inhibition in cucumber height was significant at measured 0.034 lb ai/A and higher. Inhibitions in carrot and lettuce height were significant at measured 0.14 lb ai/A, the highest test concentration for these species. Inhibition in onion height was significant at measured 0.27 lb ai/A and higher.

Significant inhibitions in seedling dry weight were found in all species tested. When compared to the negative control, inhibition in cucumber dry weight was significant at measured 0.034 lb ai/A and higher. Inhibitions in carrot and lettuce dry weight were significant at measured 0.14 lb ai/A, the highest test concentration for these species. Inhibition in onion dry weight was significant at measured 0.27 lb ai/A and higher.

Only one monocot species (*i.e.,* onion) was tested. The most sensitive endpoint for onion was reduced dry weight, with NOAEC and IC_{25} values of 0.14 and 0.263 lb ai/A, respectively. The most sensitive dicot species was cucumber based on reductions in dry weight, with NOAEC and IC_{25} values of 0.016 and 0.0266 lb ai/A, respectively.

The following signs of phytotoxic effects were noted for all test species: chlorosis, necrosis, and leaf curling. In carrots, signs of phytotoxic symptoms were categorized as “slight” while “moderate” phytotoxicity was observed in lettuce and onion, and “severe” phytotoxicity was observed in cucumber. Onion and cucumber phytotoxicity exhibited a concentration-dependent response. Signs of phytotoxicity were observed in control plants, but these signs were “slight” in severity. This study is scientifically sound and is classified as acceptable.

850.4400 – Aquatic Vascular Plant Toxicity (MRID 51036694)

In a 7-day toxicity study, fronds of the freshwater floating aquatic vascular plant duckweed (*Lemna gibba*) were exposed to chirally enriched technical grade L-glufosinate free acid (Glufosinate-P; 94.14% active ingredient) at nominal concentrations of 0 (negative control), 0.10, 0.26, 0.64, 1.6, 4.0, and 10 mg ai/L under static-renewal conditions. Mean-measured concentrations were <0.013 (<MDL, control), 0.097, 0.25, 0.60, 1.5, 3.9, and 10 mg ai/L.

The percent inhibition in the number of fronds in the L-glufosinate-treated cultures ranged from -9 to 93% relative to the negative control. Significant ($p<0.05$) and concentration-dependent reductions in frond number yield, frond number growth rate, final biomass, and biomass growth rate were observed in plants exposed to L-glufosinate at concentrations $\geq$0.60 mg ai/L, with inhibitions ranging from 14-100% relative to controls. After 7 days of exposure

under static-renewal conditions, phytotoxic effects such as chlorotic fronds, reduced root formation, and smaller fronds compared to the control, were observed in the four highest L-glufosinate treatment levels. The most sensitive endpoint was final biomass, with NOAEC and IC_{50} values of 0.25 and 0.59 mg ai/L, respectively. This study is scientifically sound and is classified as acceptable.

850.4400 – Aquatic Non-vascular Plant Toxicity (MRID 51036696)

In a 72-hour toxicity study, cultures of the freshwater green alga *Raphidocelis subcapitata* [formerly *Pseudokirchneriella subcapitata* (strain ATCC 22662)], were exposed to chirally enriched formulated end-use product of L-glufosinate acid (AH-01 Liquid; 11.5% ai) at nominal concentrations of 0 (negative control), 0.500, 1.58, 5.00, 15.8, and 50.0 mg form/L under static conditions representing nominal concentrations of the active ingredient of 0 (negative control), 0.0575, 0.182, 0.575, 1.82, and 5.75 mg ai/L, respectively. Analytical verification of the control and exposure solutions was not performed during the study; therefore, results are presented based on nominal concentrations.

A concentration-dependent decrease in cell density, growth rate, and area under the curve (AUC) was observed in the treatment groups. Phytotoxic effects (*i.e*., swollen cells and aggregation of algae), were observed in all L-glufosinate treatment levels at test termination. After 72 hours of exposure, all endpoints were significantly affected by the test material. The most sensitive endpoint was yield, with NOAEC and IC_{50} values of 0.0575 and 0.699 mg ai/L, respectively, based on the active ingredient nominal concentrations.

The pH at the beginning of the exposure ranged from 7.8 to 7.9. After 72 hours of exposure, the pH slightly increased in the control and all treatment levels. The pH in the control and highest treatment level was 7.9 while the pH in all other treatment levels was 8.0.

Analytical verification of the control and exposure solutions was not performed during the study and, therefore, the reviewer could not confirm that the control group was not contaminated with L-glufosinate, that the exposure in each treatment groups approximated the reported nominal concentrations, nor that the L-glufosinate was stable under the test conditions. While L-glufosinate acid dosing solutions prepared correctly should approximate nominal concentrations for the TGAI, it is uncertain if this remains true for formulations. It is, therefore, uncertain whether the nominal concentrations of L-glufosinate reported in this TEP study reflect the actual concentration in solution.

This study is scientifically sound and is classified as supplemental. The results of this study may be used qualitatively only.

***850.4550 – Cyanobacteria Toxicity* (MRID 51036697)**

In a 96-hour toxicity study, cultures of freshwater cyanobacterium, *Anabaena flos-aquae* (strain 67), were exposed to chirally enriched technical grade L-glufosinate acid (Glufosinate-P

Technical; 94.14% active ingredient; ai) at nominal concentrations of 0 (negative control), 1.0, 2.6, 6.4, 16, 40, and 100 µg ai/L under static conditions. The test material was stable at all but the lowest test concentration (nominal 1.0 µg ai/L) under test conditions. Mean-measured concentrations <0.16 (<MDL, control), 0.84, 2.9, 7.0, 18, 45, and 110 µg ai/L were used for analysis and reporting.

The percent growth inhibition in cell density of the glufosinate-treated cultures relative to the negative control ranged from -31 to 96%. All cyanobacteria cells appeared normal throughout the exposure. After preparation, the control and glufosinate exposure solutions appeared clear and colorless with no undissolved test material observed. After 96 hours, the most sensitive endpoint was yield, with NOAEC and IC_{50} values of 18 and 26 µg ai/L, respectively, based on the mean-measured concentrations. Based on the study results, glufosinate was algistatic as opposed to algicidal.

The pH at test initiation ranged from 7.3 to 7.4 in the control and in all the glufosinate exposure levels. The pH increased in the control and in the four lowest glufosinate exposure levels substantially. By test termination, the pH increased in the control to 8.6 and in the four lowest (*i.e.,* 0.84 – 18 µg ai/L) glufosinate treatments ranged from 8.8 to 8.9. In the 45 and 110 µg ai/L, the pH increased less dramatically and was 7.6 and 7.4, respectively. This study is scientifically sound and is classified as acceptable.

Non-guideline – Non-target Arthropod Acute Contact Toxicity **(MRID 51631401)**

In an acute contact non-target arthropod study, recently hatched predaceous mites (*Phytoseiulus persimilis*) were exposed for 48 hours to dried residues of AH-01 Technical (ai: L-glufosinate acid; 93.9% ai) on kidney bean leaves at a nominal concentration of 22.4 µg ai/cm^2 (~2 lbs ai/A). Dimethoate was used as a reference chemical at a nominal application concentration of 0.1 mL product/100 mL water.

Mortality was 0% in the negative control at 48 hours. In the nominal 22.4 µg ai/cm^2 treatment group, mortality increased with exposure duration resulting in 0, 90, and 100% mortality at 2, 24, and 48 hours after treatment. Sublethal effects were not evaluated in this study. Based on an empirical evaluation, the NOAEC is <22.4 µg ai/cm^2 and the LOAEC is 22.4 µg ai/cm^2. Mortality was 100% at 48 hours in the reference item (dimethoate) group.

This study is scientifically sound but is classified as supplemental because the study authors did not analytically verify the nominal concentrations, a definitive NOAEC could not be established, and due to uncertainty as to whether the study followed a GLP standard. The results of this study may only be used qualitatively for risk assessment.

Non-guideline – Non-target Arthropod Acute Contact Toxicity **(MRID 51631402)**

In the first part of an acute contact toxicity study, <48 hour old adult parasitic wasps (*Aphidius rhopalosiphi*) were exposed for 48 hours to fresh dried residues of the Glufosinate-P (AH-01)

Technical [active ingredient (ai): L-glufosinate acid; 93.9% ai] on glass plates at the nominal application rates of 0 (negative control), 0.00070, 0.0028, 0.0112, 0.0446, 0.178 lbs ai/A (corresponding to 0, 0.78, 3.125, 12.5, 50, and 200 g ai/ha, respectively). After the 48-hour exposure, reproduction was evaluated in adults in a parasitization test for 11 days. Dimethoate was used as a reference chemical at a nominal application rate of 0.3 mL product/ha.

Mortality was 5% in the negative control. Mortality in the L-glufosinate acid treatment groups ranged from -3 to 87% with a clear dose response at exposure levels $\geq$0.0028 lbs ai/A. Fecundity was only assessed in the three lowest test levels (*i.e.,* 0.00070, 0.0028, and 0.0112 lbs ai/A) due to the high observed adult wasp mortality in the two highest test levels (*i.e*., 0.0446 and 0.178 lbs ai/A). The number of mummies per female averaged 8.9 in the negative control group and ranged from 7.5 to 8.1 mummies per female (9-15% reduction compared to controls) in the L-glufosinate acid treatment groups. Fecundity was not significantly affected in the three lowest test levels. Mortality was the most sensitive measurement endpoint, with a NOAEC and LR_{50} of 0.0112 lbs ai/A (12.5 g ai/ha) and 0.044 lbs ai/A (48.91 g ai/ha), respectively, based on the nominal application rates expressed as active ingredient. Mortality reached 100% within 48 hours in the dimethoate treatment group.

This study is scientifically sound but is classified as supplemental due to the lack of a EPA or OCED guideline or formal guidance for this parasitic wasp (*A. rhopalosiphi*) study and the lack of analytical verification of nominal concentrations which results in increased uncertainty in the actual exposure levels in this study given issues with test media preparation and test material recovery noted in other studies conducted by this laboratory. The results of this study may only be used qualitatively for risk assessment.

Non-guideline – Non-target Arthropod Acute Contact Toxicity **(MRID 51631403)**

In an acute contact non-target arthropod study, <24-hour old adult parasitic wasps (*Aphidius colemani*) were exposed for 48 hours to dried residues of AH-01 Technical (ai: L-glufosinate acid; 93.9% ai) on glass plates at a nominal concentration of 22.4 µg ai/cm^2 (~2 lbs ai/A). Dimethoate was used as a reference chemical at a nominal application concentration of 43 mg/100 mL water.

Mortality was 7% in the negative control at 48 hours. In the nominal 22.4 µg ai/cm^2 treatment group, , the NOAEC is <22.4 µg ai/cm^2 and the LOAEC is 22.4 µg ai/cm^2. Mortality reached mortality increased with exposure duration resulting in 70, 90, and 100% mortality at 6, 24, and 48 hours after treatment. Sublethal effects were not evaluated in this study. Based on an empirical evaluation100% with 6 hours in the reference item (dimethoate) group.

This study is scientifically sound but is classified as supplemental because the study authors did not analytically verify the nominal concentrations, a definitive NOAEC could not be established, and due to uncertainty as to whether the study followed a GLP standard. The results of this study may only be used qualitatively for risk assessment.

Non-guideline – Non-target Arthropod Acute Contact Toxicity **(MRID 51631404)**

In an acute contact non-target arthropod study, 3rd instar flower bug larvae (*Orius strigicollis*) were exposed for 48 hours to dried residues of AH-01 Technical (ai: L-glufosinate acid; 93.9% ai) on glass plates at a nominal concentration of 22.4 µg ai/cm^2 (~2 lbs ai/A). Dimethoate was used as a reference chemical at a nominal application concentration of 0.1 mL product/100 mL water.

Mortality was 0% in the negative control at 48 hours. In the nominal 22.4 µg ai/cm^2 treatment group, mortality increased with exposure duration resulting in 0, 17, and 20% mortality at 2, 24, and 48 hours after larvae were released into the exposure chamber. Sublethal effects were not evaluated in this study. Based on an empirical evaluation, the NOAEC is <22.4 µg ai/cm^2 and the LOAEC is 22.4 µg ai/cm^2. Mortality reached 100% within 24 hours in the reference item (dimethoate) group.

This study is scientifically sound but is classified as supplemental because the study authors did not analytically verify the nominal concentrations, a definitive NOAEC could not be established, and due to uncertainty as to whether the study followed a GLP standard. The results of this study may only be used qualitatively for risk assessment.

Table C-3. L-glufosinate Terrestrial and Aquatic Non-target Organism Data Requirements to Support Section 3 New Active Ingredients.

Guideline Number - Study Type		Required	Data Requirement Status	MRID	DER Classification	Comments
Birds (surrogates for terrestrial amphibians and reptiles)						
850.2100 - Avian Acute Oral Toxicity Test	Passerine	Yes	**Waived**	NA	NA	NA
	Upland Game or Waterfowl	Yes	**Complete**	00142450 and 0014251	Acceptable	
850.2200 - Avian Sub-acute Dietary Toxicity Test	Waterfowl	Yes	**Complete**	00150989	Acceptable	NA
	Upland Game Bird	Yes	**Complete**	00150988	Acceptable	
850.2300 - Avian Reproduction Test	Waterfowl	Yes	**Complete**	40345650	Acceptable	NA
	Upland Game Bird	Yes	**Complete**	00150989	Acceptable	
Mammals						
850.2400 - Wild Mammal Toxicity Testing		No[1]	**Not Triggered**	NA	NA	NA
850.2500 - Field Testing for Terrestrial Wildlife		No[1]	**Not Triggered**	NA	NA	NA
Aquatic Invertebrates Acute Toxicity (Water-Column Exposure)						
850.1010 - Aquatic Invertebrate Acute Toxicity Test, Freshwater Daphnids		Yes	**Complete**	51036681	Acceptable	NA
850.1025 - Oyster Acute Toxicity Test (Shell Deposition)		Yes	**Complete**	41396105	Acceptable	NA
850.1035 - Mysid Acute Toxicity Test		Yes	**Complete**	41396107	Acceptable	NA
850.1045 - Penaeid Acute Toxicity Test		No[1]	**Not Triggered**	NA	NA	NA
850.1055 - Bivalve Acute Toxicity Test (Embryo-Larval)		No[1]	**Not Triggered**	NA	NA	NA
Fish Acute Toxicity (surrogates for aquatic-phase amphibians)						
850.1075 - Freshwater Fish Acute Toxicity Test	Coldwater species	Yes	**Complete**	51036678	Supplemental	NA
				50982322	Acceptable	
	Warmwater species	Yes	**Complete**	00142455 and 51102403	Acceptable	
850.1075 - Saltwater Fish Acute Toxicity Test		Yes	**Complete**	41396104	Acceptable	NA
Aquatic Invertebrate Chronic Toxicity						
850.1300 - Daphnid Chronic Toxicity Test		Yes	**Complete**	40501010	Acceptable	NA
850.1350 - Mysid Chronic Toxicity Test		Yes	**Complete**	51036685	Supplemental	NA
Fish Chronic Toxicity						

Guideline Number - Study Type		Required	Data Requirement Status	MRID	DER Classification	Comments
850.1400 - Freshwater Fish Early Life Stage (ELS) Toxicity Test		Yes	**Complete**	51102404	Acceptable	NA
850.1400 - Estuarine/ Marine Fish Early Life Stage (ELS) Toxicity Test		No[1]	**Not Triggered**	NA	NA	NA
850.1500 - Fish Life Cycle Toxicity Test	Freshwater	Yes	**Waived**	NA	NA	NA
	Estuarine/Marine	Yes	**Waived**	NA	NA	
Bioconcentration Factor (BCF) Study						
850.1710 - Oyster Bioconcentration Factor (BCF)		No[1]	**Not Triggered**	NA	NA	NA
850.1730 - Fish Bioconcentration Factor (BCF)		Yes	**Complete**	41323130	Acceptable	NA
Aquatic Invertebrates Acute Toxicity (Benthic Exposure)						
850.1735 - Spiked Whole Sediment 10-Day Toxicity Test, Freshwater Invertebrates	Midge	No[1]	**Not Triggered**	NA	NA	NA
	Freshwater Amphipod	No[1]	**Not Triggered**	NA	NA	
850.1740 - Spiked Whole Sediment 10-Day Toxicity Test, Saltwater Invertebrates		No[1]	**Not Triggered**	NA	NA	
Non-guideline - Whole sediment: chronic (28-65-Day life cycle) Toxicity Test	Freshwater midge	No[1]	**Not Triggered**	NA	NA	
	Freshwater amphipod	No[1]	**Not Triggered**	NA	NA	
	Estuarine/Marine amphipod	No[1]	**Not Triggered**	NA	NA	
Other Aquatic Studies						
850.1850 - Aquatic food chain transfer		No[1]	**Not Triggered**	NA	NA	NA
850.1950 - Field testing for aquatic organisms		No[1]	**Not Triggered**	NA	NA	NA
Terrestrial Invertebrate Toxicity (Surrogate for both *Apis* and non-*Apis* bees)						
850.3020 (OECD Test Guideline 214)- Honey Bee Adult Acute Contact Toxicity Test		Yes	**Complete**	00149241	Acceptable	NA
OECD Test Guideline 213 - Honey Bee Adult Acute Oral (AAO) Toxicity Test[2]		Yes	**Complete**	51787601	Supplemental	Bumble bee was used instead of honey bee; non-definitive endpoints
				51036686	Supplemental	Non-definitive endpoints
OECD Test Guideline 237 - Larval Honey Bee Acute Oral (LAO) (single dose) Toxicity Test		Yes[2]	**Complete**	51036689	Acceptable	NA

Guideline Number - Study Type	Required	Data Requirement Status	MRID	DER Classification	Comments
OECD Guidance Document 239 - Larval Honey Bee Chronic Oral (LCO) (repeat dose) Toxicity Test	Yes[2]	**Complete**	50982325	Acceptable	NA
OECD Test Guideline 245 - Honey Bee Adult Chronic Oral (ACO) (repeat dose) Toxicity Test	Yes[2]	**Complete**	51102401	Supplemental	NA
850.3030 - Honey Bee Toxicity of Residues on Foliage	No[1]	**Not Triggered**	NA	NA	NA
OECD Guidance Document 75- Honey Bee Colony Brood Test (Enclosure Study) Under Semi-field Conditions	No[1]	**Not Triggered**	NA	NA	NA
Non-guideline Field Trial of Residues in Pollen/Nectar	No[1]	**Not Triggered**	NA	NA	NA
Non-guideline Semi-field Colony Feeding Study (Oomen *et al*. 1992)	No[1]	**Not Triggered**	NA	NA	NA
850.3040 - Field Testing for Pollinators	No[1]	**Not Triggered**	NA	NA	NA

NA =not applicable

[1] Per 40 CFR Part 158 or other guidance documents, specified conditions to require the study are not met.

[2] Recommended through the EFED guidance on exposure and effects testing for assessing risk to bees (https://www.epa.gov/sites/default/files/2016-07/documents/guidance-exposure-effects-testing-assessing-risks-bees.pdf)

Table C-4. L-glufosinate Non-target Plant Protection Data Requirements to Support Section 3 New Active Ingredients.

Guideline Number - Study Type		Required	Data Requirement Status	MRID	DER Classification	Comments
Terrestrial and Wetland Plant Toxicity						
850.4100 - Seedling Emergence and Seedling Growth	Tier 1	Yes	**Complete**	NA	NA	Tier 2 test submitted preemptively without the submission of Tier 1.
	Tier 2	No	**Complete**	50982323 and 41396111	Acceptable	
				51036692	Supplemental	
850.4150 - Vegetative Vigor	Tier 1	Yes	**Complete**	NA	NA	Tier 2 test submitted preemptively without the submission of Tier 1.
	Tier 2	No	**Complete**	50982324, 51036693 and 41396112/ 41396113	Acceptable	
850.4230 – Early Seedling Growth Toxicity Test		No[1]	**Not Triggered**	NA	NA	NA
850.4300 - Terrestrial Plants Field Study		No[1]	**Not Triggered**	NA	NA	NA
Aquatic Plant and Algae Toxicity						
850.4025 - Target Area Phytotoxicity		No[1]	**Not Triggered**	NA	NA	NA
850.4400 - Aquatic Plant Toxicity Test Using *Lemna spp.*	Tier 1	Yes	**Complete**	NA	NA	Tier 2 test submitted preemptively without the submission of Tier 1.
	Tier 2	No	**Complete**	51036694	Acceptable	
850.4450 - Aquatic Plants Field Study		No[1]	**Not Triggered**	NA	NA	NA
850.4500 - Algal Toxicity Test		Yes	**Complete**	51036697, 48444817 and 40345653	Acceptable	NA
				47542604 and 47542603	Supplemental	Non-definitive endpoint.
850.4550 - Cyanobacteria (*Anabaena flos-aquae*) Toxicity Test		Yes	**Complete**	50982326	Acceptable	NA

NA =not applicable

[1] Per 40 CFR Part 158 or other guidance documents, specified conditions to require the study are not met.

Table C-5. L-glufosinate Environmental Fate Test Data Requirements to Support Section 3 New Active Ingredients.

[Note: *When a study is triggered by a specific use pattern, that can be noted in the comments column. For example, an aquatic field dissipation study would be triggered by a use on rice or direct application to water.]*

Guideline Number & Study Type	Required	Data Requirement Status	MRID	DER Classification	Comments
835.2120 – Hydrolysis	Yes	**Complete**	51036698; 51036699	Acceptable	NA
835.2240 - Photodegradation in Water	Yes	**Complete**	41323115	Acceptable	NA
850.2410 - Photodegradation in Soil	Yes	**Complete**	41920102	Acceptable	NA
835.2370 - Photodegradation in Air	No[1]	**Not Triggered**	NA	NA	NA
835.4100 - Aerobic Soil	Yes	**Complete**	41323119	Acceptable	NA
835.4200 - Anaerobic Soil	Yes	**Complete**	40501014	Supplemental	Two degradates detected at ~0.04 mg/kg-soil were not identified
835.4300 - Aerobic Aquatic	Yes	**Complete**	51228424; 51228432	Acceptable	NA
835.4400 - Anaerobic Aquatic	Yes	**Complete**	46258601	Acceptable	NA
835.1230 - Batch Equilibrium	Yes	**Complete**	40345662, 48394101	Acceptable	NA
835.1240 - Column Leaching	No[1]	**Not Triggered**	NA	NA	NA
835.1410 - Volatility Laboratory	Yes	**Complete**	44032901	Acceptable	NA
835.8100 - Volatility Field	No[1]	**Not Triggered**	NA	NA	NA
835.6100 - Terrestrial Field Dissipation	Yes	**Complete**	40345663 40345664 40345665	Supplemental	MRID 40345664. Supplemental. Formation and decline of MPA was not captured and freezer storage stability data was not provided.
			43110402 43766916	Acceptable	NA
			47542601	Supplemental	ILV not included with the study report.

Guideline Number & Study Type		Required	Data Requirement Status	MRID	DER Classification	Comments
835.6200 - Aquatic Field Dissipation		No[1]	**Not Triggered**	NA	NA	NA
835.6300 - Forestry Dissipation		No[1]	**Not Triggered**	NA	NA	NA
835.7100 – Prospective Groundwater Monitoring		No[1]	**Not Triggered**	NA	NA	NA
850.6100 – Environmental Chemistry Method/ Independent Laboratory Validation	Soil (supports 835.6100 and monitoring)	Yes	**Complete**	51693101, 51693102	Acceptable	NA
	Water (supports monitoring)	Yes	**Complete**	51693101, 51693102	Acceptable	NA
	Sediment (supports monitoring)	No	**Not Triggered**	NA	NA	NA
Storage Stability	Soil (supports 835.6100)	Yes	**Complete**	43110402 43766916	Acceptable	Storage stability data contained in field dissipation study
	Water (supports 835.6200)	No[1]	**Not Triggered**	NA	NA	NA
	(supports 835.6300, 835.6400, and/or 835.7100)	No[1]	**Not Triggered**	NA	NA	NA
835.6400 - Combination and Tank Mixes		No[1]	**Not Triggered**	NA	NA	NA
Non-guideline	Comparison of soil taxonomy of global soils to US soils)	No[1]	**Not Triggered**	NA	NA	NA

NA =not applicable

[1] Per 40 CFR Part 158 or other guidance documents, specified conditions to require the study are not met.

Appendix D. Bridging Evaluation and Conclusions

Racemic glufosinate ammonium salt (*i.e.*, L- and D-isomers present in a 1:1 ratio), L-glufosinate ammonium salt, and L-glufosinate free acid are considered separate active ingredients (ais) with unique product chemistry (PC) Codes; however, EFED expects that all glufosinate ais will exist in the same deprotonation state and with the same counterions when under similar environmental conditions and that non-target taxa will, therefore, be exposed to a similar form of glufosinate regardless of which ai is applied. The ratio of isomers will, however, depend on the ratio of isomers in the different ai formulations, the amount of the different racemic or enriched isomer formulations that have been applied, as well as environmental factors that can lead to racemization or enrichment of glufosinate isomers. EFED evaluated the fate and toxicity data for L-glufosinate ai for the new glufosinate-P actions to determine if the L-glufosinate ais can be bridged with the racemic glufosinate database to develop a single glufosinate database for evaluating all glufosinate ais.

Based on the submitted hydrolysis, aqueous photolysis, and aerobic soil metabolism data for L-glufosinate ammonium salt and L-glufosinate acid, L-glufosinate degrades at a similar rate to the racemic mixture. Both the enriched isomer and racemic mixture are stable to hydrolysis at pH 5 through 9 and to photolysis at pH 5 and 7 (DP Barcodes 51036698, 51036699). Aerobic soil metabolism DT_{50} values for L-glufosinate (free acid and ammonium salt) ranged from 1.71 to 4.36 days (DP Barcodes 50982320, 51036701) and are shorter than the measured DT_{50} values for racemic glufosinate (8.5 to 23 days). While it is uncertain whether the variability in aerobic soil metabolism DT_{50} values is due to more rapid degradation of L-glufosinate or to variability in the test systems, the magnitude of the difference is small and indicates that L-glufosinate is not more persistent in soil than the racemic mixture. Additionally, L-glufosinate did not convert to D-glufosinate in any of the submitted fate studies for L-glufosinate. Based on the similarities between L-glufosinate and racemic glufosinate in biotic and abiotic systems, EFED concludes that it is appropriate to bridge the fate datasets between the racemic and chirally enriched forms to support the glufosinate-P registrations. That is, all the available data for glufosinate compounds are considered when evaluating the fate and exposure of glufosinate.

The bridging evaluation for the toxicity data focused on comparing L-isomer and racemic glufosinate ammonium toxicity endpoints in taxa for which at least one racemic study and one enriched isomer study are available. **Table D-1** summarizes the toxicity endpoints for L-glufosinate ammonium, L-glufosinate acid, and racemic glufosinate ammonium that informed the bridging evaluation. All endpoints are converted to acid equivalents (ae) to provide a more direct comparison of toxicity between the three glufosinate ais.

The toxicity of the L-isomers relative to the racemic mixture varies across taxa. In freshwater fish and aquatic invertebrates, the technical grade L-glufosinate ammonium salt and L-glufosinate acid are similar or less toxic than the racemic glufosinate on an acute exposure basis. Moreover, acute toxicity in the L-glufosinate ammonium salt typical end-use product (TEP) study (LC_{50} = 3.29 mg ae/L) is consistent with the acute lethality endpoint (LC_{50} = 3.93 mg

ae/L) estimated for a TEP of racemic glufosinate in the same species. The available chronic aquatic invertebrate and fish data for the L-isomer new ais are limited to a chronic estuarine/marine invertebrate study with the L-glufosinate acid for which no equivalent study was available for the racemic mixture. Consequently, there is some uncertainty as to the relative toxicity of the L-isomers to aquatic invertebrates and fish compared to racemic mixture on a chronic basis. EFED, however, is not requesting additional chronic data for fish and invertebrates at this time because the enriched isomers would need to be significantly more toxic than the racemic mixture to result in risks of concern, and risk to the most sensitive tax estuarine/marine invertebrates, for all ais will be evaluated based on the available L-glufosinate acid study.

The L-isomer ais are consistently more toxic to aquatic plants compared to racemic glufosinate. Racemic glufosinate and the enriched L-isomer glufosinate compounds both elicited the same effects in non-vascular plants, but the IC_{50} and NOAEC are ~2-2.5 and ~2-7 times lower, respectively, compared to the racemic glufosinate. Similarly, aquatic vascular plants are ~2 times more sensitive to L-glufosinate acid than racemic glufosinate based on the IC_{50} and ~3 times more sensitive based on the NOAEC. Although a L-glufosinate ammonium salt vascular plant toxicity study is not available, EFED expects it would exhibit toxicity similar to the L-glufosinate acid given that they would convert to the same form (*i.e.*, the free acid) in the environment. The ~2-2.5x greater sensitivity of the L-isomer relative to the racemic mixture (based on the IC_{50}) aligns well with the fact that the herbicidally active L-isomer is approximately 50% of the exposure concentration in the racemic glufosinate toxicity studies.

In contrast to aquatic plants, the typical end-use products (TEPs) for the L-isomer ais are less toxic to terrestrial plants compared to racemic glufosinate. It should be noted that the toxicity observed in the TEP studies accounts for the contributions of other components in the formulation and, thus, comparisons between TEPs across ais may confound conclusions on the relative toxicity of the ais to terrestrial plants. Data are not available to evaluate the terrestrial plant toxicity of the L-isomer technical grade active ingredients (TGAI) relative to the racemic glufosinate TGAI. The terrestrial plant risk assessment will rely on the racemic TGAI data and data specific to the ai under evaluation. EFED does not expect that the lack of TGAI terrestrial plant studies with the L-isomers will impact the risk conclusions for those ais.

Racemic glufosinate and the L-isomers exhibited similar toxicity in adult and larval honey bees on an acute dietary exposure basis; however, on a chronic exposure basis, the L-glufosinate ammonium salt appears to be more toxic to larvae than either the L-glufosinate acid or the racemic glufosinate (based on the NOAEL). In the L-glufosinate ammonium salt study, a 19% decrease in adult emergence, the most sensitive effect, was observed at 5.0 µg ae/larvae/day (the study LOAEL) and decreased in a clear dose-dependent manner at higher treatment concentrations. Decreases (*i.e.,* 23 and 69% decreases at 10 and 20 µg ae/larva/day, respectively). Decreases in adult emergence were also observed at comparable dose levels in the racemic glufosinate (decreases of 22%, 0%, and 19% at 1.0, 1.9, and 4.1 µg ae/larva/day, respectively) and L-glufosinate acid studies (decreases of 15 and 9% at 3.3 and 6.5 µg ae/larva/day, respectively); however, these findings were not statistically significant and the

data at these dose levels lacked a clear dose response, which lowered confidence that they were evidence of an adverse response to treatment. Exposure to higher L-glufosinate acid doses resulted in a significant, though flat, decrease in adult emergence (*i.e.,* 74% at both 14 and 26 µg ae/larva/day) which is consistent with findings in the L-glufosinate ammonium study, particularly at the highest dose level. The racemic glufosinate study did not test at higher doses; thus, it is unclear if it would exhibit the same pattern as L-glufosinate at higher exposure levels. Some variability in response is expected between studies, particularly when conducted at different labs. Viewed collectively, chronic larval toxicity is not substantially different between the L-isomers; however, the data for the L-glufosinate ammonium salt exhibit a clear dose response and are considered more reliable than the L-glufosinate acid data. While decreases in adult emergence are observed in the racemic glufosinate study, it is not evident that these findings are treatment-related nor whether the response at higher dose levels was comparable to the findings for the L-isomers. The relative chronic toxicity of racemic and L-glufosinate to larval bees is an uncertainty in the glufosinate database. Chronic adult bee studies are not available for the L-isomer ais to compare against the racemic glufosinate study. EFED expects the response to be similar across glufosinate ais given the consistency in observations in the other adult bee studies; therefore, EFED is not requesting additional chronic adult honey bee studies for the L-isomers at this time.

In mammals, the L-isomer ais are consistently more toxic compared to racemic glufosinate on an acute exposure basis. However, chronic exposure results in similar reproductive effects across the racemic glufosinate and L-isomer ais at similar effect levels. There are notable differences in methodology and sample size between the racemic glufosinate and L-glufosinate acute oral mammalian studies that impact how the studies estimated the LD_{50}. Whether the differences in the study design or other factors including isomer-specific toxicity were the cause of the disparate mammalian acute toxicity across glufosinate ais is unknown and is an uncertainty in the glufosinate toxicity database.

Racemic glufosinate exhibited low acute avian toxicity and it is expected that birds were not likely to be much more sensitive to the L-isomers; however, reliable avian toxicity data are not available for the L-isomer ais to confirm this assumption. The L-glufosinate acid avian acute oral toxicity study demonstrates greater sensitivity compared to racemic glufosinate, but major exposure uncertainties in this and the L-glufosinate acid avian subacute dietary toxicity study diminished confidence in the study results. Consequently, there is no reliable evidence that the L-isomer ais and racemic glufosinate differ in terms of avian toxicity. The lack of acceptable avian toxicity data for the L-isomer is an uncertainty in the glufosinate toxicity database and L-glufosinate ecological risk assessments.

Generally, the environmental fate and ecotoxicity data for the L-isomer glufosinate ais are comparable to racemic glufosinate and support bridging the racemic glufosinate database with

the L-glufosinate databases to address the 40 CFR Part 158 data requirements[47] for all glufosinate ais, including glufosinate-P. Similarities in toxicity between the L-glufosinate and racemic glufosinate ais for most taxa demonstrate the glufosinate mode of toxicity in these model species is independent of the isomer form. The only substantial differences between racemic glufosinate and the L-isomers TGAIs are noted in toxicity to aquatic plants and acute toxicity in mammals. The enhanced sensitivity in the aquatic plants to the L-isomer ais is likely due to enrichment of the herbicidally active L-isomer; however, it is uncertain as to why mammals exhibit a disparate response to acute exposure between glufosinate ais. Furthermore, the data do not clearly indicate whether the isomer ratio affects chronic toxicity in larval bees and there is a lack of data to compare avian and chronic estuarine/marine invertebrate toxicity across the racemic and L-isomers glufosinate ais which are additional sources of uncertainty. In bridging the three glufosinate databases, EFED is considering all available glufosinate data in its evaluation of exposure, toxicity, and ecological risk for new racemic glufosinate and L-glufosinate uses. New glufosinate risk assessments will rely on the most sensitive endpoints across all glufosinate ais for each taxon to account for the uncertainties described above in the toxicity database as well as uncertainty in the range of species sensitivity within a taxon. While the most sensitive endpoints expressed as ae will be used for risk assessment regardless of the glufosinate ai, EFED will further characterize risk to taxa (*i.e.,* aquatic plants) for which there is a clear, evidence-based link between the ratio of glufosinate isomers and the toxicity and discuss how the most sensitive endpoints may over or underestimate risk for these taxa.

[47] 40CFR158 https://www.ecfr.gov/cgi-bin/text-idx?SID=366f8a3ff8491e5918cbb82aefb2b2b2&mc=true&node=sp40.26.158.g&rgn=div6

Table D-1. Comparison of Racemic Glufosinate Ammonium, L-Glufosinate Ammonium, and L-Glufosinate Acid Toxicity Data for the Purposes of Bridging[1].

Taxa (Species)	Racemic Glufosinate Ammonium Endpoints	L-glufosinate Ammonium Endpoints	L-glufosinate Acid Endpoints
Freshwater Invertebrates (*Daphnia magna*)	Acute 48-hr EC_{50} = 594 mg ae/L	No data available	Acute 48-hr EC_{50} > 103 mg ae/L
Estuarine/Marine Invertebrates (*Americamysis bahia*)	Acute 96-hr LC_{50} = 6.9 mg ae/L	Acute 96-hr LC_{50} = 8.3 mg ae/L	Acute 96-hr LC_{50} = 7.9 mg ae/L
Freshwater Fish (*Oncorhynchus mykiss*)	Acute 96-hr LC_{50} > 285 mg ae/L	No data available on TGAI	Acute 96-hr LC_{50} > 92.9 mg ae/L
Aquatic Non-vascular Plants (*Anabaena flos-aquae*)	IC_{50} = 66 µg ae/L (33 µg L-isomer ae/L) 95% CI: 40-110 µg ae/L NOAEC = 38 µg ae/L based on reduced cell density	IC_{50} = 32 µg ae/L 95% CI: 29-37 µg ae/L NOAEC = 5.8 µg ae/L based on reduced yield	IC_{50} = 26 µg ae/L 95% CI: 21-32 µg ae/L NOAEC = 18 µg ae/L based on reduced yield
Aquatic Vascular Plants[2] (*Lemna gibba*)	IC_{50} = 1.34 mg ae/L (0.67 mg L-isomer ae/L) 95% CI: 1.24-1.44 mg ae/L NOAEC = 0.73 mg ae/L based on reduced frond number	No data available	IC_{50} = 0.59 mg ae/L 95% CI: 0.53-0.67 mg ae/L NOAEC = 0.25 mg ae/L based on reduced final biomass
Monocotyledonous Terrestrial Plants[3] [onion (*Allium cepa*)]	Seedling Emergence EC_{25} = 0.56 lb ae/A EC_{05} = 0.06 lb ae/A[4] Vegetative Vigor EC_{25} < 0.057 lb ae/A NOAEC < 0.057 lb ae/A	Seedling Emergence EC_{25} >0.59 lb ae/A NOAEC = 0.59 lb ae/A Vegetative Vigor EC_{25} = 0.112 lb ae/A NOAEC = 0.029 lb ae/A	Seedling Emergence EC_{25} > 0.52 lb ae/A NOAEC = 0.27 lb ae/A Vegetative Vigor EC_{25} = 0.263 lb ae/A NOAEC = 0.14 lb ae/A
Dicotyledonous Terrestrial Plants[3] [lettuce (*Lactuca sativa*), carrot (*Daucus carota*) and cucumber (*Cucumis sativus*)]	Seedling Emergence (lettuce) EC_{25} = 0.37 lb ae/A NOAEC = 0.19 lb ae/A Vegetative Vigor (cucumber) EC_{25} < 0.017 lb ae/A NOAEC < 0.017 lb ae/A	Seedling Emergence (lettuce) EC_{25} >0.63 lb ae/A NOAEC = 0.63 lb ae/A Vegetative Vigor (carrot) EC_{25} = 0.099 lb ae/A NOAEC = 0.029 lb ae/A	Seedling Emergence (lettuce) EC_{25} = 0.176 lb ae/A NOAEC = 0.14 lb ae/A Vegetative Vigor (cucumber) EC_{25} = 0.0266 lb ae/A NOAEC = 0.016 lb ae/A
Mammals (*Rattus norvegicus*)	Acute LD_{50} = 2770-3670 mg ae/kg bw[5]	Acute LD_{50} = 954 mg ae/kg bw	Acute LD_{50} > 300 mg ae/kg bw and <2000 mg ae/kg bw

Taxa (Species)	Racemic Glufosinate Ammonium Endpoints	L-glufosinate Ammonium Endpoints	L-glufosinate Acid Endpoints
	Chronic 5.5 mg ae/kg bw/day based on decreased number of viable pups	Chronic No data available	Chronic 7 mg ae/kg bw/day based on decreased number of viable pups
Honey Bees (*Apis mellifera*)	Adult Acute Contact LD_{50} > 91 µg ae/bee Larval Acute 8-day LD_{50} > 2.4 µg ae/larva[6] Larval Chronic NOAEL = 4.1 µg ae/larva/day (highest concentration tested)	Adult Acute No data available Larval Acute 8-day LD_{50} > 12 µg ae/larva[6] Larval Chronic NOAEL = 2.6 µg ae/larva/day based on reduced adult emergence	Adult Acute Oral LD_{50} > 97.7 µg ae/bee Contact LD_{50} > 96.3 µg ae/bee Larval Acute 8-day LD_{50} > 18 µg ae/larva[6] Larval Chronic NOAEL = 6.5 µg ae/larva/day based on reduced adult emergence

ae = acid equivalents

[1] Endpoints are converted to acid equivalents (ae) for a more accurate comparison of toxicity. All toxicity endpoints are from studies with the technical grade active ingredient (TGAI) except where noted.

[2] The racemic glufosinate study was 14 days whereas the L-glufosinate acid study was 7 days.

[3] Studies were conducted with a typical end-use product (TEP). Studies with the TGAI were not available for these taxa in the L-glufosinate ais.

[4] The NOAEC was not considered to be reliable in this study.

[5] Range provided for male and female LD_{50}.

[6] Estimated based on the 8-day larval mortality data and dose level administered on the first day of dosing (i.e., study Day 3) from the racemic (MRID 51102402), L-glufosinate ammonium (MRID 50982325), and L-glufosinate acid (MRID 51036690) chronic larval studies.

Appendix E. Supplemental Tables for the Direct Effects Analysis for the Biological Evaluation

The attached excel spreadsheet **Table E.1 Supplemental Tables for the BE Direct Effects Analysis** provides more detailed information on the terrestrial and aquatic EECs, and exposure to effects ratios calculated for the direct effects analysis of listed species in the Biological Evaluation (**Section 8**).

Appendix F. Supplemental Tables for the Ecological Risk Assessment

F.1 Aquatic Animals

The attached Excel spreadsheet **Table F.1.1 ERA Supplemental Tables for Aquatic Animals** provides more detailed information on the aquatic EECs, and risk quotients reported in the Ecological Risk Assessment for non-listed aquatic animal species.

F.2 Terrestrial Animals

The tables below provide more detailed information on the use patterns assessed, terrestrial EECs and risk quotients for non-listed terrestrial animal species reported in the Ecological Risk Assessment.

Table F-2.1. Summary of Use Patterns Selected to Model Terrestrial Estimated Environmental Concentrations (EECs) for Terrestrial Animal Species[1,2].

Use Type	Use Site	Use Pattern
Conventional Crops; Burndown	Canola, Sweet Corn, Field Corn, Soybean	1 application of 0.359 lbs ae/A
	Cotton (Pattern 1)	1 application of 0.359 lbs ae/A and 1 application of 0.242 lbs ae/A with a 10-day RI
	Cotton (Pattern 2)	3 applications of 0.242 lbs ae/A with a 10-day RI
Glufosinate-resistant Crops	Canola	1 application of 0.359 lbs ae/A, 1 application of 0.242 lbs ae/A, and 1 application of 0.126 lbs ae/A with a 7-day RI
	Sweet Corn	2 applications of 0.184 lbs ae/A with a 7-day RI
	Field Corn	2 applications of 0.359 lbs ae/A with a 7-day RI
	Cotton (Pattern 1)	1 application of 0.359 lbs ae/A and 1 application of 0.242 lbs ae/A with a 10-day RI
	Cotton (Pattern 2)	3 applications of 0.242 lbs ae/A with a 10-day RI
	Soybean	2 applications of 0.359 lbs ae/A with a 5-day RI
Seed Propagation	Canola	3 applications of 0.242 lbs ae/A with a 7-day RI
	Corn	2 applications of 0.184 lbs ae/A with a 10-day RI
	Soybean	2 applications of 0.359 lbs ae/A with a 5-day RI

Table F-2.2. Summary of Dietary-Based Estimated Environmental Concentrations (EECs; mg/kg-diet) as Food Residues for Birds, Reptiles, Terrestrial-phase Amphibians, Mammals, and Terrestrial Invertebrates from Labeled Uses of Glufosinate-P (T-REX v. 1.5.2, Upper-Bound and Mean Kenaga)[1,2]

Primary Feeding Strategy	Herbivores, Omnivores, and Granivores				Insectivores
Dietary Items / Use(s)	Short Grass	Tall Grass	Broad-leaf Plants	Fruits, pods, seeds, *etc.*	Arthropods
Upper bound Kenaga Values					
Maximum EECs (Glufosinate-resistant soybean)	153.11	70.18	86.13	9.57	59.97
Minimum EEC (Corn seed propagation)	70.82	32.46	39.84	4.43	27.74
Mean Kenaga Values					
Maximum EECs (Glufosinate-resistant soybean)	54.23	22.97	28.71	4.47	41.47
Minimum EEC (Corn seed propagation)	25.08	10.62	13.28	2.07	19.18

[1]The EEC range presented in this table encompasses anticipated terrestrial exposure from all glufosinate-P ammonium salt use patterns.

[2]Terrestrial EECs are modeled based on the use patterns described in **Table F-2.1** and are in accordance with the use information presented on the final labels and summarized in **Tables 3-1** and **3-2**.

Table F-2.3. Summary of Dose-based Estimated Environmental Concentrations (EECs; mg ae/kg-bw) as Food Residues for Birds, Reptiles, and Terrestrial-Phase Amphibians from the Labeled Uses of Glufosinate-P (T-REX v. 1.5.2, Upper-Bound Kenaga)[1,2]

Primary Feeding Strategy	Herbivores and Omnivores												Insectivores			Granivores		
Animal Size	Small				Med				Large				Small	Med	Large	Small	Med	Large
Dietary Items / Use(s)	Short Grass	Tall Grass	Broad-leaf Plants	Fruits, pods, seeds, *etc.*	Short Grass	Tall Grass	Broadleaf Plants	Fruits, pods, seeds, *etc.*	Short Grass	Tall Grass	Broadleaf Plants	Fruits, pods, seeds, *etc.*	Arthropods			Seeds, grains, *etc.*		
Maximum EECs (Glufosinate-resistant soybean)	174.38	79.92	98.09	10.9	99.44	45.58	55.93	6.21	44.52	20.40	25.04	2.78	68.3	38.95	17.44	2.42	1.38	0.62
Minimum EEC (Corn seed propagation)	80.66	36.97	45.37	5.04	46.0	21.08	25.87	2.87	20.59	9.44	11.58	1.29	31.59	18.02	8.07	1.12	0.64	0.29

[1]The EEC range presented in this table encompasses all labeled glufosinate-P use patterns. Mean Kenaga values are not presented because no risks of concern were identified for birds, terrestrial-phase amphibians, or reptiles from any labeled-glufosinate-P use based on the Upper Bound Kenaga values.

[2]Terrestrial EECs are modeled based on the use patterns described in **Table F-2.1** and are in accordance with the use information presented on the final labels and summarized in **Tables 3-1** and **3-2**.

Table F-2.4. Summary of dose-based Estimated Environmental Concentrations (EECs; mg ae/kg-bw) as Mammals from the Labeled Use of Glufosinate-P (T-REX v. 1.5.2, Upper-Bound and Mean Kenaga)[1,2]

Primary Feeding Strategy	Herbivores and Omnivores												Insectivores			Granivores		
Animal Size	Small				Med				Large				Small	Med	Large	Small	Med	Large
Dietary Items / Use(s)	Short Grass	Tall Grass	Broad-leaf Plants	Fruits, pods, seeds, *etc.*	Short Grass	Tall Grass	Broadleaf Plants	Fruits, pods, seeds, *etc.*	Short Grass	Tall Grass	Broadleaf Plants	Fruits, pods, seeds, *etc.*	Arthropods			Seeds, grains, *etc.*		
Upper Bound Kenaga Values																		
Maximum EECs (Glufosinate-resistant soybean)	145.98	66.91	82.11	9.12	100.89	46.24	56.75	6.31	23.39	10.72	13.16	1.46	57.18	39.52	9.16	2.03	1.40	0.32
Minimum EEC (Corn seed propagation)	67.53	30.95	37.98	4.22	46.67	21.39	26.25	2.92	10.82	4.96	6.09	0.68	26.45	18.28	4.24	0.94	0.65	0.15
Mean Kenaga Values																		
Maximum EECs (Glufosinate-resistant soybean)	51.70	21.90	27.37	4.26	35.73	15.13	18.92	2.94	8.28	3.51	4.39	0.68	39.54	27.32	6.34	0.95	0.65	0.15
Minimum EEC (Corn seed propagation)	23.92	10.13	12.66	1.97	16.53	7.00	8.75	1.36	3.83	1.62	2.03	0.32	18.29	12.64	2.93	0.44	0.30	0.07

[1]The EEC range presented in this table encompasses all labeled glufosinate-P use patterns.

[2]Terrestrial EECs are modeled based on the use patterns described in **Table F-2.1** and are in accordance with the use information presented on the final labels and summarized in **Tables 3-1** and **3-2**.

Table F-2.5. Chronic Dietary-based Risk Quotient (RQ) values for Non-listed Birds, Reptiles, Terrestrial-Phase Amphibians from the Labeled Uses of Glufosinate-P (T-REX v. 1.5.2, Upper-Bound Kenaga)[1,2]

Primary Feeding Strategy	Herbivores, Omnivores, and Granivores				Insectivores
Dietary Items / Use(s)	Short Grass	Tall Grass	Broad-leaf Plants	Fruits, pods, seeds, *etc.*	Arthropods
Burndown and Non-GMO Uses					
Canola	0.24	0.11	0.13	0.01	0.09
Sweet Corn	0.24	0.11	0.13	0.01	0.09
Field Corn	0.24	0.11	0.13	0.01	0.09
Cotton (Pattern 1)	0.30	0.14	0.17	0.02	0.12
Cotton (Pattern 2)	0.31	0.14	0.17	0.02	0.12
Soybean	0.24	0.11	0.13	0.01	0.09
GMO Crop Uses					
Canola	0.32	0.15	0.18	0.02	0.13
Sweet Corn	0.20	0.09	0.11	0.01	0.08
Field Corn	0.40	0.18	0.23	0.03	0.16
Cotton (Pattern 1)	0.30	0.14	0.17	0.02	0.12
Cotton (Pattern 2)	0.31	0.14	0.17	0.02	0.12
Soybean	0.42	0.19	0.24	0.03	0.16
GMO Seed Propagation Uses[3]					
Canola	0.35	0.16	0.19	0.02	0.14
Corn	0.19	0.09	0.11	0.01	0.07
Soybean	0.42	0.19	0.24	0.03	0.16

Bolded RQ values indicate at least one use exceeds the chronic risk level of concern (LOC) of 1.0. RQ values based on NOAEC of 366 mg ae/kg diet for Mallard Duck (*Anas platyrhynchus*).

[1] RQs presented in this table are for glufosinate-P except where noted and are comparable to RQs calculated for glufosinate-P ammonium. Separate RQs for the two L-isomer ais are presented for the fallow/post-harvest use because the use patterns between the glufosinate-P ais are distinct and the RQs are not comparable.

[2]Terrestrial RQs are calculated based on the use patterns described in **Table F-2-1** and are in accordance with the use information presented on the final labels and summarized in **Tables 3-1** and **3-2**.

[3]Although use for propagation of glufosinate tolerant cotton seeds is permitted based on the final labels, a specific use pattern was not provided. Given that exposure from general agricultural uses on GMOs for the other crops is expected to be similar or higher than seed propagation uses for the same crop, the RQs for cotton GMO crop use are expected to approximate the risk for the cotton seed propagation use.

Table F-2.6. Acute Dose-based RQ values for Non-listed Mammals from the Labeled Uses of Glufosinate-P (T-REX v. 1.5.2, Upper-Bound Kenaga)[1,2]

Primary Feeding Strategy	Herbivores and Omnivores												Insectivores			Granivores		
Animal Size	Small				Med				Large				Small	Med	Large	Small	Med	Large
Dietary Items	Short Grass	Tall Grass	Broad-leaf Plants	Fruits, pods, seeds, *etc.*	Short Grass	Tall Grass	Broadleaf Plants	Fruits, pods, seeds, *etc.*	Short Grass	Tall Grass	Broadleaf Plants	Fruits, pods, seeds, *etc.*	Arthropods			Seeds, grains, *etc.*		
Use(s)																		
Burndown and Non-GMO Uses																		
Canola	0.04	0.02	0.02	<0.01	0.03	0.02	0.02	<0.01	0.02	<0.01	0.01	<0.01	0.02	0.01	<0.01	<0.01	<0.01	<0.01
Sweet Corn	0.04	0.02	0.02	<0.01	0.03	0.02	0.02	<0.01	0.02	<0.01	0.01	<0.01	0.02	0.01	<0.01	<0.01	<0.01	<0.01
Field Corn	0.04	0.02	0.02	<0.01	0.03	0.02	0.02	<0.01	0.02	<0.01	0.01	<0.01	0.02	0.01	<0.01	<0.01	<0.01	<0.01
Cotton (Pattern 1)	0.05	0.02	0.03	<0.01	0.04	0.02	0.02	<0.01	0.02	0.01	0.01	<0.01	0.02	0.02	<0.01	<0.01	<0.01	<0.01
Cotton (Pattern 2)	0.05	0.02	0.03	<0.01	0.04	0.02	0.02	<0.01	0.02	0.01	0.01	<0.01	0.02	0.02	<0.01	<0.01	<0.01	<0.01
Soybean	0.04	0.02	0.02	<0.01	0.03	0.02	0.02	<0.01	0.02	<0.01	0.01	<0.01	0.02	0.01	<0.01	<0.01	<0.01	<0.01
GMO Crop Uses																		
Canola	0.05	0.02	0.03	<0.01	0.05	0.02	0.03	<0.01	0.02	0.01	0.01	<0.01	0.02	0.02	<0.01	<0.01	<0.01	<0.01
Sweet Corn	0.03	0.02	0.02	<0.01	0.03	0.01	0.02	<0.01	0.02	<0.01	<0.01	<0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01
Field Corn	0.07	0.03	0.04	<0.01	0.06	0.03	0.03	<0.01	0.03	0.01	0.02	<0.01	0.03	0.02	0.01	<0.01	<0.01	<0.01
Cotton (Pattern 1)	0.05	0.02	0.03	<0.01	0.04	0.02	0.02	<0.01	0.02	0.01	0.01	<0.01	0.02	0.02	<0.01	<0.01	<0.01	<0.01
Cotton (Pattern 2)	0.05	0.02	0.03	<0.01	0.04	0.02	0.02	<0.01	0.02	0.01	0.01	<0.01	0.02	0.02	<0.01	<0.01	<0.01	<0.01
Soybean	0.07	0.03	0.04	<0.01	0.06	0.03	0.03	<0.01	0.03	0.01	0.02	<0.01	0.03	0.02	0.01	<0.01	<0.01	<0.01
GMO Seed Propagation Uses[3]																		
Canola	0.06	0.03	0.03	<0.01	0.05	0.02	0.03	<0.01	0.03	0.01	0.01	<0.01	0.02	0.02	0.01	<0.01	<0.01	<0.01
Corn	0.03	0.01	0.02	<0.01	0.03	0.01	0.02	<0.01	0.01	<0.01	<0.01	<0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01
Soybean	0.07	0.03	0.04	<0.01	0.06	0.03	0.03	<0.01	0.03	0.01	0.02	<0.01	0.03	0.02	0.01	<0.01	<0.01	<0.01

Dark shaded cells indicate the RQ exceeds Level of concern (LOC) of 0.1 for acute risk to listed mammals.

RQ values are based on an LD_{50} of 954 mg ae/kg-bw for the Norway Rat (*Rattus norvegicus*).

[1] RQs presented in this table are for glufosinate-P and are comparable to RQs calculated for glufosinate-P ammonium.

[2]Terrestrial RQs are calculated based on the use patterns described in **Table F-2.1** and are in accordance with the use information presented on the final labels and summarized in **Tables 3-1** and **3-2**.

[3]Although use for propagation of glufosinate-resistant cotton seeds is permitted based on the final labels, a specific use pattern was not provided. Given that exposure from general agricultural uses on GMOs for the other crops is expected to be similar or higher than seed propagation uses for the same crop, the RQs for cotton GMO crop use are expected to approximate the risk for the cotton seed propagation use.

Table F-2.7. Chronic Dose-based Risk Quotient (RQ) values for Federally listed and Non-Listed Mammals from the Labeled Uses of Glufosinate-P (T-REX v. 1.5.2, Upper-Bound Kenaga)[1]

Primary Feeding Strategy	Herbivores and Omnivores												Insectivores			Granivores		
Animal Size	Small				Med				Large				Small	Med	Large	Small	Med	Large
Dietary Items	Short Grass	Tall Grass	Broad-leaf Plants	Fruits, pods, seeds, *etc.*	Short Grass	Tall Grass	Broadleaf Plants	Fruits, pods, seeds, *etc.*	Short Grass	Tall Grass	Broadleaf Plants	Fruits, pods, seeds, *etc.*	Arthropods			Seeds, grains, *etc.*		
Use(s)																		
Burndown and Non-GMO Uses																		
Canola	**6.81**	**3.12**	**3.83**	0.43	**5.82**	**2.67**	**3.27**	0.36	**3.12**	**1.43**	**1.76**	0.20	**2.67**	**2.28**	**1.22**	0.09	0.08	0.04
Sweet Corn	**6.81**	**3.12**	**3.83**	0.43	**5.82**	**2.67**	**3.27**	0.36	**3.12**	**1.43**	**1.76**	0.20	**2.67**	**2.28**	**1.22**	0.09	0.08	0.04
Field Corn	**6.81**	**3.12**	**3.83**	0.43	**5.82**	**2.67**	**3.27**	0.36	**3.12**	**1.43**	**1.76**	0.20	**2.67**	**2.28**	**1.22**	0.09	0.08	0.04
Cotton (Pattern 1)	**8.66**	**3.97**	**4.87**	0.54	**7.40**	**3.39**	**4.16**	0.46	**3.96**	**1.82**	**2.23**	0.25	**3.39**	**2.90**	**1.55**	0.12	0.10	0.06
Cotton (Pattern 2)	**8.94**	**4.10**	**5.03**	0.56	**7.64**	**3.50**	**4.30**	0.48	**4.10**	**1.88**	**2.30**	0.26	**3.50**	**2.99**	**1.60**	0.12	0.11	0.06
Soybean	**6.81**	**3.12**	**3.83**	0.43	**5.82**	**2.67**	**3.27**	0.36	**3.12**	**1.43**	**1.76**	0.20	**2.67**	**2.28**	**1.22**	0.09	0.08	0.04
GMO Crop Uses																		
Canola	**9.33**	**4.28**	**5.25**	0.58	**7.97**	**3.65**	**4.48**	0.50	**4.27**	**1.96**	**2.40**	0.27	**3.65**	**3.12**	**1.67**	0.13	0.11	0.06
Sweet Corn	**5.80**	**2.66**	**3.26**	0.36	**4.96**	**2.27**	**2.79**	0.31	**2.66**	**1.22**	**1.49**	0.17	**2.27**	**1.94**	**1.04**	0.08	0.07	0.04
Field Corn	**11.60**	**5.32**	**6.53**	0.73	**9.91**	**4.54**	**5.58**	0.62	**5.31**	**2.44**	**2.99**	0.33	**4.54**	**3.88**	**2.08**	0.16	0.14	0.07
Cotton (Pattern 1)	**8.66**	**3.97**	**4.87**	0.54	**7.40**	**3.39**	**4.16**	0.46	**3.96**	**1.82**	**2.23**	0.25	**3.39**	**2.90**	**1.55**	0.12	0.10	0.06
Cotton (Pattern 2)	**8.94**	**4.10**	**5.03**	0.56	**7.64**	**3.50**	**4.30**	0.48	**4.10**	**1.88**	**2.30**	0.26	**3.50**	**2.99**	**1.60**	0.12	0.11	0.06
Soybean	**12.11**	**5.55**	**6.81**	0.76	**10.35**	**4.74**	**5.82**	0.65	**5.55**	**2.54**	**3.12**	0.35	**4.74**	**4.05**	**2.17**	0.17	0.14	0.08
GMO Seed Propagation Uses[3]																		
Canola	**9.98**	**4.57**	**5.61**	0.62	**8.52**	**3.91**	**4.79**	0.53	**4.57**	**2.09**	**2.57**	0.29	**3.91**	**3.34**	**1.79**	0.14	0.12	0.06
Corn	**5.47**	**2.51**	**3.07**	0.34	**4.67**	**2.14**	**2.63**	0.29	**2.50**	**1.15**	**1.41**	0.16	**2.14**	**1.83**	0.98	0.08	0.06	0.03
Soybean	**12.11**	**5.55**	**6.81**	0.76	**10.35**	**4.74**	**5.82**	0.65	**5.55**	**2.54**	**3.12**	0.35	**4.74**	**4.05**	**2.17**	0.17	0.14	0.08

Dark shaded cells indicate the RQ exceeds the chronic risk level of concern (LOC) of 1.0 for listed and non-listed mammals.

RQ values are based on NOAEC of 5.5 mg ae/kg-bw/day for Norway Rat (*Rattus norvegicus*).

[1]Terrestrial RQs are calculated based on the use patterns described in **Table F-2.1** and are in accordance with the use information presented on the final labels and summarized in **Tables 3-1** and **3-2**.

[3]Although use for propagation of glufosinate-resistant cotton seeds is permitted based on the final labels, a specific use pattern was not provided. Given that exposure from general agricultural uses on GMOs for the other crops is expected to be similar or higher than seed propagation uses for the same crop, the RQs for cotton GMO crop use are expected to approximate the risk for the cotton seed propagation use.

Table F-2.8. Chronic Dose-based Risk Quotient (RQ) values for Non-listed Mammals from the Labeled Use of Glufosinate-P (T-REX v. 1.5.2, Mean Kenaga)[1]

Primary Feeding Strategy	Herbivores and Omnivores												Insectivores			Granivores		
Animal Size	Small				Med				Large				Small	Med	Large	Small	Med	Large
Dietary Items	Short Grass	Tall Grass	Broad-leaf Plants	Fruits, pods, seeds, *etc.*	Short Grass	Tall Grass	Broadleaf Plants	Fruits, pods, seeds, *etc.*	Short Grass	Tall Grass	Broadleaf Plants	Fruits, pods, seeds, *etc.*	Arthropods			Seeds, grains, *etc.*		
Use(s)																		
Burndown and Non-GMO Uses																		
Canola	**2.41**	**1.02**	**1.28**	0.20	**2.06**	0.87	**1.09**	0.17	**1.11**	0.47	0.59	0.09	**1.85**	**1.58**	0.85	0.04	0.04	0.02
Sweet Corn	**2.41**	**1.02**	**1.28**	0.20	**2.06**	0.87	**1.09**	0.17	**1.11**	0.47	0.59	0.09	**1.85**	**1.58**	0.85	0.04	0.04	0.02
Field Corn	**2.41**	**1.02**	**1.28**	0.20	**2.06**	0.87	**1.09**	0.17	**1.11**	0.47	0.59	0.09	**1.85**	**1.58**	0.85	0.04	0.04	0.02
Cotton (Pattern 1)	**3.07**	**1.30**	**1.62**	0.25	**2.62**	**1.11**	**1.39**	0.22	**1.40**	0.59	0.74	0.12	**2.35**	**2.00**	**1.07**	0.06	0.05	0.03
Cotton (Pattern 2)	**3.17**	**1.34**	**1.68**	0.26	**2.71**	**1.15**	**1.43**	0.22	**1.45**	0.61	0.77	0.12	**2.42**	**2.07**	**1.11**	0.06	0.05	0.03
Soybean	**2.41**	**1.02**	**1.28**	0.20	**2.06**	0.87	**1.09**	0.17	**1.11**	0.47	0.59	0.09	**1.85**	**1.58**	0.85	0.04	0.04	0.02
GMO Crop Uses																		
Canola	**3.30**	**1.40**	**1.75**	0.27	**2.82**	**1.20**	**1.49**	0.23	**1.51**	0.64	0.80	0.12	**2.53**	**2.16**	**1.16**	0.06	0.05	0.03
Sweet Corn	**2.05**	0.87	**1.09**	0.17	**1.76**	0.74	0.93	0.14	0.94	0.40	0.50	0.08	**1.57**	**1.34**	0.72	0.04	0.03	0.02
Field Corn	**4.11**	**1.74**	**2.18**	0.34	**3.51**	**1.49**	**1.86**	0.29	**1.88**	0.80	**1.00**	0.15	**3.14**	**2.68**	**1.44**	0.08	0.06	0.03
Cotton (Pattern 1)	**3.07**	**1.30**	**1.62**	0.25	**2.62**	**1.11**	**1.39**	0.22	**1.40**	0.59	0.74	0.12	**2.35**	**2.00**	**1.07**	0.06	0.05	0.03
Cotton (Pattern 2)	**3.17**	**1.34**	**1.68**	0.26	**2.71**	**1.15**	**1.43**	0.22	**1.45**	0.61	0.77	0.12	**2.42**	**2.07**	**1.11**	0.06	0.05	0.03
Soybean	**4.29**	**1.82**	**2.27**	0.35	**3.66**	**1.55**	**1.94**	0.30	**1.96**	0.83	**1.04**	0.16	**3.28**	**2.80**	**1.50**	0.08	0.07	0.04
GMO Seed Propagation Uses[3]																		
Canola	**3.53**	**1.50**	**1.87**	0.29	**3.02**	**1.28**	**1.60**	0.25	**1.62**	0.69	0.86	0.13	**2.70**	**2.31**	**1.24**	0.06	0.06	0.03
Corn	**1.94**	0.82	**1.02**	0.16	**1.65**	0.70	0.88	0.14	0.89	0.38	0.47	0.07	**1.48**	**1.26**	0.68	0.04	0.03	0.02
Soybean	**4.29**	**1.82**	**2.27**	0.35	**3.66**	**1.55**	**1.94**	0.30	**1.96**	0.83	**1.04**	0.16	**3.28**	**2.80**	**1.50**	0.08	0.07	0.04

Dark shaded cells indicate the RQ exceeds the chronic risk level of concern (LOC) of 1.0 for listed and non-listed mammals.

RQ values are based on NOAEC of 5.5 mg ae/kg-bw/day for Norway Rat (*Rattus norvegicus*).

[1] RQs presented in this table are for L-glufosinate acid except where noted and are comparable to RQs calculated for L-glufosinate. Separate RQs for the two L-isomer ais are presented for the fallow/post-harvest use because the use patterns between the L-glufosinate ais are distinct and the RQs are not comparable.

[2] Terrestrial RQs are calculated based on the use patterns described in **Table F-2.1** and are in accordance with the use information presented on the final labels and summarized in **Tables 3-1** and **3-2**.

Primary Feeding Strategy	Herbivores and Omnivores												Insectivores			Granivores		
Animal Size	Small				Med				Large				Small	Med	Large	Small	Med	Large
Dietary Items / Use(s)	Short Grass	Tall Grass	Broad-leaf Plants	Fruits, pods, seeds, *etc.*	Short Grass	Tall Grass	Broadleaf Plants	Fruits, pods, seeds, *etc.*	Short Grass	Tall Grass	Broadleaf Plants	Fruits, pods, seeds, *etc.*	Arthropods			Seeds, grains, *etc.*		

[3]Although use for propagation of glufosinate-resistant cotton seeds is permitted based on the final labels, a specific use pattern was not provided. Given that exposure from general agricultural uses on GMOs for the other crops is expected to be similar or higher than seed propagation uses for the same crop, the RQs for cotton GMO crop use are expected to approximate the risk for the cotton seed propagation use.

Table F-2.9. Chronic Dietary-based Risk Quotient (RQ) values for Non-listed Mammals from the Labeled Uses of Glufosinate-P (T-REX v. 1.5.2, Upper-Bound Kenaga)[1,2]

Primary Feeding Strategy	Herbivores, Omnivores, and Granivores				Insectivores
Dietary Items / Use(s)	Short Grass	Tall Grass	Broad-leaf Plants	Fruits, pods, seeds, *etc.*	Arthropods
Burndown and Non-GMO Uses					
Canola	0.79	0.36	0.44	0.05	0.31
Sweet Corn	0.79	0.36	0.44	0.05	0.31
Field Corn	0.79	0.36	0.44	0.05	0.31
Cotton (Pattern 1)	1.00	0.46	0.56	0.06	0.39
Cotton (Pattern 2)	**1.03**	0.47	0.58	0.06	0.40
Soybean	0.79	0.36	0.44	0.05	0.31
GMO Crop Uses					
Canola	**1.08**	0.49	0.60	0.07	0.42
Sweet Corn	0.67	0.31	0.38	0.04	0.26
Field Corn	**1.34**	0.61	0.75	0.08	0.52
Cotton (Pattern 1)	**1.00**	0.46	0.56	0.06	0.39
Cotton (Pattern 2)	**1.03**	0.47	0.58	0.06	0.40
Soybean	**1.40**	0.64	0.79	0.09	0.55
GMO Seed Propagation Uses[3]					
Canola	**1.15**	0.53	0.65	0.07	0.45
Corn	0.63	0.29	0.35	0.04	0.25
Soybean	**1.40**	0.64	0.79	0.09	0.55

Dark shaded cells indicate the RQ exceeds the chronic risk level of concern (LOC) of 1.0 for listed and non-listed mammals.

RQ values based on NOAEL of 110 mg ae/kg diet for Norway Rat (*Rattus norvegicus*).

[1] Terrestrial RQs are calculated based on the use patterns described in **Table F-1** and are in accordance with the use information presented on the final labels and summarized in **Tables 3-1** and **3-2**.

[3]Although use for propagation of glufosinate-resistant cotton seeds is permitted based on the final labels, a specific use pattern was not provided. Given that exposure from general agricultural uses on GMOs for the other crops is expected to be similar or higher than seed propagation uses for the same crop, the RQs for cotton GMO crop use are expected to approximate the risk for the cotton seed propagation use.

Table F-2.10. Chronic Dietary-based Risk Quotient (RQ) values for Non-listed Mammals from the Labeled Uses of Glufosinate-P (T-REX v. 1.5.2, Mean Kenaga)[1]

Primary Feeding Strategy	Herbivores, Omnivores, and Granivores				Insectivores
Dietary Items / Use(s)	Short Grass	Tall Grass	Broad-leaf Plants	Fruits, pods, seeds, *etc.*	Arthropods
Burndown and Non-GMO Uses					
Canola	0.28	0.12	0.15	0.02	0.21
Sweet Corn	0.28	0.12	0.15	0.02	0.21
Field Corn	0.28	0.12	0.15	0.02	0.21
Cotton (Pattern 1)	0.35	0.15	0.19	0.03	0.27
Cotton (Pattern 2)	0.37	0.15	0.19	0.03	0.28
Soybean	0.28	0.12	0.15	0.02	0.21
GMO Crop Uses					
Canola	0.38	0.16	0.20	0.03	0.29
Sweet Corn	0.24	0.10	0.13	0.02	0.18
Field Corn	0.47	0.20	0.25	0.04	0.36
Cotton (Pattern 1)	0.35	0.15	0.19	0.03	0.27
Cotton (Pattern 2)	0.37	0.15	0.19	0.03	0.28
Soybean	0.49	0.21	0.26	0.04	0.38
GMO Seed Propagation Uses[3]					
Canola	0.41	0.17	0.22	0.03	0.31
Corn	0.22	0.09	0.12	0.02	0.17
Soybean	0.49	0.21	0.26	0.04	0.38

RQ values based on NOAEL of 110 mg ae/kg diet for Norway Rat (*Rattus norvegicus*).

[1]Terrestrial RQs are calculated based on the use patterns described in **Table F-1** and are in accordance with the use information presented on the final labels and summarized in **Tables 3-1** and **3-2**.

[3]Although use for propagation of glufosinate-resistant cotton seeds is permitted based on the final labels, a specific use pattern was not provided. Given that exposure from general agricultural uses on GMOs for the other crops is expected to be similar or higher than seed propagation uses for the same crop, the RQs for cotton GMO crop use are expected to approximate the risk for the cotton seed propagation use.

Table F-2.11. Additional Output for Taxa with Level of Concern (LOC) Exceedances Including Off-site Distances and Number of Days Exceeding for Mammals from the Labeled Uses of Glufosinate-P (T-REX v. 1.5.2, Upper-Bound and Mean Kenaga)

Duration and Basis	Application Equipment	Upper-Bound Kenaga		Mean Kenaga	
		Maximum distance off site of LOC exceedance (ft)[1]	Maximum days exceeding LOC	Maximum distance off site of LOC exceedance (ft)	Maximum days exceeding LOC
Chronic Dietary	Ground	0	7	N/A	
	Aerial	0			
Chronic Dose	Ground	3-7	64	3	44
	Aerial	76		16	

N/A = not applicable; there were no LOC exceedances for chronic dietary exposure on the field based on the mean exposure estimates.

[1] Maximum distance is based on risk quotients (RQs) calculated for the use on soybeans which has the largest RQs for ground and aerial application.

Table F-2.12. Tier 1 (Default) Risk Quotients (RQs) for Non-listed Adult Nectar Forager and Larval Worker Honey Bees from BeeRex (ver. 1.0)

Use Site[2]	Max Single Application Rate (lbs ae/a)[1]	Total Oral Dose (µg ae/bee)		Bee Lifestage/Exposure Scenario			
				Adult		Larval	
		Adult Nectar Forager	Larval Worker	Acute Dietary and Contact[2]	Chronic Dietary[3]	Acute Dietary[2]	Chronic Dietary[3]
Burndown and Non-GMO Uses							
Canola	0.36	11.6	4.90	NE	**41**	NE	**1.9**
Sweet Corn	0.36	11.6	4.90	NE	**41**	NE	**1.9**
Field Corn	0.36	11.6	4.90	NE	**41**	NE	**1.9**
Cotton (Pattern 1)	0.36	11.6	4.90	NE	**41**	NE	**1.9**
Cotton (Pattern 2)	0.24	7.71	3.26	NE	**27**	NE	**1.3**
Soybean	0.36	11.6	4.90	NE	**41**	NE	**1.9**
GMO Crop Uses							
Canola	0.36	11.6	4.90	NE	**41**	NE	**1.9**
Sweet Corn	0.18	5.78	2.45	NE	**20**	NE	0.94
Field Corn	0.36	11.6	4.90	NE	**41**	NE	**1.9**
Cotton (Pattern 1)	0.36	11.6	4.90	NE	**41**	NE	**1.9**
Cotton (Pattern 2)	0.24	7.71	3.26	NE	**27**	NE	**1.3**
Soybean	0.36	11.6	4.90	NE	**41**	NE	**1.9**
GMO Seed Propagation Uses							
Canola	0.24	7.71	3.26	NE	**27**	NE	**1.3**
Corn	0.18	5.78	2.45	NE	**20**	NE	0.94
Soybean	0.36	11.6	4.90	NE	**41**	NE	**1.9**

Dark shaded cells indicate the RQ exceeds the listed and non-listed bee chronic risk level of concern (LOC) of 1.0.

NE= not estimated, see footnotes.

[1] RQs presented in this table are based on the single maximum application rate for the final glufosinate-P uses. The risk estimates are comparable to RQs calculated for glufosinate-P ammonium because the single maximum application rate for both ais are similar across all uses.

[2] Acute RQs are not estimated because the acute oral LD_{50} for adults (LD_{50} >97.7 µg ae/bee) and larvae (8-d LD_{50} >18 µg ae/bee) are non-definitive.

[3] Based on a 10-d EC_{10} of 0.238 µg ae/bee/d for adults and a 22-d chronic NOAEL of 2.6 µg ae/bee/d for larvae.

Table F-2.13. Chronic Dietary-based Risk Quotient (RQ) values for Non-listed Adult Non-Bee Terrestrial Invertebrates from the Labeled Uses of Glufosinate-P (T-REX v. 1.5.2, Upper-Bound Kenaga)[1,2]

Primary Feeding Strategy	Herbivores, Omnivores, and Granivores				Insectivores
Dietary Items / Use(s)	Short Grass	Tall Grass	Broad-leaf Plants	Fruits, pods, seeds, *etc.*	Arthropods
Burndown and Non-GMO Uses					
Canola	**10.31**	**4.73**	**5.80**	0.64	**4.04**
Sweet Corn	**10.31**	**4.73**	**5.80**	0.64	**4.04**
Field Corn	**10.31**	**4.73**	**5.80**	0.64	**4.04**
Cotton (Pattern 1)	**13.10**	**6.00**	**7.37**	0.82	**5.13**
Cotton (Pattern 2)	**13.53**	**6.20**	**7.61**	0.85	**5.30**
Soybean	**10.31**	**4.73**	**5.80**	0.64	**4.04**
GMO Crop Uses					
Canola	**14.12**	**6.47**	**7.94**	0.88	**5.53**
Sweet Corn	**8.78**	**4.02**	**4.94**	0.55	**3.44**
Field Corn	**17.55**	**8.05**	**9.87**	**1.10**	**6.87**
Cotton (Pattern 1)	**13.10**	**6.00**	**7.37**	0.82	**5.13**
Cotton (Pattern 2)	**13.53**	**6.20**	**7.61**	0.85	**5.30**
Soybean	**18.32**	**8.40**	**10.31**	**1.15**	**7.18**
GMO Seed Propagation Uses[3]					
Canola	**15.09**	**6.92**	**8.49**	0.94	**5.91**
Corn	**8.27**	**3.79**	**4.65**	0.52	**3.24**
Soybean	**18.32**	**8.40**	**10.31**	**1.15**	**7.18**

Dark shaded cells RQ values indicate at least one use exceeds the chronic risk level of concern (LOC) of 1.0. RQ values based on NOAEC of 8.38 mg ae/kg diet for Honey bee (*Apis mellifera*).

[1] RQs presented in this table are for glufosinate-P except where noted and are comparable to RQs calculated for glufosinate-P ammonium.

[2]Terrestrial RQs are calculated based on the use patterns described in **Table F-2.1** and are in accordance with the use information presented on the final labels and summarized in **Tables 3-1** and **3-2**.

[3]Although use for propagation of glufosinate-resistant cotton seeds is permitted based on the final labels, a specific use pattern was not provided. Given that exposure from general agricultural uses on GMOs for the other crops is expected to be similar or higher than seed propagation uses for the same crop, the RQs for cotton GMO crop use are expected to approximate the risk for the cotton seed propagation use.

Table F-2.14. Chronic Dietary-based Risk Quotient (RQ) values for Non-listed Larval Non-Bee Terrestrial Invertebrates from the Labeled Uses of Glufosinate-P (T-REX v. 1.5.2, Upper-Bound Kenaga)[1,2]

Primary Feeding Strategy	Herbivores, Omnivores, and Granivores				Insectivores
Dietary Items / Use(s)	Short Grass	Tall Grass	Broad-leaf Plants	Fruits, pods, seeds, *etc.*	Arthropods
Burndown and Non-GMO Uses					
Canola	**1.34**	0.61	0.75	0.08	0.53
Sweet Corn	**1.34**	0.61	0.75	0.08	0.53
Field Corn	**1.34**	0.61	0.75	0.08	0.53
Cotton (Pattern 1)	**1.70**	0.78	0.96	0.11	0.67
Cotton (Pattern 2)	**1.76**	0.81	0.99	0.11	0.69
Soybean	**1.34**	0.61	0.75	0.08	0.53
GMO Crop Uses					
Canola	**1.84**	0.84	**1.03**	0.11	0.72
Sweet Corn	**1.14**	0.52	0.64	0.07	0.45
Field Corn	**2.28**	**1.05**	**1.28**	0.14	0.89
Cotton (Pattern 1)	**1.70**	0.78	0.96	0.11	0.67
Cotton (Pattern 2)	**1.76**	0.81	0.99	0.11	0.69
Soybean	**2.38**	**1.09**	**1.34**	0.15	0.93
GMO Seed Propagation Uses[3]					
Canola	**1.96**	0.90	**1.10**	0.12	0.77
Corn	**1.08**	0.49	0.61	0.07	0.42
Soybean	**2.38**	**1.09**	**1.34**	0.15	0.93

Dark shaded cells RQ values indicate at least one use exceeds the chronic risk level of concern (LOC) of 1.0. RQ values based on NOAEC of 64.4 mg ae/kg diet for Honey bee (*Apis mellifera*).

[1] RQs presented in this table are for glufosinate-P except where noted and are comparable to RQs calculated for glufosinate-P ammonium.

[2]Terrestrial RQs are calculated based on the use patterns described in **Table F-1** and are in accordance with the use information presented on the final labels and summarized in **Tables 3-1** and **3-2**.

[3]Although use for propagation of glufosinate-resistant cotton seeds is permitted based on the final labels, a specific use pattern was not provided. Given that exposure from general agricultural uses on GMOs for the other crops is expected to be similar or higher than seed propagation uses for the same crop, the RQs for cotton GMO crop use are expected to approximate the risk for the cotton seed propagation use.

Table F-2.15. Chronic Dietary-based Risk Quotient (RQ) values for Non-listed Adult Non-Bee Terrestrial Invertebrates from the Labeled Use of Glufosinate-P (T-REX v. 1.5.2, Mean Kenaga)[1,2]

Primary Feeding Strategy	Herbivores, Omnivores, and Granivores				Insectivores
Dietary Items / Use(s)	Short Grass	Tall Grass	Broad-leaf Plants	Fruits, pods, seeds, *etc.*	Arthropods
Burndown and Non-GMO Uses					
Canola	**3.65**	**1.55**	**1.93**	0.30	**2.79**
Sweet Corn	**3.65**	**1.55**	**1.93**	0.30	**2.79**
Field Corn	**3.65**	**1.55**	**1.93**	0.30	**2.79**
Cotton (Pattern 1)	**4.64**	**1.96**	**2.46**	0.38	**3.55**
Cotton (Pattern 2)	**4.79**	**2.03**	**2.54**	0.39	**3.66**
Soybean	**3.65**	**1.55**	**1.93**	0.30	**2.79**
GMO Crop Uses					
Canola	**5.00**	**2.12**	**2.65**	0.41	**3.82**
Sweet Corn	**3.11**	**1.32**	**1.65**	0.26	**2.38**
Field Corn	**6.22**	**2.63**	**3.29**	0.51	**4.75**
Cotton (Pattern 1)	**4.64**	**1.96**	**2.46**	0.38	**3.55**
Cotton (Pattern 2)	**4.79**	**2.03**	**2.54**	0.39	**3.66**
Soybean	**6.49**	**2.75**	**3.44**	0.53	**4.96**
GMO Seed Propagation Uses[3]					
Canola	**5.35**	**2.26**	**2.83**	0.44	**4.09**
Corn	**2.93**	**1.24**	**1.55**	0.24	**2.24**
Soybean	**6.49**	**2.75**	**3.44**	0.53	**4.96**

Dark shaded cells RQ values indicate at least one use exceeds the chronic risk level of concern (LOC) of 1.0. RQ values based on NOAEC of 8.38 mg ae/kg diet for Honey bee (*Apis mellifera*).

[1] RQs presented in this table are for glufosinate-P except where noted and are comparable to RQs calculated for glufosinate-P ammonium.

[2]Terrestrial RQs are calculated based on the use patterns described in **Table F-2.1** and are in accordance with the use information presented on the final labels and summarized in **Tables 3-1** and **3-2**.

[3]Although use for propagation of glufosinate resistant cotton seeds is permitted based on the final labels, a specific use pattern was not provided. Given that exposure from general agricultural uses on GMOs for the other crops is expected to be similar or higher than seed propagation uses for the same crop, the RQs for cotton GMO crop use are expected to approximate the risk for the cotton seed propagation use.

Table F-2.16. Chronic Dietary-based Risk Quotient (RQ) values for Federally Listed and Non-listed Larval Non-Bee Terrestrial Invertebrates from the Labeled Uses of Glufosinate-P (T-REX v. 1.5.2, Mean Kenaga)[1,2]

Primary Feeding Strategy	Herbivores, Omnivores, and Granivores				Insectivores
Dietary Items / Use(s)	Short Grass	Tall Grass	Broad-leaf Plants	Fruits, pods, seeds, *etc.*	Arthropods
Burndown and Non-GMO Uses					
Canola	0.48	0.20	0.25	0.04	0.36
Sweet Corn	0.48	0.20	0.25	0.04	0.36
Field Corn	0.48	0.20	0.25	0.04	0.36
Cotton (Pattern 1)	0.60	0.26	0.32	0.05	0.46
Cotton (Pattern 2)	0.62	0.26	0.33	0.05	0.48
Soybean	0.48	0.20	0.25	0.04	0.36
GMO Crop Uses					
Canola	0.65	0.28	0.34	0.05	0.50
Sweet Corn	0.40	0.17	0.21	0.03	0.31
Field Corn	0.81	0.34	0.43	0.07	0.62
Cotton (Pattern 1)	0.60	0.26	0.32	0.05	0.46
Cotton (Pattern 2)	0.62	0.26	0.33	0.05	0.48
Soybean	0.84	0.36	0.45	0.07	0.65
GMO Seed Propagation Uses[3]					
Canola	0.70	0.29	0.37	0.06	0.53
Corn	0.38	0.16	0.20	0.03	0.29
Soybean	0.84	0.36	0.45	0.07	0.65

Dark shaded cells RQ values indicate at least one use exceeds the chronic risk level of concern (LOC) of 1.0. RQ values based on NOAEC of 64.4 mg ae/kg diet for Honey bee (*Apis mellifera*).

[1] RQs presented in this table are for glufosinate-P except where noted and are comparable to RQs calculated for glufosinate-P ammonium.

[2]Terrestrial RQs are calculated based on the use patterns described in **Table F-2.1** and are in accordance with the use information presented on the final labels and summarized in **Tables 3-1** and **3-2**.

[3]Although use for propagation of glufosinate-resistant cotton seeds is permitted based on the final labels, a specific use pattern was not provided. Given that exposure from general agricultural uses on GMOs for the other crops is expected to be similar or higher than seed propagation uses for the same crop, the RQs for cotton GMO crop use are expected to approximate the risk for the cotton seed propagation use.

F.3 Terrestrial and Aquatic Plants

The attached excel spreadsheet **Table F.3.1 ERA Supplemental Tables for Plants** provides more detailed information on the T-PEZ, W-PEZ, and aquatic EECs and risk quotients for upland, semi-aquatic, and aquatic plants reported in the Ecological Risk Assessment.

Appendix G. AgDRIFT™ (version 2.1.1) Input and Output for Spray Drift Assessments

G.1 Ecological Risk Assessment

Table G-1. Spray Drift Assessment for Listed and Non-listed Species Based on Highest Application Rate.

Taxa	Most Sensitive Endpoint	Type of Endpoint	Use/Use Site	Highest RQ/App Rate[1]	Fraction of Applied[2]	Application Method	Boom Height	Distance from the Field Edge (ft)[3]
Mammals	NOAEL = 5.5 mg ae/kg-bw	Chronic[4]	Soybean	12	0.083	Ground	Low	3
							High	**7**
						Aerial	NA	**76**
Adult Bees	EC_{10} = 0.283 µg ae/bee	Chronic	Soybean, Canola, Corn, Cotton	41	0.024	Ground	Low	13
							High	**23**
						Aerial	NA	**203**
Non-bee Terrestrial Invertebrates	LR_{50} = 0.044 lbs ae/A	Acute Contact	Soybean, Canola, Corn, Cotton	0.359	0.111	Ground	Low	3
							High	**7**
						Aerial	NA	**53**
	EC_{10} = 8.38 mg ae/kg-diet	Chronic Dietary	Soybean	18	0.056	Ground	Low	7
							High	**10**
						Aerial	NA	**105**
Terrestrial Plants (Dicots)	NOAEL = 0.023 lbs ae/A	NA	Soybean, Canola, Corn, Cotton	0.359	0.064	Ground	Low	7
							High	**10**
						Aerial	NA	**89**

Bolded values identify the longest distance from the field edge for each taxon and application method. RQ = risk quotient; The chronic level of concern (LOC) for non-listed animals and the LOC for non-listed plants is 1.0. NA= not applicable.

[1]RQs are based on upper bound dose-based exposure estimates.

[2] Fraction of applied for mammals and adult bees is calculated as the LOC/RQ. The fraction of applied for terrestrial plants and acute contact in non-bee terrestrial invertebrates is the highest single application rate/most sensitive endpoint.

[3]Distance from field edge at which the RQ no longer exceeds the LOC. The distance was estimated assuming ground application with low (20 inches above the ground) or high (50 inches above the ground) boom height and ASAE fine to medium/coarse droplet size distribution and aerial application with nozzles that produce ASAE medium to coarse droplet size distribution with 10 mph windspeed.

[4]Acute risk to non-listed mammals is expected to be low both on and off-field.

G.2 Spray Drift Analysis for the Biological Evaluation

Table G-2. Spray Drift Distances Based on Highest Application Rate Used to Establish the Action Area for the Listed Species May Affect/No Effect (MA/NE) Determination

Taxa	Most Sensitive Endpoint	Duration of Exposure and Waterbody Bin	Use/Use Site	Highest RQ/App Rate[1]	Fraction of Applied	Application Method	Boom Height	Distance from the Field Edge (ft)[2]	Spray Drift Distance for Action Area (m)[3]
Mammals	NOAEL = 5.5 mg ae/kg-bw	Chronic Dose-based[4]	GMO-Soybean	12.11	0.0826	Ground	Low	3	0
							High	7	
						Aerial	NA	76	30
Adult Bees	EC_{10} = 0.283 µg ae/bee	Chronic Dietary	GMO/Non-GMO-Soybean, Field Corn, Canola, Cotton	41	0.0244	Ground	Low	13	30
							High	23	
						Aerial	NA	203	60
Larval Bees	NOAEL = 2.6 µg ae/bee	Chronic Dietary		1.9	0.526	Ground	Low	3	0
							High		
						Aerial	NA	0	
Non-Bee Terrestrial Invertebrates	LR_{50} = 0.040 lbs ae/A	Acute Contact	GMO/Non-GMO-Soybean, Field Corn, Canola, Cotton	0.359	0.123	Ground	Low	3	0
							High	7	
						Aerial	NA	53	30
	EC_{10} = 8.38 mg ae/kg-diet	Chronic Dietary	GMO-Soybean	18.32	0.0546	Ground	Low	7	0
							High	10	
						Aerial	NA	105	30
Terrestrial Plants - Dicots	NOAEL = 0.023 lbs ae/A	NA	GMO/Non-GMO-Soybean, Field Corn, Sweet Corn, Canola, Cotton	0.359	0.0641	Ground	Low	7	0
							High	10	
						Aerial	NA	89	30
	NOAEL = 0.046 lbs ae/A	NA	GMO/Non-GMO-	0.359	0.128	Ground	Low	3	0
							High	7	

Taxa	Most Sensitive Endpoint	Duration of Exposure and Waterbody Bin	Use/Use Site	Highest RQ/App Rate[1]	Fraction of Applied	Application Method	Boom Height	Distance from the Field Edge (ft)[2]	Spray Drift Distance for Action Area (m)[3]
Terrestrial Plants - Monocots			Soybean, Field Corn, Canola, Cotton			Aerial	NA	39	30
Aquatic Invertebrates[5]	NOAEC = 0.067 mg ae/L	Chronic, Bin 2	GMO/Non-GMO-Soybean, Field Corn, Canola, Cotton	0.359	0.167	Ground	Low	3	0
							High		
						Aerial	NA	26	30
Non-Vascular Aquatic Plants[5]	NOAEC = 0.018 mg ae/L	Bin 2	GMO/Non-GMO-Soybean, Field Corn, Canola, Cotton	0.359	0.0447	Ground	Low	3	0
							High		
						Aerial	NA	121	30

Bolded values identify the longest distance from the field edge for each taxon and application method. RQ = risk quotient; NA= not applicable.

[1]RQs reported for mammals and non-bee terrestrial invertebrates (chronic dietary only) are based on upper bound dose-based and dietary-based exposure estimates, respectively, modeled in T-REX for the use patterns with the highest potential for exposure (generally multiple applications with the highest single application rate and the shortest retreatment interval). RQs for adult and larval bees are based on estimated residues in pollen and nectar following a single application modeled in BeeREX. Spray drift distance for acute contact toxicity in non-bee terrestrial invertebrates, terrestrial plants, aquatic plants, and aquatic invertebrates are based on the application rate for a single application; therefore, the highest single application rate is reported in this column.

[2] Distance from field edge at which exposure no longer exceeds the endpoint. The distance was estimated assuming ground application with low (20 inches above the ground) or high (50 inches above the ground) boom height and ASAE fine to medium/coarse droplet size distribution and aerial application with nozzles that produce ASAE medium to coarse droplet size distribution with 10 mph windspeed.

[3] The spray drift distance from AgDrift output in feet was converted to meters to establish a spray drift buffer for the exposure area in the predictions of the likelihood of future jeopardy for listed species. Since the spray drift buffers for the action area are in 30-meter increments, the AgDrift output was rounded to the nearest 30 m increment. Spray drift distances within 10 feet (~3 m) of a lower increment were rounded down, otherwise the spray drift distance was rounded up (*i.e.,* spray drift effects within 1-10 ft (1-3 m) of the use site were considered to be on-field so spray drift was not included in the action area whereas effects between 11 and 100 ft (4 - 30 m) would be rounded up to 30 m).

[4]The buffer distances estimated based on chronic risk are also protective of off-field acute risk to listed mammals.

[5]Spray drift buffers for aquatic plants and aquatic invertebrates are based on a low-volume, static waterbody that is 1 m (3.28 ft) wide and 0.1 m (0.328 ft) deep. These dimensions are based on the representative waterbody for Bin 2 and Bin 5 and are a conservative estimate of exposure for larger waterbodies.

Table G-3. Spray Drift Distances Based on Highest Application Rate Used to Establish the Exposure Area for Evaluating Adverse Effects to Individuals of Listed Species (Likely to Adversely Affect/Not Likely to Adversely Affect (LAA/NAA) Determination)

Taxa	Individual Adverse Effects Endpoint	Duration of Exposure and Waterbody Bin	Use/Use Site	Highest MoE or App Rate[1]	Fraction of Applied	Application Method	Boom Height	Distance from the Field Edge (ft)[2]	Spray Drift Distance for Action Area (m)[3]
Mammals[4]	MATC = 9.5 mg ae/kg-bw	Chronic Dose-based	GMO-Soybean	8.32	0.12	Ground	Low	3	0
							High	7	
						Aerial	NA	43	30
Adult Bees	MATC = 25.7 µg ae/bee (mortality)	Chronic Dietary	Residue levels in pollen and nectar are not estimated to exceed the MATC for adult bee mortality. Therefore, the final uses are not likely to result in adverse effects to adult listed bees.						
Larval Bees	MATC = 3.6 µg ae/bee	Chronic Dietary	GMO/Non-GMO-Soybean, Field Corn, Canola, Cotton	1.36	0.735	Ground	Low	3	0
							High		
						Aerial	NA	0	
Non-Bee Terrestrial Invertebrates	MATC = 92.9 mg ae/kg-diet	Chronic Dietary	GMO-Soybean	1.65	0.606	Ground	Low	3	0
							High	3	
						Aerial	NA	0	
Terrestrial Plants - Dicots	NOAEL = 0.023 lbs ae/A	NA	GMO/Non-GMO-Soybean, Field Corn, Canola, Cotton	0.359	0.0641	Ground	Low	7	0
							High	10	
						Aerial	NA	89	30
Terrestrial Plants - Monocots	NOAEL = 0.046 lbs ae/A	NA	GMO/Non-GMO-Soybean, Field Corn, Canola, Cotton	0.359	0.128	Ground	Low	3	0
							High	7	
						Aerial	NA	39	30
Aquatic Invertebrates[5]	MATC = 0.108 mg ae/L	Chronic, Bin 2	GMO/Non-GMO-Soybean, Field	0.359	0.268	Ground	Low	3	0
							High		
						Aerial	NA	13	30

Taxa	Individual Adverse Effects Endpoint	Duration of Exposure and Waterbody Bin	Use/Use Site	Highest MoE or App Rate[1]	Fraction of Applied	Application Method	Boom Height	Distance from the Field Edge (ft)[2]	Spray Drift Distance for Action Area (m)[3]
			Corn, Canola, Cotton						
Non-Vascular Aquatic Plants	Direct effects to individuals or populations of non-vascular plants are not a concern given that there are no non-vascular aquatic plant species federally listed as endangered or threatened Indirect effects to listed species is also not a concern for any use given that exposure is not anticipated to impact non-vascular aquatic plant communities in any size water body.								

MoE = Magnitude of effect calculated as the estimated exposure divided by the individual adverse effects endpoint; MATC = maximum acceptable toxicant concentration; NA= not applicable.

[1]MoEs reported for mammals and non-bee terrestrial invertebrates (chronic dietary only) are based on upper bound dose-based and dietary-based exposure estimates, respectively, modeled in T-REX for the use patterns with the highest potential for exposure (generally multiple applications with the highest single application rate and the shortest retreatment interval). MoEs for larval bees are based on estimated residues in pollen and nectar following a single application at the maximum single application rate modeled in BeeREX. Spray drift distance for terrestrial plants and aquatic invertebrates are based on the maximum single application rate which is reported in this column.

[2]Distance from field edge at which exposure no longer exceeds the endpoint. The distance was estimated assuming ground application with low (20 inches above the ground) or high (50 inches above the ground) boom height and ASAE fine to medium/coarse droplet size distribution and aerial application with nozzles that produce ASAE medium to coarse droplet size distribution with 10 mph windspeed.

[3] The spray drift distance from AgDrift output in feet was converted to meters to establish a spray drift buffer for the exposure area in the predictions of the likelihood of future jeopardy for listed species. Since the spray drift buffers for the action area are in 30-meter increments, the AgDrift output was rounded to the nearest 30 m increment. Spray drift distances within 10 feet (~3 m) of a lower increment were rounded down, otherwise the spray drift distance was rounded up (*i.e.,* spray drift effects within 1-10 ft (1-3 m) of the use site were considered to be on-field so spray drift was not included in the action area whereas effects between 11 and 100 ft (4 - 30 m) would be rounded up to 30 m).

[4] Spray drift distance for mammals reported in this table is based on the highest magnitude of effect for listed mammals (the Anastasia Island Beach Mouse and Southeastern Beach Mouse that consume reptiles and amphibians). This represents the furtherest distance off-site at which direct effects from spray drift may occur. While the individual direct MoE will vary among listed species based on body weight and dietary items, adverse effects to listed species individuals from spray drift residues is not likely to be further than 30 m from the field. For PPHD effects, the furthest distance to effects is 33 ft (10 m). This represents the area in which indirect effects from spray drift may occur to listed species that have a relationship with small mammals (15 g).

[5]Spray drift buffers for aquatic invertebrates are based on a low-volume, static waterbody that is 1 m (3.28 ft) wide and 0.1 m (0.328 ft) deep. These dimensions are based on the representative waterbody for Bin 2 and Bin 5 and are a conservative estimate of exposure for larger waterbodies.

Table G-4. Spray Drift Distances Based on Highest Application Rate Used to Establish the Exposure Area for Evaluating Adverse Effects to Listed Species Populations and Communities[1]

Taxa	Population/Community Adverse Effects Endpoint	Duration of Exposure and Waterbody Bin	Use/Use Site	Highest MoE/App Rate[2]	Fraction of Applied	Application Method	Boom Height	Distance from the Field Edge (ft)[3]	Spray Drift Distance for Action Area (m)[4]
Terrestrial Plants	HC_{05} = 0.0417 lbs ae/A (Population)	NA	GMO/Non-GMO-Soybean, Field Corn, Canola, Cotton	0.359	0.116	Ground	Low	3	0
							High	7	
						Aerial	NA	46	30
	HC_{25} = 0.058 lbs ae/A (Community)			0.359	0.162	Ground	Low	3	0
							High	3	
						Aerial	NA	30	30

MoE = Magnitude of effect calculated as the estimated exposure divided by the individual adverse effects endpoint; MATC = maximum acceptable toxicant concentration; NA= not applicable.

[1] Spray drift distances are only reported for terrestrial plants because it is the only taxa where population-level impacts are likely off-field. As reported in **Table G-2.2**, individual impacts to terrestrial invertebrates are likely to be on-field only. Furthermore, glufosinate-P uses are not likely to result in adverse effects to listed non-bee terrestrial invertebrates, mammals, and aquatic invertebrate populations nor non-bee terrestrial invertebrates, mammal, and aquatic invertebrate communities that may serve as a prey base for other listed species (see **Section 8.3**).

[2] MoEs reported for mammals are based on mean dose-based exposure estimates modeled in T-REX for the use patterns with the highest potential for exposure (generally multiple applications with the highest single application rate and the shortest retreatment interval). Spray drift distance for terrestrial plants is based on the maximum single application rate which is reported in this column.

[3] Distance from field edge at which exposure no longer exceeds the endpoint. The distance was estimated assuming ground application with low (20 inches above the ground) or high (50 inches above the ground) boom height and ASAE fine to medium/coarse droplet size distribution and aerial application with nozzles that produce ASAE medium to coarse droplet size distribution with 10 mph windspeed.

[4] The spray drift distance from AgDrift output in feet was converted to meters to establish a spray drift buffer for the exposure area in the predictions of the likelihood of future jeopardy for listed species. Since the spray drift buffers for the action area are in 30-meter increments, the AgDrift output was rounded to the nearest 30 m increment. Spray drift distances within 10 feet (~3 m) of a lower increment were rounded down, otherwise the spray drift distance was rounded up (*i.e.,* spray drift effects within 1-10 ft (1-3 m) of the use site were considered to be on-field so spray drift was not included in the action area whereas effects between 11 and 100 ft (4 - 30 m) would be rounded up to 30 m).

Appendix H. Glufosinate Species Sensitivity Distribution Analysis for Vegetative Vigor Endpoints

- **Summary**

Species Sensitivity Distributions (SSDs) were fit to inhibition concentrations (IC_{25} values) for vegetative vigor (VV) dry weight and height endpoints for plants exposed to glufosinate. Separate SSDs for height and weight were developed.

Six distributions (normal, logistic, triangular, gumbel, weibull and burr) were fit to the available vegetative vigor data for glufosinate. For dry weight, the gumbel distribution provided the best fit for the datasets (**Figure H-1**). For plant height, the normal distribution provided the best fit for the dataset (**Figure H-2**). This decision was based on the Akaike Information Criterion $(AIC)_c$ weight and confidence limits for the different distributions. Summary statistics from the fitted SSD for dry weight and height are provided in
Table H-**1**. The fifth, tenth, twenty-fifth, fiftieth, seventy-fifth, ninetieth and ninety-fifth percentiles of the SSD (abbreviated HC_{05}, HC_{10}, HC_{25}, HC_{50}, HC_{75}, HC_{90}, and HC_{95}, respectively, where "HC" stands for "hazard concentration") are used to calculate endpoints representing effects to listed species of plants associated with height and weight.

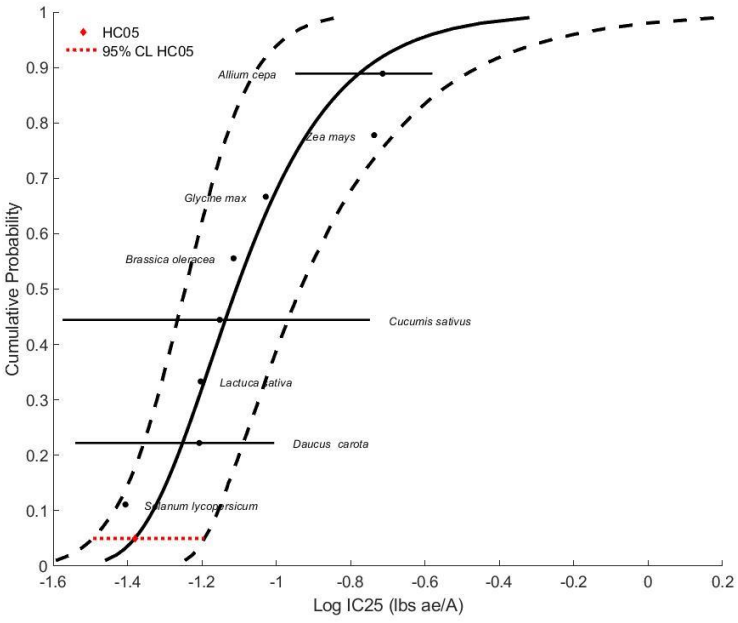


Figure H-1. Gumbel Species Sensitivity Distribution (SSD) for glufosinate vegetative vigor toxicity endpoints for dry weight. (HC05=5th percentile hazard concentration)

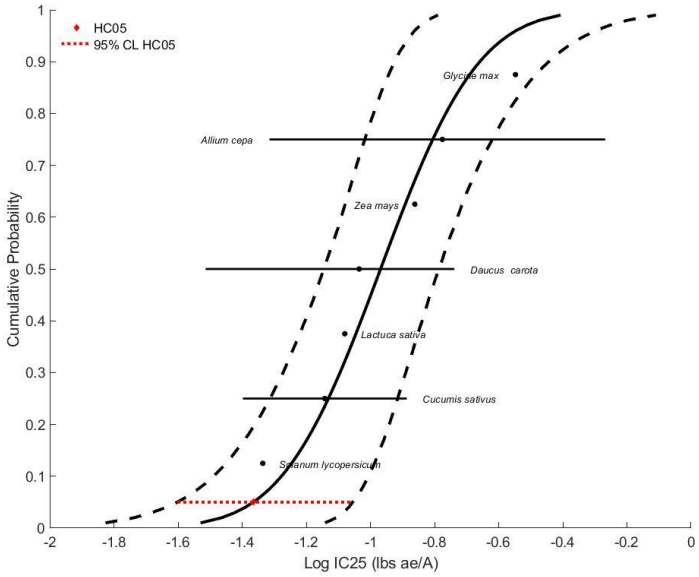


Figure H-2. Normal Species Sensitivity Distribution (SSD) for glufosinate vegetative vigor toxicity endpoints for height. (HC05=5th percentile hazard concentration)

Table H-1. Summary of glufosinate vegetative vigor (VV) IC25 endpoints (values in lb ae/A).

Statistic	VV Dry Weight (Gumbel)	VV Height (Normal)
HC_{05} (95% CI)	**0.0417 (0.0322-0.0641)**	**0.0431 (0.0250-0.0880)**
HC_{10} (95% CI)	0.0466 (0.0367-0.0698)	0.0528 (0.0325-0.0986)
HC_{25} (95% CI)	0.0580 (0.0454-0.0844)	0.0739 (0.0486-0.1216)
HC_{50} (95% CI)	0.0780 (0.0569-0.1161)	0.1076 (0.0715-0.1636)
HC_{75} (95% CI)	0.1138 (0.0714-0.1904)	0.1565 (0.0961-0.2400)
HC_{90} (95% CI)	0.1750 (0.0893-0.3485)	0.2193 (0.1191-0.3598)
HC_{95} (95% CI)	0.2383 (0.1044-0.5479)	0.2683 (0.1333-0.4669)

CI = confidence interval

- ## Toxicity Data

Because an SSD depicts relative sensitivities of different species exposed to the same stressor, it is necessary to standardize the data as much as possible to eliminate variables that would confound the relative sensitivities of species. Such variables can include study exposure duration and other study design factors. All IC_{25} values that were included in the analysis were all height or dry weight endpoints that followed the OCSPP 850.4150 guideline. Endpoints without definitive endpoints were not used to derive SSDs.

Data used to derive SSDs are from registrant-submitted studies. Those data are included in **Table H-2** and **Table H-3**. EPA utilized data generated for L-glufosinate ammonium and L-glufosinate acid typical end use products (TEP) as well as racemic glufosinate ammonium technical grade active ingredient (TGAI). All IC_{25} endpoints are reported as acid equivalents and the racemic glufosinate ammonium TGAI data are adjusted for L-isomer content to ensure

consistent units across endpoints. Although data are available on the racemic glufosinate ammonium TEP, a comparison to the substantially different increasing uncertainty whether the racemic TEP is representative of the L-glufosinate TEPs. Those data are discussed qualitatively in the assessment for characterization purposes but are not included in the SSD. The SSD were developed from a total of 8 plant species tested for dry weight and 7 plant species tested for height (
Table H-**4**). In cases where multiple endpoints were available for the same test species, values ranged in similarity (differing by 2.3-6.7x for dry weight and by 3.2-11x for height). The data in **Table H-3** and in **Table H**-4 are from 4 different studies.

Table H-2. Test results used to derive species sensitivity distributions (SSDs) for glufosinate for Vegetative Vigror (VV) dry weight.

Plant	Plant Type	IC_{25} value (lb ae/A)	Reference (MRID)
Cucumber	Dicotyledonous	0.0266	51036693
Carrot	Dicotyledonous	0.028791	41396113
Tomato	Dicotyledonous	0.039302	41396113
Lettuce	Dicotyledonous	0.062609	41396112
Cucumber	Dicotyledonous	0.073577	41396113
Cabbage	Dicotyledonous	0.076776	41396113
Carrot	Dicotyledonous	0.0842	51036693
Soybean	Dicotyledonous	0.093685	41396113
Carrot	Dicotyledonous	0.098712	50982324
Onion	Monocotyledonous	0.112422	50982324
Cucumber	Dicotyledonous	0.178687	41396112
Corn	Monocotyledonous	0.183257	41396113
Onion	Monocotyledonous	0.243581	41396113
Onion	Monocotyledonous	0.263	51036693

Table H-3. Test results used to derive species sensitivity distributions (SSDs) for glufosinate for Vegetative Vigor (VV) height.

Plant	Plant Type	IC_{25} value (lb ae/A)	Reference (MRID)
Carrot	Dicotyledonous	0.030619	41396113
Cucumber	Dicotyledonous	0.04	51036693
Tomato	Dicotyledonous	0.046157	41396113
Onion	Monocotyledonous	0.048442	41396113
Lettuce	Dicotyledonous	0.083174	41396112
Cucumber	Dicotyledonous	0.129788	41396113
Corn	Monocotyledonous	0.137557	41396113
Carrot	Dicotyledonous	0.14	51036693
Onion	Monocotyledonous	0.180058	50982324
Carrot	Dicotyledonous	0.1828	50982324
Soybean	Dicotyledonous	0.28334	41396113

Plant	Plant Type	IC_{25} value (lb ae/A)	Reference (MRID)
Onion	Monocotyledonous	0.54	51036693

Table H-4. Distribution of test results available for glufosinate vegetative vigor endpoints.

Endpoint	Test results	Species
VV Dry Weight	14	8
VV Height	12	7

- **Determining Distribution with Best Fit**

  - **P-values**

Six potential distributions for the glufosinate data were considered (*i.e.,* normal, logistic, triangular, Gumbel, Weibull and Burr). To fit each of the six distributions, the toxicity values were common log (log_{10}) transformed. The SSD toolbox includes four different fitting methods (*i.e.,* maximum likelihood, moment estimators, linearization and metropolis-hastings). All six distributions were fit using the maximum likelihood (ML) method. To test goodness-of-fit, all six distributions were fit to the glufosinate data and bootstrap goodness-of-fit tests were run with 10,000 replicates. The results of these fitting exercises are presented in **Table H-5**.

Table H-5. P-values calculated for Species Sensitivity Distributions (SSDs) using vegetative vigor height and dry weight toxicity data for glufosinate.

Distribution	VV Dry Weight SSD	VV Height SSD
Normal	0.29	0.90
Logistic	0.31	0.79
Triangular	0.52	0.93
Gumbel	0.72	0.98
Weibull	0.096	0.83
Burr	0.65	0.96

  - Akaike's Information Criteria Weights

Akaike's Information Criterion corrected for sample size (AIC_c) was used to compare the distributions for plant height and weight at the HC_{05}[2]. For dry weight, the majority of the weight is attributed to the triangular and Gumbel distributions (with ≤19% each attributed to normal, logistic, Weibull, and Burr;
Table H). Based on the AIC weights, the fit of the triangular and gumbel distributions are further considered below for plant dry weight data. For height, the majority of the weight is attributed to the triangular, normal, and Gumbel distribution (with ≤18% each attributed to logistic, Weibull, and Burr; **Table H-6**). Based on the AIC weights, the fit of the triangular, normal, and Gumbel distributions are further considered below for plant height data.

Table H-6. Akaike's Information Criteria (AICc) for distributions for Vegetative Vigor (VV) dry weight toxicity data for glufosinate.

Distribution	AICc	Delta AICc	Wt	HC_{05}	SE HC_{05}
Triangular	-21.9	0	0.30	0.0386	0.0111
Gumbel	-21.5	0.41	0.25	0.0417	0.0071
Normal	-21.0	0.90	0.19	0.0366	0.0102
Logistic	-20.6	1.32	0.16	0.0337	0.0102
Weibull	-19.4	2.49	0.087	0.0243	0.0122
Burr	-15.9	6.01	0.015	0.0416	0.0074

Table H-7. Akaike's Information Criteria (AICc) for distributions for Vegetative Vigor (VV) height toxicity data for glufosinate.

Distribution	AICc	Delta AICc	Wt	HC_{05}	SE HC_{05}
Triangular	-13.0	0	0.27	0.0458	0.0145
Normal	-12.6	0.47	0.22	0.0431	0.0139
Gumbel	-12.6	0.50	0.21	0.0482	0.0099
Logistic	-12.2	0.87	0.18	0.0401	0.0145
Weibull	-11.4	1.65	0.12	0.0282	0.0161
Burr	-5.56	7.49	0.006	0.0478	0.0119

- **Distributions**

Figures H-3 and **H-4** depict the triangular and Gumbel distributions fit to the IC_{25} values for plant species dry weight. **Table H-8** includes the HC_{05}, HC_{10}, HC_{25}, HC_{50}, HC_{75}, HC_{90}, and HC_{95} values for the two distributions, along with the associated 95% confidence intervals. When comparing the two distributions to the individual toxicity data, the Gumbel appears to be a better fit for the data compared to triangular distribution (**Figures H-3 and H-4**).

Since the HC_{05} is an important threshold used in the assessment, the estimated HC_{05} of the two distributions is also considered to select the best fit. Although the triangular distribution estimates the most sensitive HC_{05}, it is similar to the estimate from the Gumbel distribution and neither report confidence intervals that encompass the lowest empirical value (*i.e.,* 0.0266 lbs ae/A for cucumber; MRID 51036693). Given that the Gumbel distribution exhibits a better fit for the data (*i.e.*, all empirical data points are within the 95% confidence interval of the distribution), EPA considers its HC_x estimates more reliable.

Table H-8. HC_x values (in lbs ae/A) for triangular and Gumbel distributions based on vegetative vigor plant dry weight IC_{25} values.

Distribution	HC_{05} (95% CI)	HC_{10} (95% CI)	HC_{25} (95% CI)	HC_{50} (95% CI)	HC_{75} (95% CI)	HC_{90} (95% CI)	HC_{95} (95% CI)
Triangular	0.0386 (0.0297 - 0.0697)	0.0448 (0.0348- 0.0759)	0.0602 (0.0465- 0.0910)	0.0841 (0.0616- 0.1147)	0.1173 (0.0779- 0.1515)	0.1577 (0.0934- 0.2030)	0.1830 (0.1014- 0.2371)
Gumbel	0.0417 (0.0322- 0.0641)	0.0466 (0.0367- 0.0698)	0.0580 (0.0454- 0.0844)	0.0780 (0.0569- 0.1161)	0.1138 (0.0714- 0.1904)	0.1750 (0.0893- 0.3485)	0.2383 (0.1044- 0.5479)

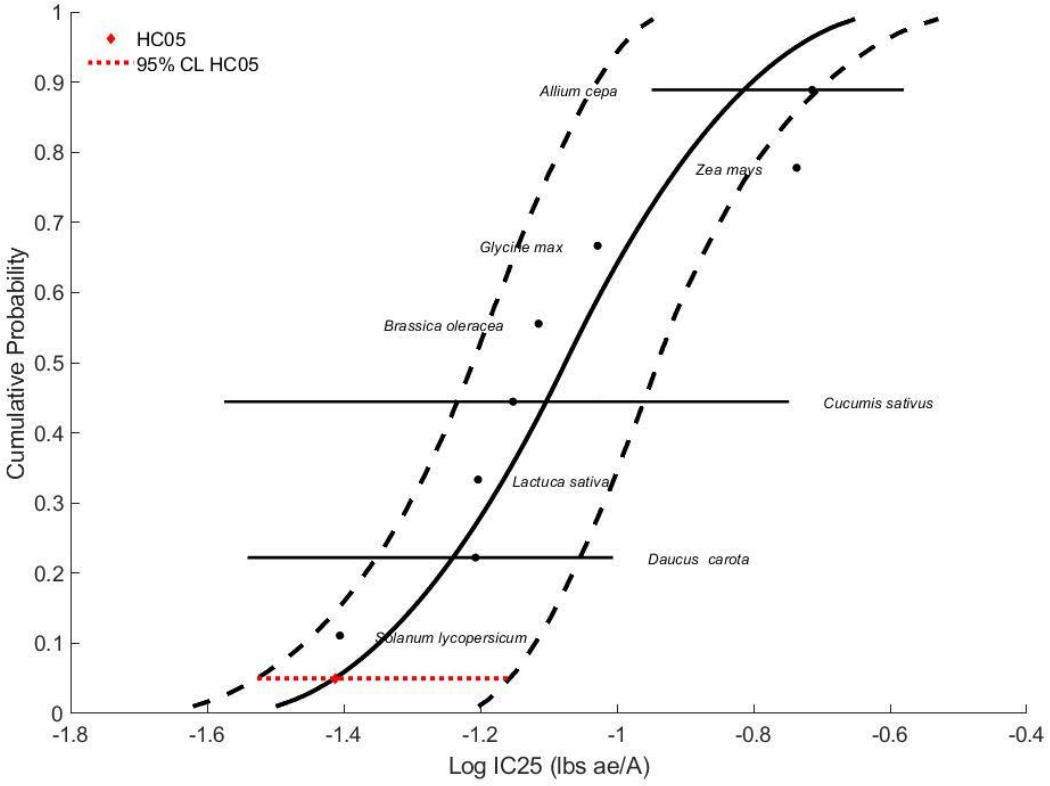


Figure H-3. Triangular species sensitivity distribution (SSD) for glufosinate toxicity values for vegetative vigor dry weight. (HC05=5th percentile hazard concentration)

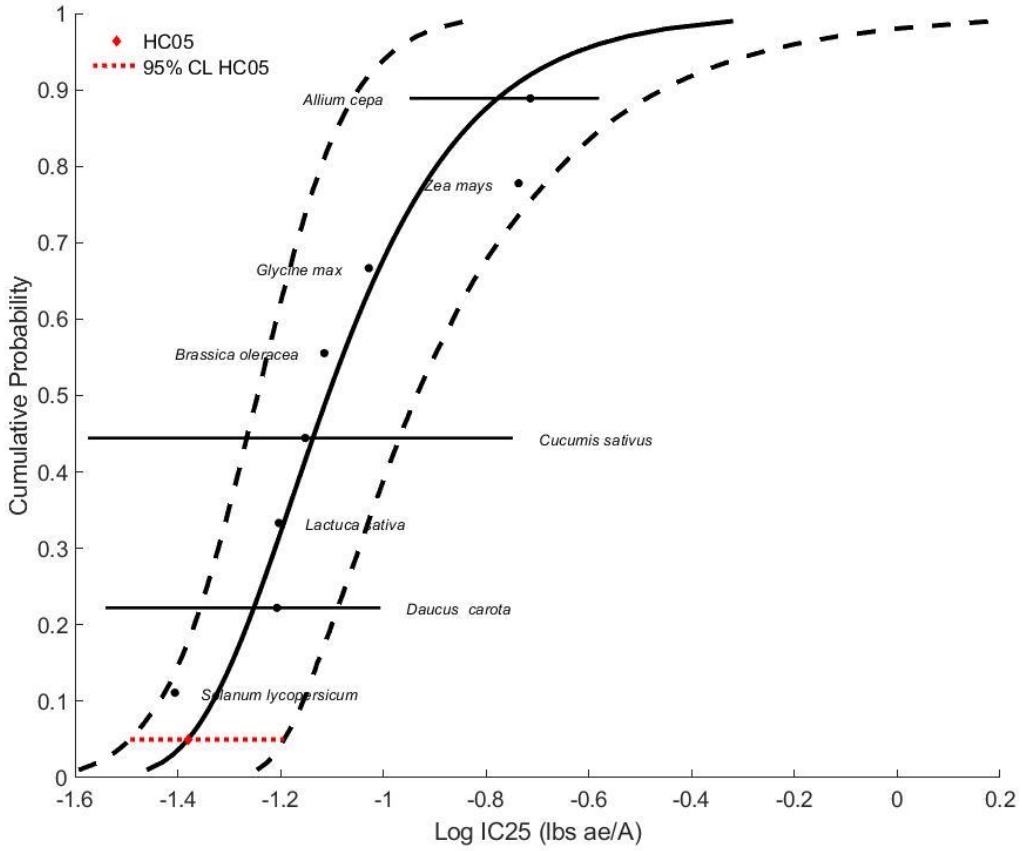


Figure H-4. Gumbel species sensitivity distribution (SSD) for glufosinate toxicity values for vegetative vigor dry weight. (HC05=5th percentile hazard concentration)

Figures H-5 through **H-7** depict the three distributions fit to the IC_{25} values for plant species height. **Table H-9** includes the HC_{05}, HC_{10}, HC_{25}, HC_{50}, HC_{75}, HC_{90}, and HC_{95} values for all three distributions, along with the associated 95% confidence intervals. When comparing the three distributions to the individual toxicity data, the normal and Gumbel distributions appear to be good fits for the data.

Since the HC_{05} is an important threshold used in the assessment, the estimated HC_{05} of the normal and Gumbel distributions is used to select the best fit. Since the HC_{05} for both distributions are similar, the normal distribution is chosen because it generates the most conservative of the HC_{05} values and the one that is closest to the lowest empirical value (*i.e.,* 0.0306 lbs ae/A for carrot; MRID 41396113). This value is within the 95% confidence intervals of the HC_{05} for the normal distribution (**Table H-9**).

Table H-9. HC_x values (in lbs ae/A) for triangular, normal, and Gumbel distributions based on vegetative vigor plant height IC_{25} values.

Distribution	HC_{05} (95% CI)	HC_{10} (95% CI)	HC_{25} (95% CI)	HC_{50} (95% CI)	HC_{75} (95% CI)	HC_{90} (95% CI)	HC_{95} (95% CI)
Triangular	0.0458 (0.0341 - 0.0920)	0.0540 (0.0402- 0.1004)	0.0750 (0.0548- 0.1215)	0.1084 (0.0739- 0.1560)	0.1566 (0.0945- 0.2115)	0.2172 (0.1150- 0.2909)	0.2562 (0.1262- 0.3467)
Normal	0.0431 (0.0250- 0.0880)	0.0528 (0.0325- 0.0986)	0.0739 (0.0486- 0.1216)	0.1076 (0.0715- 0.1636)	0.1565 (0.0961- 0.2400)	0.2193 (0.1191- 0.3598)	0.2683 (0.1333- 0.4669)
Gumbel	0.0482 (0.0354- 0.0829)	0.0548 (0.0411- 0.0903)	0.0701 (0.0523- 0.1115)	0.0982 (0.0674- 0.1602)	0.1505 (0.0870- 0.2800)	0.2452 (0.1098- 0.5757)	0.3480 (0.1289- 0.9700)

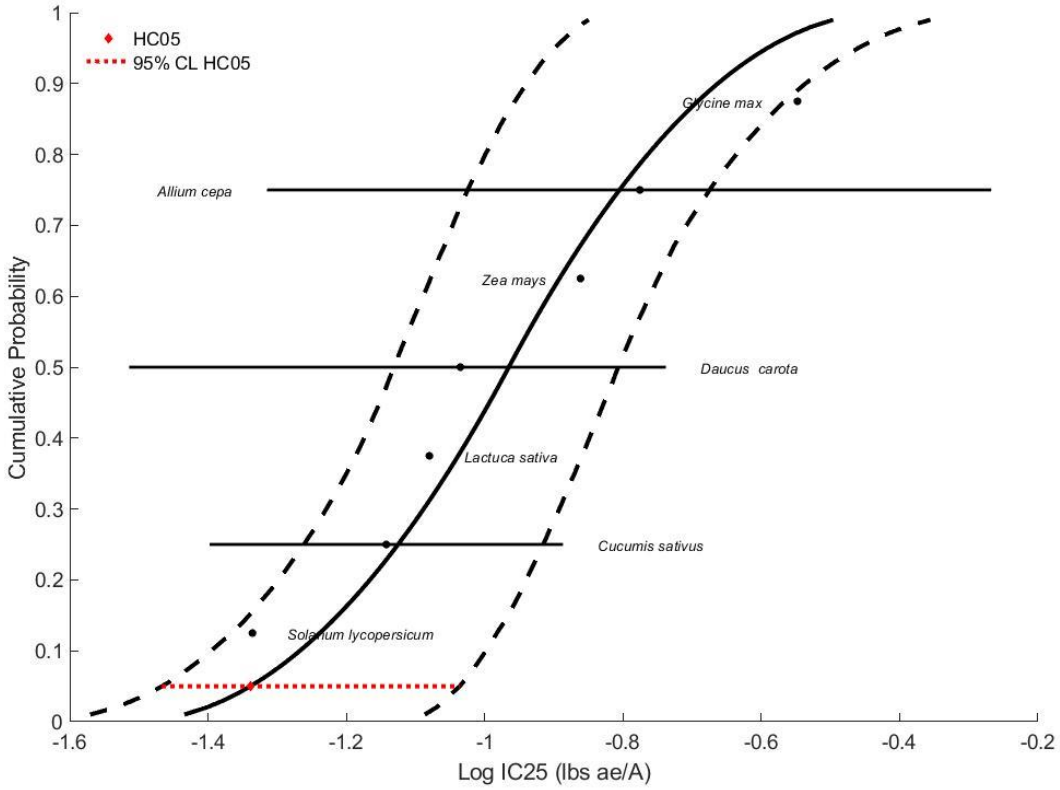


Figure H-5. Triangular species sensitivity distribution (SSD) for glufosinate toxicity values for vegetative vigor height. (HC05=5th percentile hazard concentration)

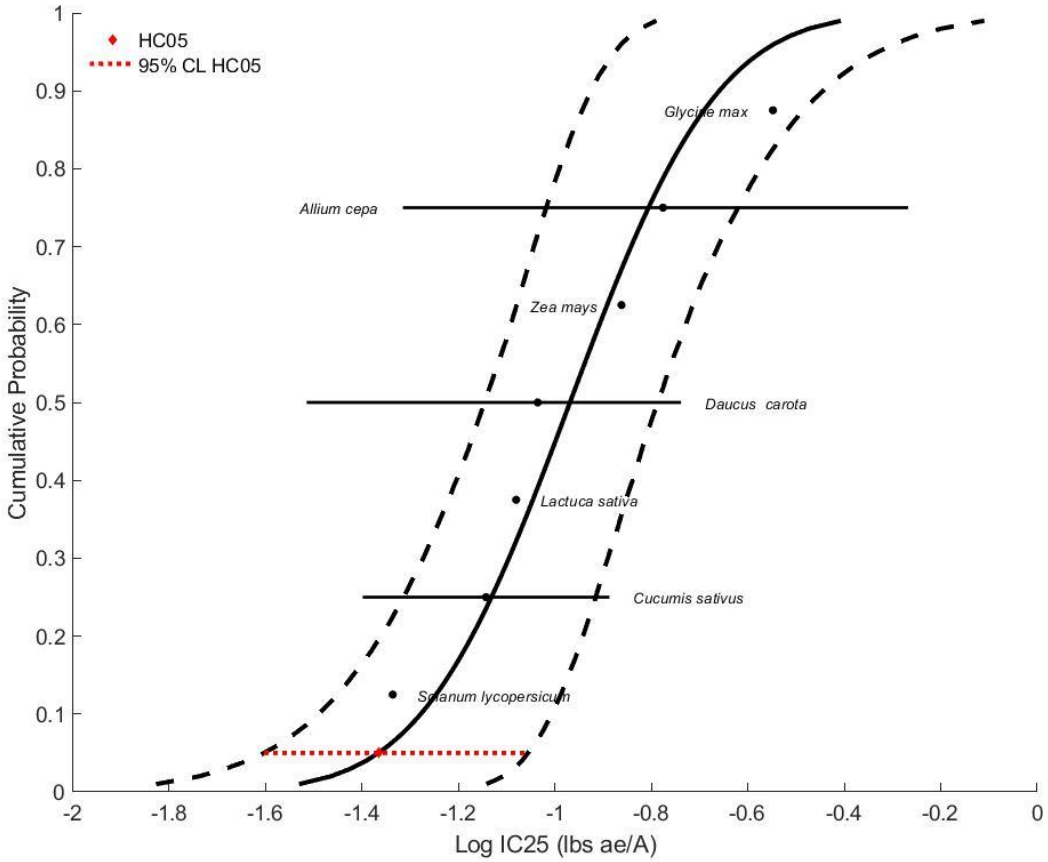


Figure H-6. Normal species sensitivity distribution (SSD) for glufosinate toxicity values for vegetative vigor height. (HC05=5th percentile hazard concentration)

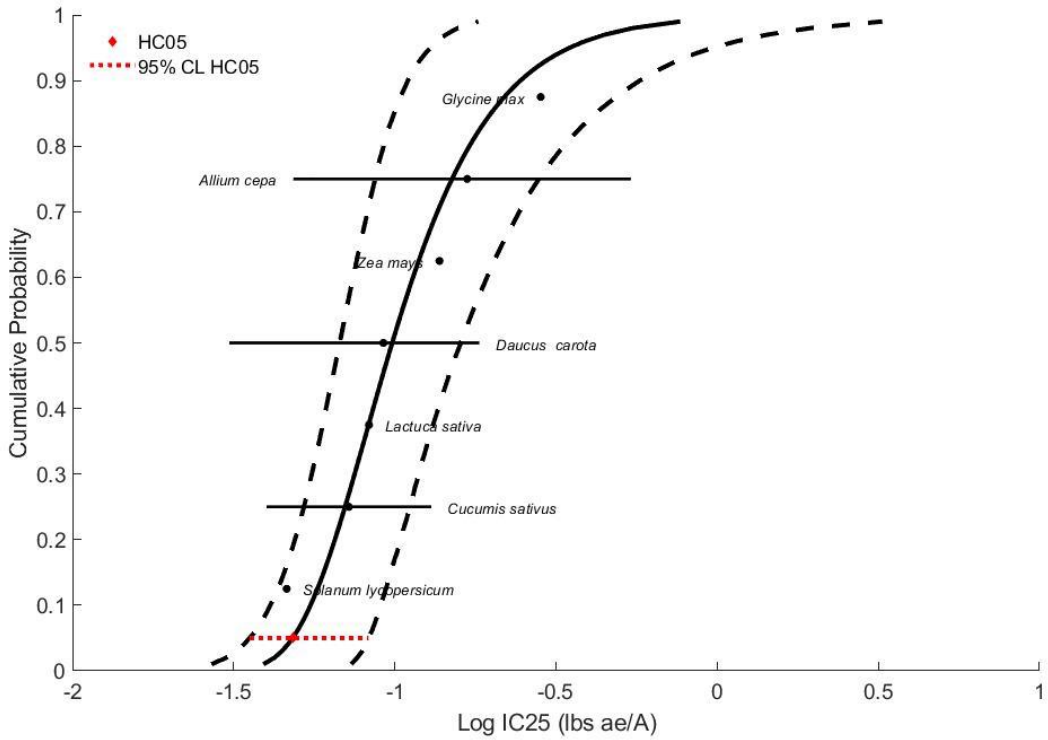


Figure H-7. Gumbel species sensitivity distribution (SSD) for glufosinate toxicity values for vegetative vigor height. (HC05=5th percentile hazard concentration)

- ## Conclusions

The Gumbel and normal distributions provided the best fit for the plant dry weight and plant height datasets, respectively. This decision was based on the AIC_c weight, and confidence limits for the different distributions and by visually examining the distributions and their consistency with the toxicity data.

Appendix I. Generation of the ESA Agricultural Use Data Layers (UDLs) from the Cropland Data Layer (CDL)

Use Data Layers (UDLs) spatially represent application sites for agricultural and non-agricultural label uses in EPA's Endangered Species Biological Evaluations (BEs). They leverage several different landcover and land use datasets acquired from remote sensing[48] technology to create a spatial footprint for a given label use. EPA uses USDA's Cropland Data Layer[49] (CDL) for the agricultural use sites found in the conterminous United States (ConUS). Updated annually, this publicly available dataset includes a robust accuracy assessment which is used by EPA to ensure the UDLs used in the BEs are of sufficient accuracy for decision making. This document provides a brief history of how this remotely sensed data is assessed for accuracy, introduces key topics related to assessing remotely sensed data, and outlines the criteria used by EPA when generating the agricultural UDLs and finally outlines the UDLs used in the glufosinate-P BE.

- Introduction to Accuracy Assessments

When selecting data sources to use to create its UDLs, EPA prefers to use publicly available national-level datasets; however, it may use proprietary data if it cannot identify appropriate publicly available data. By using existing datasets, EPA leverages the expertise of other agencies and organizations, rather than becoming a 'data maker'. Generally, the selected datasets follow national standards for the creation of spatial data and, in the case of remotely sensed data, includes accuracy assessments. Accuracy assessments provide a measure of "correctness" for the data layer. Without this measure of understanding in the spatial layers, decisions based on the dataset may lead to unexpected and possibly unacceptable results (Congalton, 2019). The goal of a quantitative accuracy assessment is to identify and measure map errors so that the map can be as useful as possible to the persons making decisions.

Two distinct types of quantitative accuracy assessments exist for spatial data: positional and thematic. Positional accuracy deals with the locational correctness of a map feature by measuring how far a spatial feature on a map is from its true or reference location on the ground (Bolstad, 2005). The Federal Geographic Data Committee (FGDC) produced the U.S. National Cartographic Standards for Spatial Accuracy (NCSSA) (FGDC, 1998) to create positional accuracy standards for medium- and small-scale maps/data. When possible, EPA leverages datasets adhering to these standards. Thematic accuracy deals with the labels or attributes of the features in the resulting Geographic Information System (GIS) product and will be the focus of the discussion in this Appendix. The thematic labels or attributes are the specific cover classes assigned in the landcover dataset. Each landcover dataset targets specific types of landscape features. In the case of the UDLs, and the underlying CDL, the primary goal of the datasets is to identify cover classes that represent agricultural crops. Other remotely sensed products may target but are not limited to non-agricultural features, non-agricultural plant cover, or water features. Each of the remotely sensed products may use the same satellite imagery, but due to the different goal of each project, the end results can differ. Thematic accuracy assessment provides measures of how different

[48] Remote sensing is defined as the collection and interpretation of information about an object from a distant vantage point. Remote sensing systems involve the measurement of electromagnetic energy reflected or emitted from an object and include instruments on balloons, aircraft, satellites, and unmanned aerial systems (UAS) (Congalton 2019).

[49] Available at USDA's National Agricultural Statistic Survey website: https://www.nass.usda.gov/Research_and_Science/Cropland/SARS1a.php

the mapped cover classes are from what occurs on the ground at specific reference locations. This is completed by comparing reference data, known/true classification of samples sites, and classified data for the same sample sites.

- History of Map Making

Before the invention of aircraft, maps were created from human observations using survey equipment. Today, most map/data makers use remote sensing data rather than collecting data using field observations. To create the spatial data from remotely sensed data, decision tree algorithms use the imagery and information from known sites, referred to as training data, to generate the cover class classifications. These algorithms look for spectral signatures across multiple wavelengths to identify unique cover classes; in the CDL, these are crop cover classes. Spectral signatures of various vegetation components include things such as canopy architecture, stem characteristics, leaf orientation, light angle, and shadowing of vegetation (Shah, 2019). Even though advances in technology have provided access to remotely sensed information, field observations are still important and provide information at specific sample locations, used as known data for the decision tree, or as a reference site for the accuracy assessment, rather than providing a complete survey of the project area's map extent. Map/data making has moved to using remotely sensed data to make maps because it:

(1) is less expensive and more efficient than creating maps from human observations;
(2) offers a bird's-eye view, improving the understanding of spatial relationships and the context of our observations; and,
(3) captures information in electromagnetic wavelengths that humans cannot see, such as the infrared portions of the electromagnetic spectrum, allowing for characterization of the landscape a human could not otherwise achieve.

However, no remotely sensed dataset is perfect. It is not possible to reach a complete one-to-one correlation between variation in remotely sensed data and the true variation found on the landscape. This means no resulting dataset will be error free. Several factors influence errors occurring in remotely sensed data, including but not limited to aircraft movement, topography, lens distortions, and other environmental factors (*e.g*., shadows, clouds, forest cover, snow morphology). These influences can reduce the strength of the relationships between the remotely sensed data and the landscape.

However, errors are not limited to remotely sense datasets. The historical method of field observation also included errors due to factors such as observer bias, equipment malfunctions, inaccuracies from sampling errors, and/or goals of the projects.

Regardless of the collection method, no dataset will be error free. The accuracy assessment allows for an understanding of those errors and provides the user the necessary information to decide if the accuracy level meets their decision-making needs. As discussed above, remotely sensed data typically includes two types of accuracy assessment: positional and thematic. The use of remotely sensed data requires an understanding of both.

Positional accuracy is assessed by comparing the coordinates of sample/reference points on a map against the coordinates of the same points derived from a survey or some other independent source. The Federal Geographic Data Committee (FGDC) produced the U.S. National Cartographic Standards for Spatial Accuracy (NCSSA) (FGDC, 1998) to create positional accuracy standards for medium- and small-scale maps/data. When possible, EPA leverages datasets adhering to these standards.

Unlike positional accuracy, there is no government or professional society standard for assessing thematic accuracy. This omission is partially due to the inherent complexity of thematic accuracy but primarily because historically, thematic accuracy was generally assumed to be at acceptable levels (Congalton 2019). The following sections explores the history of thematic accuracy and the accuracy goals set by EPA for the UDLs in absence of the government or professional society standard.

- History of Thematic Accuracy

The history of assessing thematic accuracy of maps derived from remotely sensed data is relatively brief, beginning around 1975 and was divided into four parts or epochs by Congalton in '*Assessing the Accuracy of Remotely Sensed Data'* (2019). Initially, no real accuracy assessment was performed on maps; rather, a "it looks good" mentality prevailed. This approach is typical of a new, emerging technology in which everything is changing so quickly that there is no time to assess how well you are doing. Despite the maturing of the technology over the last half century or so, some remote sensing analysts and map users still lean heavily on this mentality.

The second epoch is called the age of non-site-specific assessment. During this period, total acreages for each cover class were compared between reference estimates and measured without regard for location. It did not matter whether you knew where it was; only the how similar the total amounts were when compared. While total acreage is useful, it is equally if not more important to know where a specific landcover exists. Therefore, this second epoch was relatively short-lived and quickly led to the age of site-specific assessments.

In a site-specific assessment, reference locations for cover classes are compared with the classified cover class at the same location, and result in a measure of overall accuracy across all cover classes in the form of a 'percent correct'. This method far exceeded the non-site-specific assessment but lacked information on individual landcover categories. Site-specific assessment techniques were the dominant method until the late 1980s.

The fourth and current age of accuracy assessment is called the 'age of the error matrix'. An error matrix compares cover class information for a number of reference sites to the remotely sensed cover class results for the same location, across each cover classes in the data layer. The error matrix is a square array of numbers set out in rows and columns, accounting for each of the cover classes. Generally, the reference data cover classes are represented as the columns and the remotely sense/classified cover classes are represented by the rows. The number in each cell represent the sample sites in the corresponding cover classes from the reference data and the classified data. The major diagonal of this matrix identifies the sites where the reference and classified cover classes match, meaning the classified data correctly identified the cover class. (**Figure I-1**).

Some key terminology when considering these matrices:

(1) Reference data cover classes: the class label of the accuracy assessment site derived from field or human collected data, assumed to be correct.
(2) Classified data cover classes: the class label of the accuracy assessment site derived from the remotely sensed data.

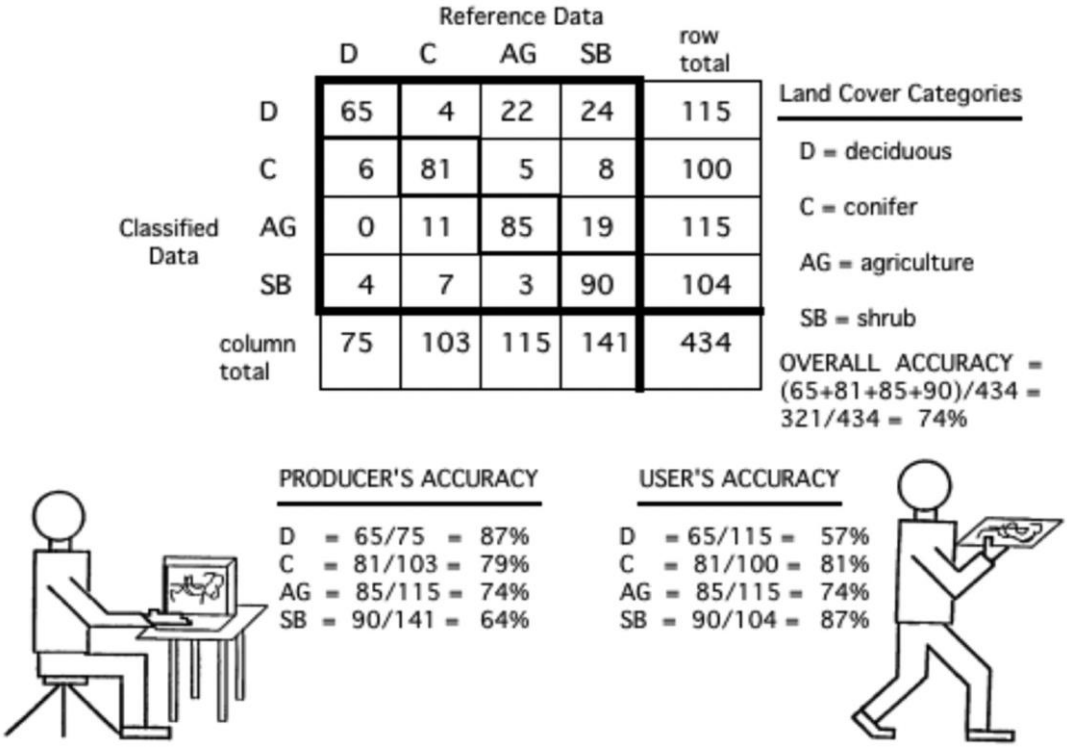


Figure I-1. Example Error Matrix and Accuracy Values (Congalton, 2019). Numbers within the bolded section of the matrix are the total number of sample sites that were identified for each cover class. In this example there are a total of 434 sample sites. The number in each cell represents the total number of sample sites found with the corresponding reference and classified cover class. For example, the 65 in the top left corner indicates that 65 samples site were identified as "D" for deciduous in both the reference and classified data. However, 65 does not account for all "D" sample sites in either classified or reference data. Moving over one cell to right, there are 4 sample sites identified as "C", conifer, in the reference data but "D" in the classified data. The classified data misidentified the cover class by including it in the incorrect category – this is an error of inclusion (also referred to as "commission errors"). Moving down to the cell directly below 65, there are 6 sites known to be "D" from the reference data but "C" in the classified data; here the misidentified cover class results in the exclusion from a category or an error of omission. The diagonal of the error matrix represents the number of sample sites matching in the reference and classified data. The column total provides the number of sample sites found each cover classes based on the reference data, and the row total provided the number of sample sites found in each cover class based on the classified data.

With each annual release of the CDL, USDA provides error matrices for their thematic classification of cultivated land at both the national and state level. The next sections provide additional details on the types of reported accuracy metrics provided with the error matrices, how the matrices are collapsed, and accuracy metrics are recalculated to represent the agricultural UDLs. Along with these descriptions is an example of the use of these metrics as outlined in **Figure I-1**.

- Error Matrices, Overall, Producer's and User's Accuracies, Kappa Statistic

Error matrices are effective representations of map accuracy because the individual accuracies of each map cover class are plainly described on the major diagonal (*i.e.*, classified data that matches the

reference data), along with both the errors of inclusion (*i.e.*, commission error) and the errors of exclusion (also referred to as "omission errors") when the classified and reference data cover classes do not match. An omission error occurs when a sample site is left out, or omitted, from the correct classes in the classified dataset. This is considered a false positive of the classified data or Type 1 error. A commission error occurs when a sample site is included in an incorrect class in the classified dataset. This is considered a false negative/false match of the classified data or Type 2 error.

In addition to clearly showing errors of omission and commission, the error matrix can be used to compute overall accuracy, producer's accuracy, and user's accuracy, which were introduced to the remote sensing community by Story and Congalton (1986). Overall accuracy is simply the sum of the major diagonal divided by the total number of sample units, providing a 'percent correct' across all cover classes. In the example error matrix found in **Figure I-1**, the overall accuracy is the sum of the values on the major diagonal, where the classified and reference data match, divided by the total number of sample sites or 321/435; resulting in an overall accuracy of 74%. This value is the most commonly reported accuracy assessment statistic. In addition to the overall accuracy, the reporting of producer's and user's accuracies allow for additional considerations, specifically of individual cover classes.

Computed to determine individual cover class accuracies, producer's and user's accuracies provide important information related to error within the individual cover class from different perspectives. The producer of the map may want to know how well a class matched the reference data, referred to the producer's accuracy. This value is computed by dividing the value from the major diagonal (the agreement between the reference and classified data) for the class of interest, by the total number of reference data points for the class. Looking at **Figure I-1**, the map producer identified 65 sites as deciduous, while the reference data indicate there were a total of 75 deciduous sites. So, 65 of 75 samples were correctly identified, resulting in a producer's accuracy of 87%, which is quite good. However, this is only half of the story. If you now view the map from the user's perspective, a user wants to know how many classified data points matched the reference data. In **Figure I-1** you see once again that 65 sites were classified as deciduous on the map that were actually deciduous, but the map shows a total of 115 site classified as deciduous, resulting in a user accuracy of 57%. In evaluating the accuracy of an individual map class, it is important to consider both the producer's and the user's accuracies.

The *kappa* statistic or coefficient ($\widehat{K}$) is used as another measure of agreement for the resulting remotely sensed data (Cohen, 1960). This measure of agreement is based on the difference between the actual agreement in the error matrix (*i.e.*, the agreement between the remotely sensed classification and the reference data as indicated by the major diagonal) and the chance agreement, which is indicated by the row and column totals (*i.e.*, marginals). The *kappa* coefficient reflects agreement between the classified cover classes and the reference cover classes, and ranges from 0 to 1. If the *kappa* coefficient equals 0 than there is no agreement between the classified and references label. The closer to 1 the *kappa* coefficient, the closer the agreement is, and if it reaches 1 then the classified and reference data match perfectly. Ultimately, a $\widehat{K}$ of 0.85 means there is an 85% or better agreement than chance alone.

$$\widehat{K} = \frac{observed\ accuracy - chance\ agreement}{1 - chance\ agreement}$$

The power of the kappa coefficient is in its ability to test whether one error matrix is statistically significantly different from another and not in simply reporting this value as another measure of accuracy.

- Use of Accuracy Values in Understanding Thematic Errors

In the past, an overall accuracy level of 85% was often adopted as representing the cutoff between acceptable and unacceptable data. This standard was first proposed in Anderson *et al.* (1976) despite the lack of any research being performed to establish this standard. Accuracy depends on many factors, including the amount of effort, level of landscape or classification detail, and variability of the classes. In some instances, an overall accuracy of 85% is more than sufficient; in others it would not be accurate enough; and in others, such an accuracy would be way too expensive to ever achieve (Congalton, 2019).

In the example described above and presented in **Figure I-1**, the error matrix has an overall map accuracy of 74%. This value provides insight on how accurate the map is, in general or across all classes, but provides no information within individual classes. For additional information on the deciduous cover class, the producer's and user's accuracies can be considered. The producer's accuracy for this class of 87% is quite good and even higher the overall accuracy of the dataset. However, if we stopped there, one might conclude that although the dataset appears to be average overall (*i.e*., 74%), it is more than adequate for the deciduous class. Making such a conclusion could be a serious mistake because the user's accuracy of 57% tells a different story. In other words, although 87% of the deciduous areas have been correctly identified as deciduous, only 57% of the areas called deciduous on the map are actually deciduous based on the reference data. This lower user accuracy tells us that there are errors of commission in the map related to the deciduous classes, meaning there are sample sites that were classified as deciduous that based on the reference belong to a different class. The result of this is more area in the map classified as deciduous than actually occurs on the ground.

A more careful look at the error matrix reveals significant confusion in discriminating deciduous from barren and shrub. Therefore, although the producer of this map can claim that 87% of the time an area that was deciduous on the ground was identified as such on the map, a user of this map will find that only 57% of the time that the map says an area is deciduous will it actually be deciduous on the ground and may often be barren/scrub.

The intended use of the data/map can drive the need to address some of the error. For example, the lower user accuracy in the example above often resulted from the confusion between discriminating deciduous from barren/shrub. Collapsing these two classes together into a deciduous/barren/shrub class increase the user's accuracy to 83% but lowers the producer's accuracy to 85% (**Figure I-2**). The higher user's accuracy means when the map identifies this grouped cover class it matches what is found on the ground more often than the two individual classes. Under certain situations it may be worth the slightly lower producer accuracy and sacrificing one of the cover classes, meaning the map will no longer distinguish between deciduous and shrub/barren.

	D/SB	**C**	**AG**	**Row total**
D/SB	183 (65+4 +114)	11	25	219
C	14 (6+8)	81	5	100
AG	19 (0+19)	11	85	115
Column total	216	103	115	434

Producer's accuracy = $\frac{183}{216} = 85\%$ User's accuracy = $\frac{183}{219} = 83\%$

Figure I-2. Example collapsing cover class to address error of commission, building off the error matrix in **Figure I-1** here the deciduous and barren/shrub are combined and accuracy metric recalculated (D=deciduous; C=conifer; Ag=agriculture; SB=Shrub).

For the purposes of the UDL, EPA targets at least 85% in both the producer's and user's accuracy and at least 90% for an overall accuracy when combining individual crops from the CDL into the UDL cover classes.

- EPA's Accuracy Value Goals for Use Data Layers Used in BEs

The native CDL landcover dataset includes over 100 cultivated cover classes in its thematic classification. The error matrices released with the CDL data provide overall, producer and user measures of accuracy at both the state and national level as well as the associated Kappa coefficients. In recent years, the overall accuracy of the CDL dataset has been in the low to mid-80% with Kappa just over 0.80. The producer's and user's accuracy for the individual cultivated classes range from less than 5% to 98%, and less than 15%-97%, respectively (Boryan 2011). When considering the individual cultivated classes of the CDL, the user's accuracy is slightly better than producer's accuracy, resulting in a lower commission error, or false negative/Type 2 error. However, when considering these BEs, reducing the false positive/Type 1 error is equally or more important. Improving all accuracy metrics as well as leveling out the producer and user accuracies is an overall goal when grouping crops into the UDLs cover classes.

To improve the overall user and producer accuracies for the UDLs, the 100+ thematic cultivated classes found in CDL are reclassified into 13 crop groupings. Consolidating CDL into aggregated categories is a documented way to significantly improve the accuracy of assessments by eliminating misclassification errors within the combined classes (Johnson 2013a, Johnson 2013b, Wright 2013 and Lark 2017). Each of the 100+ thematic cultivated classes from the original CDL, are found in at least one state but not every state will include all 100+ classes. For this reason, while the focus is on the accuracy at the national level, there are instances when the state accuracy for a UDL would be higher than observed at the national level.

When deciding how to group crops from the CDL, EPA refers to the grouping used by the U.S. Geological Survey (Baker and Capel, 2011) and the Generic Endangered Species Task Force (Amos *et al.* 2010). This information considers environmental factors that influence the location of crops and the error matrices provided by USDA with the original CDL data. By considering these agronomic factors in addition to the error matrices it is possible to improve the accuracy for these UDLs while retaining agronomic similarities. There is an infinite number of ways to group the crop cover classes found in the CDL, and each structured grouping can be reviewed in terms of recalculated accuracy compared to the native dataset.

When collapsing the available error matrices provided with the CDL into the 13 UDL groups, the sample site values for each of the CDL crops found in a UDL are summed across both rows and columns in the error matrix. Currently the 13 UDL groups bring the overall accuracy to 90%, increased from 80% for the CDL, with a Kappa coefficient of 0.88 (**Table I-1**). As described above, it is important to consider the producer's and user's accuracy of the individual thematic classes in addition to the overall accuracy.

When considering the user's and producer's accuracy, EPA targets at least 85% for each UDL, while retaining at least a 90% overall accuracy. Following the thematic grouping into the 13 UDLs and the recalculation of the user and producer accuracies, by year of the CDL, to help address errors of commission, additional steps to lower the omission errors are implemented. These include the temporal aggregation of multiple CDL years into the UDL and expanding the crop area found in the UDL layer to meet or exceed the area for the same suite of crops as reported in the Census of Agriculture. The goal of each of these steps is to improve the accuracy of the UDLs by minimizing the rate of omission error (*i.e*., false positive /Type 1 error). However, these steps are not directly related to the existing error matrices provided with the CDL; therefore, new accuracy values are not calculated following the temporal aggregation and area expansion. By reducing the omission errors, these steps result in a more protective landcover classification for each UDL.

If an individual crop class in the CDL has both the producer and user accuracies that are over 85%, the corresponding UDLs is that same as the CDL crop cover class (*e.g*., cotton from the CDL is found in the cotton UDL). These UDLs include corn, cotton, grapes/other vineyards, rice, soybeans and wheat. Five of these UDLs have user and producer accuracies in the low- to mid-90%, with Kappa coefficients ranging from ~0.89 to 0.97. The user's and producer's accuracy for the remaining cotton UDL falling above 85% with Kappa coefficients of ~ 0.85. Due to the geographically limited occurrence of cotton (*i.e.,* this crop is only grown in the South), lower national accuracy is expected compared to other crops with a broader geographic range. This is due to the fact that cotton growing states may classify cotton well, however, there is a lower accuracy in identifying cotton in states where cotton doesn't grow, and this brings down the national accuracy.

When an individual crop cover class in the CDL is below 85%, grouping multiple crops together and ultimately reducing the number of total thematic crop groups improves the accuracy of the resulting UDL. When deciding which crops to group, error of omission (Type I) and commission (Type 2) of the remotely sensed data are considered in addition to environmental and agronomic practices. EPA targets an accuracy of at least 85%; however, it is not always possible to reach the target without compromising the environmental/agronomic practices. For this reason, some of the UDLs that contain multiple crop classes have slightly lower than 85% accuracy.

The UDLs containing a number of crops include alfalfa/other agricultural grasses, citrus, other crops, other grains, other orchards, other row crops, and vegetables and ground fruit. Two of these UDLs other crops and other grains, did not meet an 85% accuracy for user's and producer's accuracy. Two additional UDLs (*i.e*., other row crops and vegetables and ground fruit) did not reach 85% for just the producer's accuracy. See **Table I-1** for a complete list of accuracy values across all 13 UDLs. Of the 13 UDLs, five were used to map the agricultural label uses for glufosinate-P. A list of the pertinent UDLs can be found in **Table I-2.** As mentioned above, the focus of the discussion is on the national accuracies; however, due to the variety and regional nature of some crops found in the UDLs, state-based accuracy assessments often reach 85% even though the national-level assessment for the same UDL does not.
Additional challenges when identifying some crops include higher frequency of change in agricultural practices (*e.g*., crop rotation), and/or lower total area on the landscape for minor crops. These two challenges are related to errors of omission, rather than errors of commission addressed by grouping crops into the UDL categories a common practice implemented to increase accuracy of remotely sensed data (Johnson 2013a, Johnson 2013b, Wright 2013 and Lark 2017). Two additional steps address some of the uncertainty related to these errors of omission, specifically, the known downward estimates of acres for remotely sensed data and changes in crop patterns over time. Although these steps are implemented on all UDLs, they have the most impact in addressing uncertainty around error of omission

for the UDLs containing multiple crops with lower accuracy values. First, a temporal aggregation of multiple years of the CDL into the UDLs is performed to account for changing agricultural practices (*e.g.*, crop rotation) from year to year. Second, the total area of the temporally aggregated UDL is compared to the reported area found in the Census of Agriculture, accounting for some of the error/difficulty in identifying minor crops. If the area of the UDL is less than the reported area in the Census of Agriculture, the UDL is grown out to meet or exceed the Census of Agriculture. Referred to as region growing, expanding the UDL area to meet or exceed the area reported in the Census of Agriculture is a conservative measure taken to minimize the error of omission. However, the Census of Agriculture generated once every 5 years, represents a single year in time. The CDL generated every year may capture agricultural practices (*e.g.*, rotations) not captured in the Census Agriculture. For this reason, there is uncertainty around the crop area found in the Census of Agriculture being representative across all years of the CDL.

At the end of the whole process, the resulting UDLs provide a more protective landcover estimate for the purposes of the Endangered Species Biological Evaluations, making them the best available spatial agricultural data to use in the ESA BEs.

Figure I-2 provides a summary of the UDLs used to map the agricultural label uses for glufosinate-P with a complete crosswalk of the original CDL crops to the UDL class provided in **Table I-3**.

Table I-1. Collapsed national error matrix from the 2018 Crop Data Layer (CDL), example of the 13 national Use Data Layers (UDLs) with associated measures of User's and Producer's Accuracy.

	Alfalfa	Citrus	Corn	Cotton	Grapes	Other Crops	Other Grains	Other Orchards	Other Row Crops	Rice	Soybeans	Vegetables and ground fruit	Wheat	User's Accuracy	Commission	Kappa
Alfalfa	2157632	325	495800	6026	440	38838	45476	4745	4226	131	27170	13039	29148	89%	11%	0.87
Citrus	147	244865	37	25	12	185	112	103	1	0	0	164	3	99%	1%	1.00
Corn	39172	26	4222089	6598	241	18927	32759	1636	6212	1454	124498	20895	13154	94%	6%	0.92
Cotton	5368	12	9800	974234	51	9753	17664	1405	43844	509	36809	5983	15474	87%	13%	0.86
Grapes	426	30	546	35	93320	1372	47	3206	607	0	56	288	92	93%	7%	0.93
Other Crops	26196	385	12842	7554	581	729904	37343	6695	4335	2888	11038	9363	32155	82%	18%	0.82
Other Grains	16615	23	14503	7531	20	18118	597678	312	3603	210	8702	7707	34988	84%	16%	0.83
Other Orchards	2870	234	1305	1717	1862	3680	521	353321	950	26	524	1424	412	96%	4%	0.96
Other Row Crops	2528	0	3208	13781	208	2860	4999	466	315797	165	3933	2981	782	90%	10%	0.89
Rice	150	0	1061	154	1	3158	340	5	36	275819	2509	190	106	97%	3%	0.97
Soybeans	28675	0	139339	54449	101	29702	25116	427	10953	15386	4754850	16137	27339	93%	7%	0.90
Vegetables and ground fruit	5221	83	6822	1587	289	6397	7439	1209	3009	106	3263	361780	5496	90%	10%	0.90

Wheat	22383	0	11027	18183	99	44103	81911	525	1618	10	22050	13228	1833412	89%	11%	0.88
Producer's Accuracy	85%	99%	93%	89%	95%	78%	68%	93%	79%	93%	94%	79%	90%			
Omission	15%	1%	7%	11%	5%	22%	32%	7%	21%	7%	6%	21%	10%			
Kappa	0.82	0.99	0.91	0.88	0.95	0.77	0.67	0.93	0.79	0.93	0.91	0.79	0.89			

Overall Accuracy	90%
Overall Kappa	0.88

These classes are not mutually exclusive to one another and are further reclassified into 13 national agricultural UDL classes; 5 UDLs are used to map the glufosinate-P agricultural uses. The complete crosswalk for all the UDL classes can be found in ***Table 2.***

Corn: 10
Cotton: 20
Soybeans: 40
Vegetables & Ground Fruit: 60
Other Grains: 80

Table I-2. Summary of Use Data Layer (UDL) Classes for Glufosinate-P

Summary of Use Data Layers (UDL) Classes

Reclass Value	UDL General Classes
10	Corn
20	Cotton
40	Soybeans
60	Vegetables and ground fruit
80	Other grains

Table I-3. Cross-walk between Crop Data Layer (CDL) class and Use Data Layer (UDL) Agricultural Classes.

CDL Value	CDL Class Name	Reclass Category for UDLs	Reclass Code
1	Corn	Corn	10
2	Cotton	Cotton	20
4	Sorghum	Other grains	80
5	Soybeans	Soybeans	40
12	Sweet Corn	Vegetables and ground fruit	60
13	Popcorn Corn	Vegetables and ground fruit	60
14	Mint	Vegetables and ground fruit	60
21	Barley	Other grains	80
25	Other Small Grains	Other grains	80
27	Rye	Other grains	80

CDL Value	CDL Class Name	Reclass Category for UDLs	Reclass Code
28	Oats	Other grains	80
29	Millet	Other grains	80
30	Speltz	Other grains	80
31	Canola	Other grains	80
32	Flaxseed	Other grains	80
33	Safflower	Other grains	80
34	Rape Seed	Other grains	80
35	Mustard	Vegetables and ground fruit	60
38	Camelina	Other grains	80
39	Buckwheat	Other grains	80
42	Dry Beans	Vegetables and ground fruit	60
43	Potatoes	Vegetables and ground fruit	60
45	Sugarcane	Other grains	80
46	Sweet Potatoes	Vegetables and ground fruit	60
47	Misc Vegs & Fruits	Vegetables and ground fruit	60
48	Watermelons	Vegetables and ground fruit	60
49	Onions	Vegetables and ground fruit	60
50	Cucumbers	Vegetables and ground fruit	60
51	Chick Peas	Vegetables and ground fruit	60
52	Lentils	Vegetables and ground fruit	60
53	Peas	Vegetables and ground fruit	60
54	Tomatoes	Vegetables and ground fruit	60
57	Herbs	Vegetables and ground fruit	60
205	Triticale	Other grains	80
206	Carrots	Vegetables and ground fruit	60
207	Asparagus	Vegetables and ground fruit	60
208	Garlic	Vegetables and ground fruit	60
209	Cantaloupes	Vegetables and ground fruit	60
213	Honeydew Melons	Vegetables and ground fruit	60
214	Broccoli	Vegetables and ground fruit	60
216	Peppers	Vegetables and ground fruit	60
219	Greens	Vegetables and ground fruit	60
222	Squash	Vegetables and ground fruit	60
227	Lettuce	Vegetables and ground fruit	60
229	Pumpkins	Vegetables and ground fruit	60
231	Double Crop Lettuce/Cantaloupe	Vegetables and ground fruit	60
235	Double Crop Barley/Sorghum	Other grains	80
243	Cabbage	Vegetables and ground fruit	60
244	Cauliflower	Vegetables and ground fruit	60
245	Celery	Vegetables and ground fruit	60
246	Radishes	Vegetables and ground fruit	60
247	Turnips	Vegetables and ground fruit	60
248	Eggplants	Vegetables and ground fruit	60
249	Gourds	Vegetables and ground fruit	60

- References

Amos, J.J., C.M. Holmes, C.G. Hoogeweg, and S.A. Kay. 2010. Development of Datasets to Meet USEPA Threatened and Endangered Species Proximity to Potential Use Sites Data Requirements. Report Number: 437.01-Overview. Prepared by Waterborne Environmental, Inc. for the Generic Endangered Species Task Force.

Anderson, J. R., E. E. Hardy, J. T. Roach, and R. E. Witner. 1976. A land use and land cover classification system for use with remote sensor data. USGS Professional Paper. Vol. 964, 28 pp.

Boryan, C., Yang, Z., Mueller, R., & Craig, M. (2011). Monitoring US agriculture: the US Department of Agriculture, National Agricultural Statistics Service, Cropland Data Layer Program. Geocarto International, 26(5), 341-358. https://doi.org/10.1080/10106049.2011.562309

Baker, N.T., and Capel, P.D., 2011, Environmental factors that influence the location of crop agriculture in the conterminous United States: U.S. Geological Survey Scientific Investigations Report 2011–5108, 72 p.
Bolstad, Paul. 2005. GIS Fundamentals. 2nd edition. Eider Press, White Bear Lake, MN. 543 pp.

Cohen, Jacob. 1960. A coefficient of agreement for nominal scales. Educational and Psychological Measurement. Vol. 20, No. 1, pp. 37– 40.

Congalton, R. and Green, K 2019. Assessing the Accuracy of Remotely Sensed Data Principles and Practices. Third Edition CRC Press, Boca Raton, FL 328pp

Federal Geographic Data Committee. FGDC-STD-001-1998. Content standard for digital geospatial metadata (revised June 1998). Federal Geographic Data Committee. Washington, D.C.

Johnson, D.M, 2013a. A 2010 map estimate of annually tilled cropland within the conterminous United States. Agric. Syst., 114 (2013), pp. 95-105, 10.1016/j.agsy.2012.08.004

Johnston, C.A, 2013b. Wetland losses due to row crop expansion in the Dakota Prairie Pothole region Wetlands, 33, pp. 175-182, 10.1007/s13157-012-0365-x

Lark, Tyler J., Mueller, Richard M., Johnson, David M., and Gibbs, Holly K., 2017.Measuring land-use and land-cover change using the U.S. department of agriculture's cropland data layer: Cautions and recommendations. International Journal of Applied Earth Observation and Geoinformation 62 (2017), pp 224-23. https://doi.org/10.1016/j.jag.2017.06.007

Shah, S.H.; Angel, Y.; Houborg, R.; Ali, S.; McCabe, M.F,2019. A Random Forest Machine Learning Approach for the Retrieval of Leaf Chlorophyll Content in Wheat. Remote Sens. 11(8):920.https://doi.org/10.3390/rs11080920

Story, M. and R. Congalton. 1986. Accuracy assessment: A user' s perspective. Photogrammetric Engineering and Remote Sensing. Vol. 52, No. 3, pp. 397– 399.

Wright, C.K. and M.C. Wimberly, 2013.Recent land use change in the Western Corn Belt threatens grasslands and wetlands. Proc. Natl. Acad. Sci, 110 (10) pp. 4134-4139.

Appendix J. Supplemental Overlap Information

- Estimating Off-Site Buffer Area from Drift or Runoff Exposure

In addition to the potential pesticide use sites, each Use Data Layer (UDL) has an omnidirectional off-site buffer area used to assess impacts by spray drift and/or run-off, collectively referred to as the exposure area. Each UDL includes numerous distance options from the use sites for calculating the exposure area. Generated with the Euclidean distance tool in ArcGIS, areas adjacent to those identified as a potential use site are assigned a distance value based on the shortest distance to the closest source (*i.e.,* potential use site) from cell center to cell center "as the crow flies".

Figure J-1 depicts a conceptual model of how the distance values are assigned to the area adjacent to a use site. However, in practice, use sites are found throughout the landscape; as you move away from one site, you move toward a different use site. The distance value for a given location always represents the minimum distance to the closest use site (see **Figure J-1**). The values increase as distance from the closest use site increases but then starts to decrease when a different use site becomes the closest source (see **Figure J-1**).

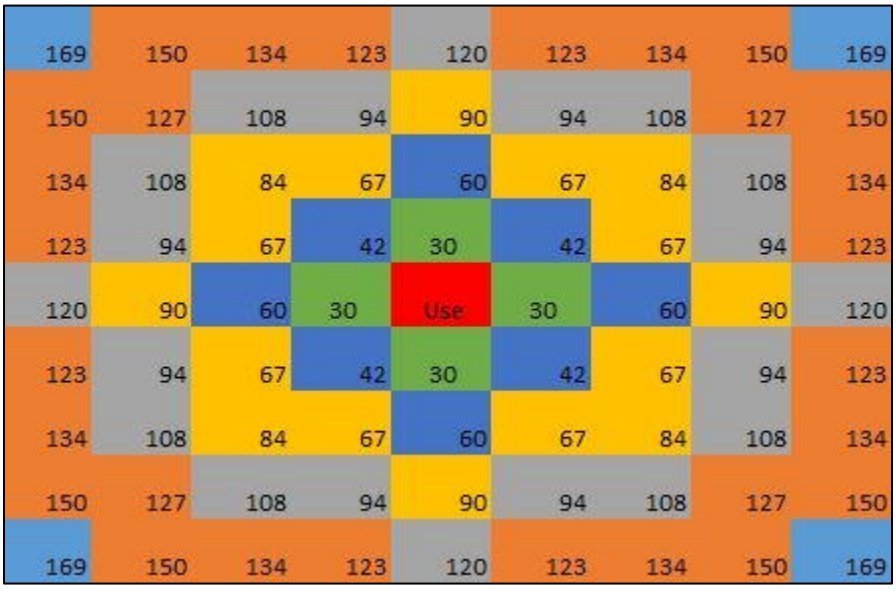


Figure J-1. Conceptual diagram of the Euclidean distance calculation for generating the buffer area from a use site.

The resulting GIS layer represents the potential pesticide use sites and associated off-site area buffered based on the minimum distance to the closest pesticide use site (**Figure J-2**). Inclusive of numerous distance values, the exposure area can be adjusted as part of the assessment based on the distance to effect for a specific aspect of the assessment.

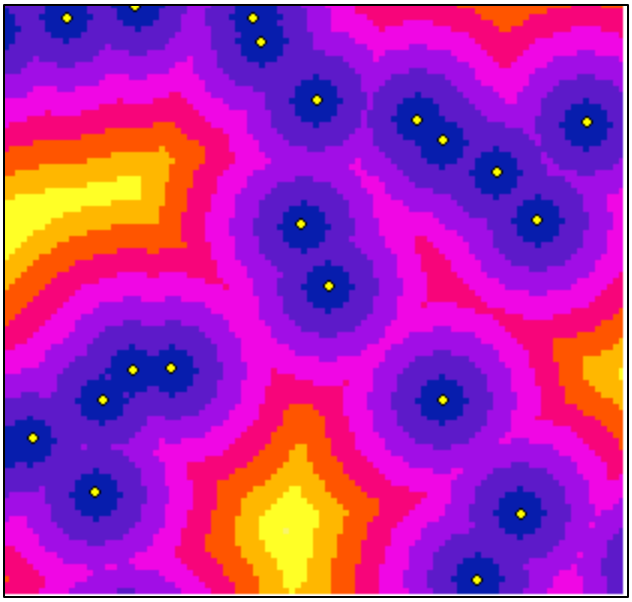


Figure J-2. Example offsite buffered area Geographic Information System (GIS) layer based on the minimum distance to a use site.

A unique overlap metric is reported for each distance, with the use site at distance zero, and off-site area values greater than 0. Chemical-specific distance(s) based on label requirements and the results of the AgDrift™ modeling set the extent of the exposure area for the UDL when evaluating the results of the overlap analysis.

- Standardizing Spatial Files

Prior to the overlap calculations, EPA used ARCGIS (v. 10.8.1) to standardize all spatial files, UDLs, and species locations into the selected regional projections (see **Table J-1**). Regional projections were selected to minimize distortion in area and are based on the most common projection used by the parent GIS sources in the given region. Regional snap rasters are also used to support consistency in the resulting overlap values.

Table J-1. Projected coordinate systems used in the co-occurrence analysis.

Region	Projection
Conterminous United States (ConUS)	Albers_Conical_Equal_Area.prj.
Hawaii (HI)	NAD_1983_UTM_Zone_4N.prj
Alaska (AK)	WGS_1984_Albers.prj
Puerto Rico (PR)	Albers_Conical_Equal_Area.prj
United States Virgin Islands (VI)	WGS_1984_UTM_Zone_20N.prj
American Samoa (AS)	WGS_1984_UTM_Zone_2S.prj
Guam (GU) and Commonwealth of the Northern Mariana (CNMI)	WGS_1984_UTM_Zone_55N.prj

Uncertainties and Conservative Assumptions Associated with the Overlap Analysis

EPA based the overlap analysis on the species locations provided by USFWS and NMFS (USFWS, NMFS 2020). Species range is defined as the geographical area where a species could be found in its lifetime. These data are produced and managed by the species experts in the Services responsible for

implementing the ESA. EPA uses the Services' range data to estimate the overlap of the species range with potential exposure areas. This represents a likelihood that the species will be exposed; however, there are assumptions related to the range data that influence the likelihood that the species is exposed. The range information is not sub-divided into additional qualifiers such as current/historical locations or temporal information to account for distribution variations relating to timing such as seasons. Without additional distribution information, EPA assumes that the species is present in all sections of the range at all times of the year.

Other commonly known and related sources of uncertainty for GIS data generally relate to accuracy and precision. Accuracy can be defined as how well information on a map matches the values in the real world. Precision relates to how well the description of the data used for mapping matches reality, based on closeness of repeated sets of measurements. The more precise the data, the more likely additional measurement or calculation will show the same result. Some sources of inaccuracy and imprecision in GIS data are obvious while others are difficult to identify. It is important to consider these sources of error as GIS software can make it appear that data are accurate and precise beyond the limits of the data. When conducting this spatial analysis to assess the relationship between the species' range and agricultural location, EPA made conservative assumptions related to the accuracy and precision of the available data (*e.g.,* using a 30-m resolution for the overlap process). These assumptions impact the uncertainty of the relationship and generally overestimate the overlap between species range and agricultural locations.

To address classification accuracy and positional accuracy of the agricultural GIS data used, EPA combined multiple years into a UDL for each crop to represent anywhere the crop could be found. This is likely an overestimate of where a crop is found in any given year due to common agricultural practices such as crop rotation. Data resolution (*i.e*., the smallest difference between features that could be recorded) is related to accuracy. The raster land cover data used to identify agricultural land (*i.e*., the Cropland data layer (CDL) produced by United States Department of Agriculture (USDA)) have a resolution of 30 meters. A raster data set can be re-sampled into smaller increments, but this does not improve the resolution or accuracy of the dataset. For this reason, values cannot be established with a higher level of resolution than 30 meters; values that are not multiples of 30 cannot be determined (*e.g.,* 30, 60, 90 are distances in the dataset; 50 is not).

Precision errors can be introduced when formatting data for processing. Formatting changes can include changes to scale, reprojections of data, and data format conversions (raster to vector or vice versa). Sources of errors that are not as obvious can include those originating from the initial measurements, digitizing of data, and using different versions of a dataset. These types of precision error may introduce edge effect, or misaligned dataset when conducting the spatial analysis. Borders following the general shape of the county boundaries but not aligning exactly with range information used could be the result from this type of precision error.

These uncertainties impact the relationship between the agricultural areas and species locations. EPA's spatial analysis makes conservative assumptions to err on the side of overestimating the potential for species exposure when assessing the relationship of the species range to agricultural land. EPA uses five years of crop information in constructing the UDLs representing the agricultural land, so that the UDLs include every location where the crop was grown during those five years. Due to normal agricultural practices (*e.g.,* crop rotations), this is more land than expected in a given year for a given crop. The relationship between the species and the agricultural land may be overestimated when the range is

larger than the actual area occupied, and the additional area includes agricultural use or where edge effects were introduced.

When considering the species location data, all areas may be occupied at the time the pesticide is used. County or state boundaries can be used as a conservative estimate for species range but species and natural habitats are not expected to follow man-made boundaries. When the species locations have not been refined beyond these man-made boundaries, underestimates of the relationship between species range and agricultural use can occur. While this underestimation is possible, EPA makes several conservative assumptions for agricultural land and species life history to account for this possibility. For agricultural land, use of the UDLs representing multiple years of agriculture expands the agricultural footprint beyond what is expected in a given year. In addition to these assumptions, EPA uses the best available species location information from the species experts at USFWS and NMFS, minimizing this possibility.

Appendix K. Methods for the Census of Agriculture Overlap Tool (V1.1) Information

Background

This document provides background information and the methods used to develop the Census of Agriculture (CoA) Overlap Tool. This tool was developed to expedite the process for conducting an overlap analysis for federally listed endangered and threatened ("listed") species assessments. The purpose of the overlap analysis is to determine the percent overlap of the final labeled use sites and the listed species' ranges and designated critical habitats (CH[50]). The outputs from the Overlap Tool are conservative in nature and intended to maximize efficiency estimating potential overlap. This tool may be used along with the Use Data Layer (UDL) Overlap tool, as both tools provide areas of refinement based on different principles. In cases when a more refined spatial analysis is required, a higher-tier analysis can be conducted.

This tool runs in Python editor and has a Graphical User Interface (GUI) for selecting the key inputs for analysis. Key features that the tool provides from a user perspective are the following:

1. Geographic Information System (GIS) analysis is not required for the user;
2. The GUI uses Individual Crop or Crop-Group nomenclature for ease-of-use site selection;
3. The GUI includes entering geographic restrictions;
4. The overlap is presented as cumulative and by the individual Use Site;
5. Buffering for offsite transport is included and presented in multiple formats.
6. In addition to the continental United States (ConUS), data for Alaska, Hawaii, and Puerto Rico are included in the tool by crop. Island territories (*i.e.,* Guam, American Samoa, Virgin Islands of US, and Northern Mariana Islands) are included at the Total Agriculture level.
7. The tool utilizes two years of USDA Census of Agriculture (CoA) data and reports the highest acreage value over the two reports. The current scope of the tool is for agricultural uses. Overlaps for non-agricultural uses, such as residential, rangeland, forestry, *etc*. are not included.

Conceptual Model

This section provides a brief overview of the conceptual model for the tool. Details of the method are further described in "General Data/Inputs" and "Methodology" sections below.

There are two inputs to the Overlap tool (*i.e*., the Census of Agriculture (CoA) county-level crop acreage values and the species range and CH acreage in each county). For deriving the species acreage by county using ArcGIS spatial overlap analysis, the key process is the "intersect" of the CH and species range location with the U.S. County boundaries. Together, with the crop acreage inputs by county, these inputs are used to determine an upper-bound maximum potential percent overlap based on the number of acres of crop within the county. This is considered an "upper-bound percent overlap" as it is assumed that the species location (range or CH) county acres overlap with the crop acres.

For example, in **Figure K-12,** the green shape represents the species range. This range can fall anywhere within a county and overlap with county borders. The crop acres are shown with the orange box but the

[50] Henceforth in this document, the acronym CH is used to represent designated critical habitat.

exact location within the county is unknown, and it may be distributed across the county with varying intensity. For the overlap analysis, these two areas (*i.e.,* species range or CH and the crop acreage) are assumed to coexist in space as shown in the overlap where the green shape overlaps with the orange box. This overlap may occur, or it may not occur in the landscape. The overlapping assumption is made to be certain any potential overlap of range and CH is accounted for in the percent overlap for a species.

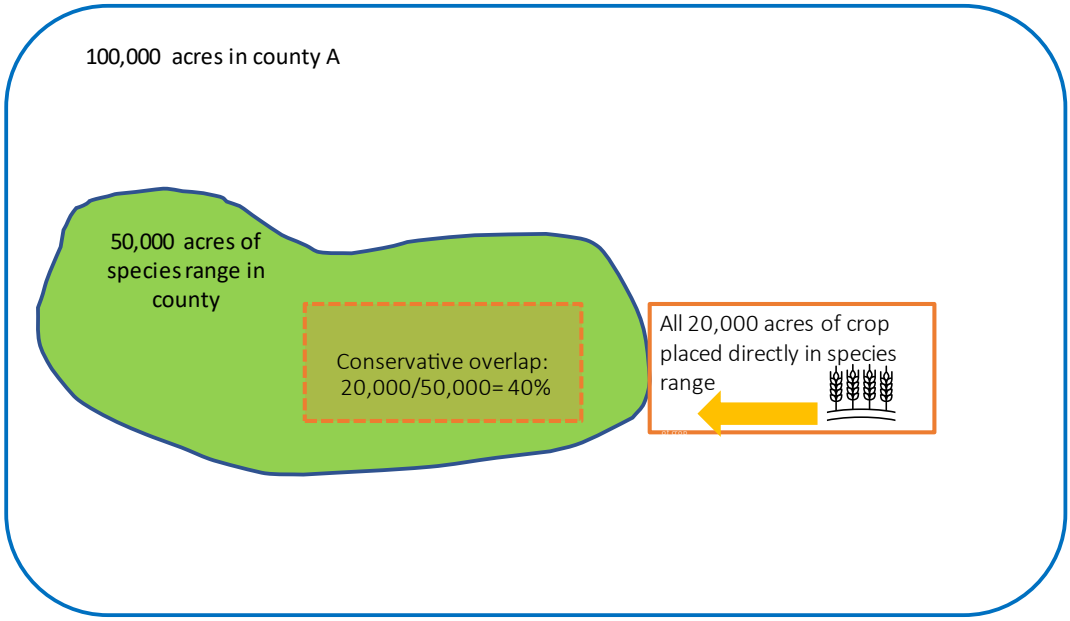


Figure K-12. General Example of Overlap ASSUMPTION with Species Acres

A limitation of working with CoA data is that there is non-disclosed acreage for some crop-county combinations (*e.g.,* acreage is not reported to protect the confidentiality of the growers). For this reason, a conservative proxy is utilized to account for these non-disclosed acres and is described further in methodologies section (see non-disclosed acreage imputation). This is a preprocessing step.
To begin calculating the overlap, for each species, the county crop acres are summed but are capped (*i.e.,* cannot exceed) at the species range/CH for each individual county. For example, **Figure K-2** shows a simple example of three counties and how the acreage may be capped if the crop acreage exceeds the species range. Counties B and C have crop acres (100 and 300 acres, respectively) that exceed the species range for the county, therefore, they are capped at the species range (20 and 200 acres, respectively). County A has less crop acres than the species range and does not require capping. After the crop acres are capped (if needed) at the county level the values for the crop acres and the species range are summed for the state level (**Figure K-2**).

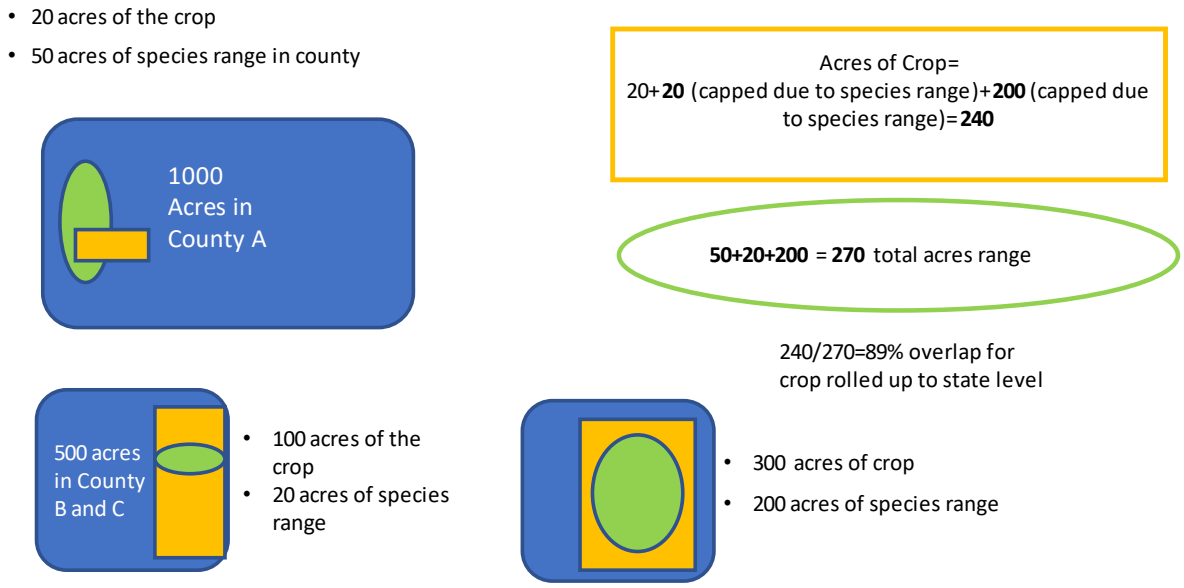


Figure K-23. ***Depiction of Capping Using Species Range by County***

Figure K-23 depicts a single crop, however, when there are multiple crops selected, a redundancy step may be used in cases where the sum of overlap from all potential use sites within a county exceeds the county species acreage. In such cases, an adjustment is applied that maintains the ratio of crop overlap areas while reducing the sum of the overlap areas to the total species area (described further in "Methodology" section below).

To check the potential overestimation of the earlier assumptions (*e.g.,* non-disclosed acre proxy, species acres distribution), the county crop acres, when rolled up (*e.g.*, added together) to the state and national level are compared to the state/national acreage for the individual crops and are capped if the sum of the county crop acres for a species exceeds the state or national crop value. The direct overlap value is then calculated by dividing the sum of the crop acres across all states by the total species range or CH acres. **Figure K-3.4** depicts the national level for a species with a multi-state range, thus, as an example, the "rolled up values" depicted in **Figure K-2** would fit into a single state (the blue boxes in **Figure K-3.4**).

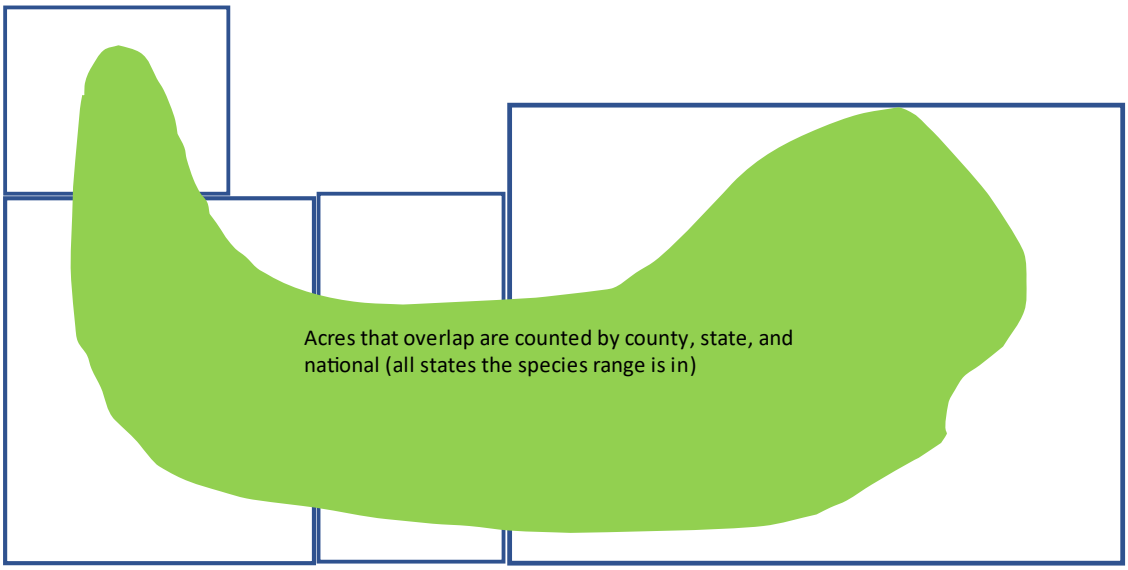


Figure K-3.4 Species Range- across multiple states

The overlap tool also accounts for offsite transport by buffering out the use area. To account for spray drift this is done by using 30 m increments, 305 m and 792m buffer distances (based on the AgDRIFT™ maximum/model limits for aerial and ground). To account for runoff, the tool includes a 1,500m buffer for assessments that require maximum 'runoff' buffering (US EPA, 2022).

For the buffering, the method assumes that the acreage within a county is divided up into multiple fields. Because there can be differences in field size by crop, the crops from the CoA are binned into two size categories for the spray drift calculations. In general, the row crops (*e.g.*, corn, soybean, and wheat) have larger field sizes and the specialty crops (*e.g.*, strawberries, apples, cucumbers, *etc.*) have a smaller field size. Data are available from USDA Census of Agriculture (USDA, 2017- Tables 35-38) to inform on the breakdown of crop acres grown/harvested by field size. Based on a review of the available data, the specialty crops are assigned a field size of 25 acres and row crops are assigned a field size of 500 acres. These field size acreages are used to adjust the spray drift by assuming that the crop acreage in the county is divided into multiple fields (*i.e.*, divided by the field size of either 25 or 500 acres) and then the drift is calculated for each field before summing up. Using this model, the buffer extends from all four sides of the modeled field to the various buffer distances

General Data /Inputs

1. Census of Agriculture (2017 and 2012)- national, state and county acreage (preprocessed by BEAD[51])- The CoA is a complete count of agricultural activity on U.S. farms and ranches. This analysis utilizes the crop acreage data. The CoA census is published every 5 years (2012 and 2017 being the most recent two surveys conducted) and the two most recent surveys are used to account for temporal variability in crop patterns and ensure conservatism. Data are available for all states.

[51] Census Acreage Data (USDA NASS 2012, 2017) Processed by the Biological and Economic Assessment Division (BEAD)- 2012 version 111/15/2018; 2017 version 1- 11-23-2020.

2. Census of Agriculture-2017[52]- For Puerto Rico and the Island Territories of Guam, American Samoa, Virgin Islands of US, and Northern Mariana Islands, data were not available in a preprocessed format. Data were extracted from the USDA National Agricultural Statistics Service (NASS) Quick Stats database. For Puerto Rico, the crop acres were extracted for the territory as a whole. For the other islands, the data resolution was at the total acres in agriculture level (*i.e.*, not available by crop).

3. Location files for listed species- (range and designated critical habitat) and the U.S. County boundary shapefile. All files were provided by EFED/EISB with the requisite data preparation. Originally, the source files of the species location files were provided by the Services. For EPA's

[52] USDA, NASS. 2017. Census of Agriculture for Outlying Areas
https://www.nass.usda.gov/Surveys/Guide_to_NASS_Surveys/Census_for_Outlying_Areas/index.php
https://www.nass.usda.gov/Surveys/Guide_to_NASS_Surveys/Census_for_Outlying_Areas/index.php

endangered species biological evaluation, these source files were standardized and organized by taxonomic group in file geodatabases (referred to as species libraries)[53].

4. Master Species List-Species subject to Section 7 under the Endangered Species Act are obtained from the US Fish and Wildlife Threatened and Endangered Species System (TESS[54]). The resulting table is filtered to include listing statuses[55] currently subject to Section 7 or potentially subject to Section 7 during the registration period. Information from TESS for species under the jurisdiction of the National Marine Fisheries Service (NMFS) is supplemented with information from the NMFS website[56], deferring to the NMFS website if conflicts exist between the sources. The master species list was *provided by EFED/EISB* (file version generated- 09_2022).

Methodology

There are three main sections for the methods descriptions:

- Preprocessing the CoA Data
- ArcGIS Species Range and CH County Projection and Processing
- Overlap Calculations

Preprocessing of Census of Agriculture Crop Acreage Data

Crop acreages at the county-, state-/territory-, and national-level are sourced from the CoA. To account for temporal variability in crop patterns, crop acreage values from both the 2012 and 2017 CoA are used to generate the input values used in the overlap analysis. Due to the presence of non-disclosed acreage values (assigned as D values in CoA) for specific crop/location combinations in the two CoA datasets a preprocessing step is conducted prior to overlap analysis to fill missing values.

- Non-Disclosed Acreage Imputation[57]

The imputation method for missing acreage values requires that all crops have national-level acreage values. In limited cases where national-level acreage values are unavailable[58], estimates are obtained from other datasets (*i.e.*, alternate CoA years). Once a complete set of national-level crop acreage estimates are obtained, the missing state acreage values are imputed. To generate the most conservative crop acreage estimates, each state/crop combination with a non-disclosed acreage value is filled with the difference between the national-level crop acreage values and the sum of available state acreage values. An example of this approach is described below.

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[53] More details about the location files preparation can be found in the EISB document titled "Tool Documentation – Processed GIS Data – Listed Species Spatial Files"-Updated 2020 Ver 1.2.

[54] https://ecos.fws.gov/ecp/

[55] Statuses included: Threatened, Endangered, Experimental Population Non-Essential, Proposed Threatened, Proposed Endangered, and Candidate

[56] https://www.fisheries.noaa.gov/national/endangered-species-conservation/esa-threatened-endangered-species

[57] Imputation refers to the process of replacing missing data with substituted values.

[58] Guar, jojoba, ginger root, birdsfoot trefoil-seed, miscanthus and sugarcane, sugar all were national "D" values in 2012. 2017 values were subbed as a proxy. Sugarcane had similar values in the 2007 and 2017 census.

Before Imputation:

State 1 Acres	State 2 Acres	State 3 Acres	State 4 Acres	State 5 Acres	National Acres
100	300	200	(D)	(D)	1000

D=acreage non-disclosed

After Imputation (Imputed values in Red):

State 1 Acres	State 2 Acres	State 3 Acres	State 4 Acres	State 5 Acres	National Acres
100	300	200	400	400	1000

In this example shown in the Before Imputation table there are 3 states (*i.e*., State 1, State 2, and State 3) with disclosed crop acreage values totaling 600 (100+300+200) acres, a national crop acreage value of 1000 acres, and 2 states with non-disclosed acreage values. Because the distribution of the non-disclosed acres is unknown, each state is assumed to have acreage equal to the difference (1000 acres – 600 acres = 400 acres), which represents the maximum possible acreage in each non-disclosed state given all known acreage values. This is shown in the After Imputation table (assumed acres shown in red).

Following the state-level non-disclosed acreage imputation, the county-level non-disclosed acreage values are imputed. This county-level imputation is performed using a similar approach to the state-level imputation; each non-disclosed county/crop combo is filled with the difference between the state-level acreage total for the crop and the sum of disclosed county-level acreage values for that crop.

In addition to the non-disclosed acreage values (indicated by a "(D)" in the CoA tables), some crop/location combinations entries are labeled as "(Z)", which indicates that the value corresponds to half an acre or less of the crop in the location. Once the non-disclosed (D) values have been filled using the approach described above, all crop/location combinations with (Z) values in the CoA tables are filled with 0.5 acres (the maximum possible value). The filling of (Z)-values occurs after the imputation of (D) values to ensure that (D) maximum estimates (*i.e*., each (Z)-value reflects an acreage value between 0 and 0.5 acres, so the program first estimates (D) values assuming that (Z) values are 0 to obtain the highest possible acreage for both sets of unknown values).

Once the imputation steps are complete, tables of county- state- and national- level crop acreage values with numeric values for all crop/location combinations are available.

- Merging multiple CoA Years

To capture the potential difference (*e.g*., crop rotation) in cropping overtime both the 2012 CoA and 2017 CoA values are used in the final crop acreage input table that is used for overlap calculations. Both CoA datasets are first processed using the imputation approach described in the previous section to fill missing values. Following the imputation steps, acreages from the two datasets for each location/crop combination are compared at the county, state, and national level. For each combination, if both or neither crop area was imputed (*i.e*., estimated because of a non-disclosed acreage entry in the raw CoA table), the maximum acreage value was selected from the two years. If one dataset contains an imputed value and the other contains a value that did not require imputation, then the non-imputed value was retained in the final crop area table. This approach assumes that non-imputed values will introduce less uncertainty into the final overlap estimates compared with imputed values.

- **ArcGIS Overlap Analysis of Species Locations and U.S. Counties**

This section provides information on how the ArcGIS analysis was done for the spatial overlap of listed species locations and the U.S. Counties. The described overlap analysis was conducted in ArcMap/ArcGIS Pro and ArcGIS version of Python 2.7, with ArcPy and ArcPy.sa modules imported. The goal of this spatial overlap analysis is to generate chemical-independent species acreage in each county of the United States. The output tables of this analysis are used as the inputs by the overlap tool (written in Python).

In this spatial analysis, the key process is the "intersect" of CH and range files of species with U.S. County boundaries. Intersect is a ArGIS intersect tool that calculates the geometric intersection of any number of feature classes and feature layers. Prior to this key step, all input files (*i.e.*, species location files and U.S. County boundary files) were projected to the appropriate projection (*i.e.*, Albers Equal-area Conic) for the projected coordinate system (PCS). Following the intersect analysis, the acreage of species per county was calculated and, together with the other identifiers (*i.e.*, entity ID, GEOID, state, *etc.*), exported to output tables. **Figure K-4** illustrates the conceptual model for this spatial analysis. A more detailed explanation is described below.

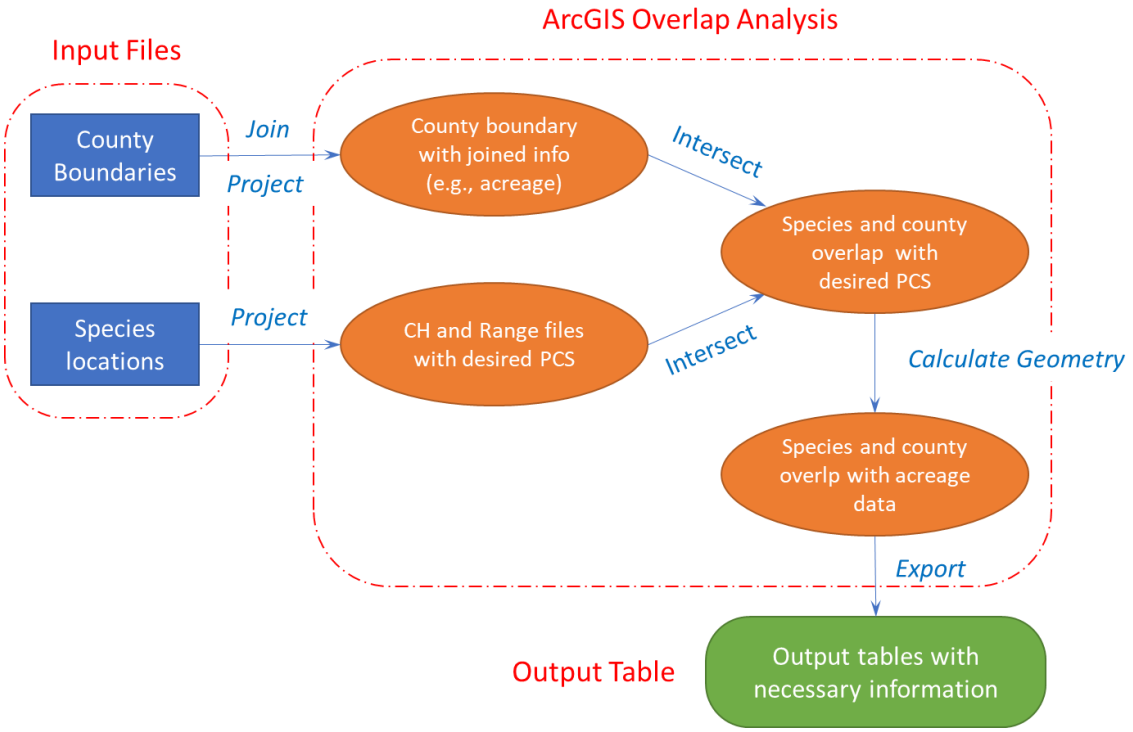

Figure K-45. Conceptual Model for the Spatial Overlap Analysis for the Listed Species and US Counties

- Input files

The input files of this overlap analysis included location files for list species (range and CH) and U.S. County boundary shapefile. All these files were provided by the Environmental Fate and Effect Division Environmental Information Services Branch (EFED/EISB) with the requisite data preparation. Originally, the source files of the species location files were provided by the Services. For EPA's endangered species

biological evaluation, these source files were standardized and organized by taxonomic group in file geodatabases (referred to as species libraries). More details about the location file preparation can be found in the EISB document titled "Tool Documentation – Processed GIS Data – Listed Species Spatial Files" -Updated 2020 Ver 1.2.

- **Approach**
  - Integrating county acreage info into county boundary shapefile

A set of county boundary shapefiles were provided by EISB containing slightly different aspects of information of the counties in each file. To integrate all essential information into one shapefile, especially the acreage of the counties, the 'join' tool in ArcGIS was used to combine attribute tables together and generate a new county boundary shapefile based on the "COUNTYNS" (a common attribute contained in each county shapefile). The newly generated county boundary shapefile contained all the essential information and was used as an input file of the overlap analysis.

Projecting species location and county boundary shapefiles

Prior to being used as inputs in the spatial overlap analysis, both species location and county boundary shapefiles were projected to the appropriate projected coordinate systems (PCS). For the 48 ConUS states, the Albers Equal-area Conic projection was used because it is suitable for land masses that extend in an east-to-west orientation (*e.g.*, the ConUS) to minimize the distortion of the shape and linear scale, therefore increasing the accuracy of the geometry calculation (*e.g.*, areas and distance). For the states/regions outside the ConUS, the following selected PCSs were used in projecting species location and county boundary shapefiles (**Table K.1**). Projecting analysis was conducted by using the "projection" tool in ArcGIS or "arcpy.Project_managment" function in ArcPy.

Table K-1. Projected coordinate system used for U.S. regions.

Region	Projected Coordinate System
Conterminous United States (ConUS)	Albers_Conical_Equal_Area.prj.
Hawaii (HI)	NAD_1983_UTM_Zone_4N.prj
Alaska (AK)	WGS_1984_Albers.prj
Puerto Rico (PR)	Albers_Conical_Equal_Area.prj
United States Virgin Islands (VI)	WGS_1984_UTM_Zone_20N.prj
American Samoa (AS)	WGS_1984_UTM_Zone_2S.prj
Guam (GU	WGS_1984_UTM_Zone_55N.prj
Commonwealth of the Northern Mariana (CNMI)	WGS_1984_UTM_Zone_55N.prj

  - Intersection of species location and county shapefiles

As mentioned above, the "intersect" process was the key step of the overlap analysis. The "intersect" tool in ArcGIS or "arcpy.Intersect_analysis" function in ArcPy was used to calculate the geometric intersection of species locations and U.S. Counties. The projected species spatial files (CH and range files) and county shapefile were used as input files in this step. The output features were species locations per county, only including the areas where a polygon from species critical habitat or range file

intersected from the county boundary file. See **Figure K-56** for an illustration of the result of intersecting two polygon feature classes.[59]

In the intersect analysis, the acreage of each intersected polygon in square meters was calculated using the intersect tool. This analysis used the default shape area from the attribute table and the units were confirmed as square meters. This information tells the acreage of a species in a specific county (*i.e.*, species acreage per county, in square meters).

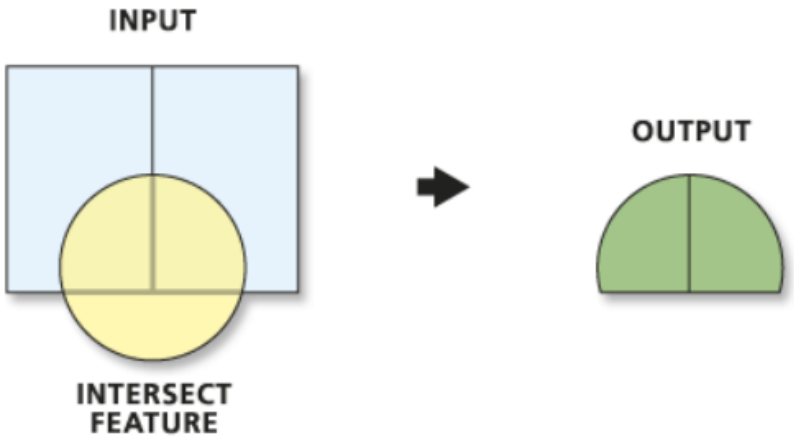

Figure K-56. Illustration of intersect of polygons

- *Exporting attribute table*

Once the intersect was completed, the attribute table was exported as a .csv file. This was done by using the "table to table" tool in ArcGIS or "arcpy.TableToTable_conversion" function in ArcPy. The intersect output tables contained all the attributes from species location files and county boundary files. In addition, the intersect output table also included species by county acreage which was calculated in the intersect process. Once exported to the .csv files, all the intersect output tables were combined into two separate all-in-one tables (one for range and the other for critical habitat) and used as the input data for the overlap Python tool.

- *Use of Python and ArcPy*

As mentioned above, the species location files were organized by taxonomic group in file geodatabases (referred to as species libraries). One location shapefile was designated for each individual species range and critical habitat. Each location file was processed following the same approach (*i.e.*, projected to Albers project) intersected with the county boundary file, and exported the interest output attributes to a .csv file.

Due to the large number of location files and the same process for each file, Python scripts were developed to employ ArcPy functions to run files in a batch for each step described above where spatial files were involved.

[59] Figure 5 was cited from ArcGIS online help document (https://pro.arcgis.com/en/pro-app/latest/tool-reference/analysis/intersect.htm)

The key ArcPy functions used in the Python scripts and their corresponding ArcGIS tools were listed in the **Table K-2** and mentioned above in each step as well.

Table K-2. Key ArcPy functions used and their corresponding ArcGIS tools

Process	ArcPy function	ArcGIS tool
Project	arcpy.Project_management	Project
Intersect feature classes	arcpy.Intersect_analysis	Intersect
Export attribute table	arcpy.TableToTable_conversion	Table to table

Output tables

The final output generated from this spatial overlap analysis includes two all-in-one tables with all species included in each table. One is for the species range, and the other is for designated critical habitat. Each row of the tables represents one species in one county, i.e., single species per county. The attributes/columns of the two tables are slightly different from each other depending on the attribute tables in the source files. However, both output tables contain the essential attributes (but not limited to) that are utilized in the overlap Python tool or further analysis. **Table K-3** listed the essential attributes and the corresponding aspect that each attribute represents.

Table K-3. Output Attribute Tables for Species' Ranges and Critical Habitats

Attribute	Note
EntityID	The unique integer value of the species entity within the database
STATEFP	State FIPS code – the unique two digits value for the state
GEOID	Geographic identifiers – the unique codes identify all administrative/legal and statistical geographic areas i.e., counties.
NAME	Common name of the species
State	The name of the state
Shape_Area	The acreage of the species in the county in square meters
Area*	The acreage of the county in square meters

Note: * This attribute was not used as a filter in the overlap tool but may be needed for other analysis.

- **Overlap Calculations**

  - Direct Overlap

Calculations of direct overlap percentages begin with tables of county-level acreage values for both listed species and crops of interest. The analysis uses GEOIDs as unique identifiers for counties, allowing assessors to match up entries in the species and CoA input tables. For each county/crop/species combination, the minimum of the county/species area and county/crop area is extracted and stored in a table as an overlap area. For this calculation, it was assumed that each additional marginal unit of cropped area within a county will overlap any available species range/critical habitat within that county until 100% of the species area is overlapped. By taking the minima of the two area values it ensures that county-level overlap area cannot exceed the species acreage (i.e., overlap cannot exceed 100%).

Redundancy Adjustment

While individual crop overlap in each county is capped at 100% of the county species area, the initial overlap calculation described above may result in cases where the sum of overlap from all crops of

interest within a county exceeds the county species acreage when multiple crops are considered. In such cases, a redundancy adjustment is applied that maintains the ratio of crop overlap areas while reducing the sum of the overlap areas to the total species area. An example of this redundancy adjustment is provided below:

Unadjusted Overlap Acreage:

Crop 1 Overlap Area (Acres)	Crop 2 Overlap Area (Acres)	Crop 3 Overlap Area (Acres)	Species Range in County (Acres)
30	20	50	50

Overlap Acreage after Redundancy Adjustment (Adjusted values in Red):

Crop 1 Overlap Area (Acres)	Crop 2 Overlap Area (Acres)	Crop 3 Overlap Area (Acres)	Species Range in County (Acres)
15	10	25	50

In the example, the first step is to calculate overlap areas for each crop independently and compares the sum of overlap areas with the species range area. Because the sum of overlap areas for the three crops in the example (100 acres) exceeds the species range (50 acres), each overlap area was multiplied by a factor that represents the species range divided by the sum of individual overlap areas (in this case the factor equals ½). The adjusted overlap areas are consequently reduced in such a way that they sum to the species range area but maintain their original proportions relative to one another.

State-Level Rollup/Capping

Once the redundancy adjustment factor to applicable county-level overlap values was applied, the process of rolling up county-level overlap values to obtain state-level overlap values begins. This process initially involves summing county-level overlap values from the same state for each crop/species combination. Once the initial sums have been obtained, the resulting state-level overlap areas was compared with the state-level crop acreage values from the CoA input tables. The minimum of these two values was then taken as the state-level overlap area. The primary function of this capping procedure is to correct for the highly conservative county-level crop acreage estimates introduced by the non-disclosed acreage imputation procedure. In the imputation all county-level non-disclosed acreage values were assigned with the difference between state acreage values and sum of disclosed county acreage values within that state. While this procedure produces maximum possible acreage estimates in each county (due to the uncertainty regarding the distribution of the acres), it has the potential to result in state-level overlap values that exceed the (known) maximum acreage of crop within the state. The capping procedure enforces this maximum value and corrects state-level overlap estimates downward where necessary.

- National-Level Rollup/Capping

The rollup of state-level overlap acreages to national-level overlap acreage values follows a similar procedure to the county-to-state rollup. Rollup of state-level overlap areas to national-level overlap areas is accomplished by first taking the all state-level overlap areas for each crop/species combination and then taking the minimum of the sum and national-level CoA acreage value for that crop (like the state-level capping described in the previous section).

- Conversion of National Overlap Areas to Percentages

Once national-level overlap areas have been obtained for each crop/species combination, the overlap areas are divided by the total area of range for the corresponding species to generate percentage values. These final percentage values represent an estimate of the portion of species range or critical habitat that overlapped with each selected crop.

Overlap Calculations – Drift

The process for calculating drift overlap areas differs from direct overlap calculations in a few key aspects. As in the direct overlap procedure, we begin with tables of county-level acreage values for both species and crops of interest. For "all ag" estimates of drift overlap, we first take the sum of acreages for all crops of interest within each county (this allows for more straightforward subsequent calculations that do not require redundancy considerations). A list of buffer distances (*i.e.*, distances from the original field over which we might expect drift to occur under different application scenarios) is also specified for drift calculations.

The area impacted by drift for each county/buffer distance combination is estimated by dividing the total crop area in a county into square 25-acre fields, and modeling the areas impacted by drift as the difference between the area of a square determined by extending each side of the original field by the buffer distance and the area of the original 25-acre field as shown in **Figure K-6.**

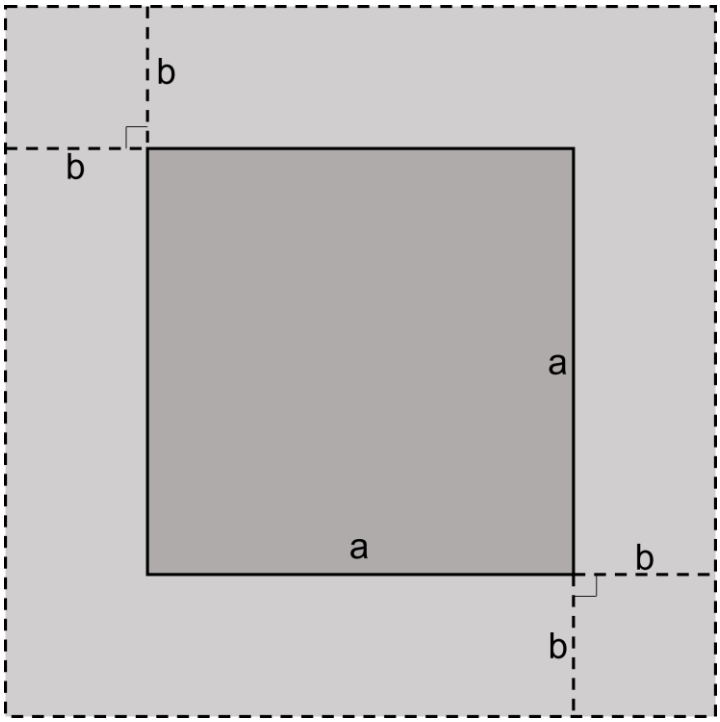

Figure K-6. Illustration of drift model: light gray represents area affected by drift extending distance b (buffer length) from a square field of area a2 (shown in dark gray).

Each 25-acre field in a county has an "a" value of ~318 meters, with specified buffer distance "b" values. The calculation of drift for all crops within a county is shown in **Equation 1**:

$$DriftArea = \frac{Total\ Crop\ Area}{25\ Acres} \cdot \left(\left(\sqrt{25\ Acres} + 2 \cdot Buffer\ Dis\tan c\ e \right)^2 - 25\ Acres \right)$$

Equation 1. Calculation of county-level drift area for all ag columns and specialty crops.

Estimates produced by **Equation 1** thus reflect the conservative assumption that drift areas produced by different 25-acre fields do not overlap one another.

In the "all ag" calculation of drift for a given buffer distance, drift areas are first calculated using **Equation 1** for each county/crop/species combination. Then the overlap area is capped so that the direct overlap of the crop area + drift zone cannot exceed the species range in the county. The drift overlap areas can be summed for each crop/state/species combination to roll up to state-level overlap or sum all drift overlap areas for a given crop/species combination to roll up to national-level overlap areas. Unlike in the direct overlap calculations, state- or national-level crop area caps do not apply to the estimated drift overlap areas. Once the national overlap areas have been obtained, the values are divided by the sums of range/critical habitat areas for the corresponding species to arrive at an overlap percentage.

The overlap tool output tables contain two types of "all ag" drift overlap columns. One group consists of total overlap percentages, which represent all overlap due to drift up to the specified buffer distances of 305 meters, 792 meters, and 1500 meters and these columns require no further calculations besides those already described. Another set of columns output marginal increases in percent overlap over a specified buffer interval (*e.g.*, 60 meters to 90 meters). Marginal drift overlap increase values are obtained by subtracting the national percent overlap value at the start of the buffer interval from the national percent overlap value at the end of the interval. The overlap tool output provides these marginal drift values at 30-meter intervals over the range of 0 to 810 meters (810 selected to complete the last 30m interval). The 30-m increments are presented in the output individually and marginal increases to drift areas will become zero once the maximum number of available acres has been reached.

In addition to the "all ag" drift overlap columns, the tool also outputs a series of crop-specific overlap direct overlap and drift columns. These columns are generated on a per-crop basis by first applying a slightly modified version of Equation 1 to county-level crop acreage values using buffer distances of 0, 30, 305, 792 and 1500 meters to obtain drift areas. The crop-specific drift calculation differs slightly from the "all ag" drift calculations in that row crops (*e.g.,* corn, soybean, *etc*.) are modeled as 500-acre fields while specialty crops (*e.g.*, strawberries, apples, cucumbers, *etc.*) are modeled as 25-acre fields. Thus, specialty crop calculations use **Equation 1**, while row crops calculations make use of **Equation 2**, as shown below:

$$Drift\ Area\ =\ \frac{Total\ Crop\ Area}{500\ Acres}\cdot\left(\left(\sqrt{500\ Acres}\ +\ 2\ \cdot\ Buffer\ Dis\tan c\ e\right)^{2}\ -\ 500\ Acres\right)$$

Equation 2. Calculation of county-level drift area for row crops.

Once the drift area calculation employing the appropriate field size has been performed, the original crop area is then added to the drift areas to obtain a total affected area for each county/crop/buffer distance combination. The minimum of county-level direct + drift areas and county-level species areas are then taken to produce an overlap area for each county/crop/buffer distance/species combination. County-level overlap values for each crop/buffer distance/species combination to produce a national overlap area value. The national overlap areas are then divided by national-level species areas and multiplied by 100 to produce overlap percentage values for each crop/buffer distance/species combination. In contrast with calculations described in previous sections, no redundancy factor or state/national-level crop-acreage caps are applied in the calculation of these overlap values.

Version Updates: This document accompanies the October 31, 2022, version update from V1.0 to V1.1. Changes to the tool in this version reflect the latest updates to the species range and critical habitat files

(Master list-09_2022) as Inputs. This update incorporates new projection methods for regions outside of the conterminous United States. Additionally, this version also includes two additional output tabs [Overlap by Use (Direct and buffered) and Overlap by use in 30 m increments].

Tool Update Cycle: Crop Acreage Inputs may be updated on a 5-year cycle as inputs are available every 5 years from the Census of Agriculture. Species ranges and critical habitats are often updated more frequently, and updates will be scheduled depending on data availability from the Services.

References

US EPA, 2022. 2,4-D Choline Salt and Glyphosate Dimethylammonium Salt: 2022 Ecological Risk and Endangered Species Assessment for Use on Genetically-Modified Herbicide-Tolerant Corn, Soybean, and Cotton in Support of Registration Renewal Decision for Enlist One and Enlist Duo Products. DP Barcodes 462084, 462086

Appendix L. Determination of Overlap of Likely L-Glufosinate Exposure Area and Species Ranges and Designated Critical Habitat

The attached zip file contains the python script files along with input and output summary files associated with the UDL spatial overlap tool and the CoA tool for L-glufosinate.

Appendix M. Listed Species Determinations and Predictions of the Likelihood of Future Jeopardy

Attached is a Microsoft Excel spreadsheet that reports species and overlap information considered in the Biological Evaluation and the rationales for the effects determinations and predictions of likelihood of future jeopardy for all listed species designated as threatened or endangered as of February 2022.

Appendix N. Critical Habitat Determinations and Predictions of Likely Adverse Modification

Attached is a Microsoft Excel spreadsheet that reports critical habitat and overlap information considered in the Biological Evaluation and the rationales for the effects determinations and predictions of likely adverse modification for all critical habitat designated final as of February 2022.