UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON D.C., 20460

OFFICE OF
CHEMICAL SAFETY AND
POLLUTION PREVENTION

June 15, 2017

MEMORANDUM

SUBJECT: Drinking Water Assessment for the Registration Review of Glyphosate. PC Code: 417300, 103601, 103604, 103607, 103608, 103613, 103603, 103605, 128501; DP Barcode: 440486

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Executive Summary

This updated drinking water assessment for glyphosate includes new environmental fate data, current surface and ground water models, and a comprehensive evaluation of surface and ground water monitoring data. Parent glyphosate, expressed on an acid equivalence basis**,** is considered the residue of concern for drinking water.

Maximum observed and predicted glyphosate concentrations in surface water are shown in Table 1. The maximum glyphosate concentrations in surface source drinking water are associated with the glyphosate use as a direct water application to control aquatic weeds in potable source waters. The maximum estimated drinking water concentration (EDWC) of glyphosate in surface source water are not expected to exceed 700 µg/L for the 1 in 10 year daily peak, 104 µg/L for the 1 in 10 year 90-day average, 75 µg/L for the 1 in 10 year annual average, and 75 µg/L for the 30 year annual average. These concentrations were derived from label language that defines the maximum allowable glyphosate concentration at the intake of a treated drinking water system, as well as model predicted concentrations for the long term average glyphosate concentrations. Estimated glyphosate concentrations from monitoring sites with comparable watershed areas to

community water systems are substantially lower than the glyphosate concentration from direct water applications. The maximum EDWC's for glyphosate from monitoring data are 35.1 µg/L or the 1 in 10 year daily peak, 13.5 µg/L for the 1 in 10 year 90-day average, and 2.8 µg/L for the 1 in 10 year annual average. Although the glyphosate concentrations from monitoring data have not been corrected for the inherent underestimation due to less than daily sampling, a preliminary analysis of bias factors for glyphosate suggests that bias factor corrected EDWC from monitoring data are comparable to the recommended EDWCs from direct water application of glyphosate to potable water sources.

Table 1. Maximum EDWCS for Glyphosate in Surface Water

Use Sites	1 in 10 year				30-year Annual Average
	Daily	Average Daily	90-day Average	Annual Average	
	µg ae[1]/L				
Terrestrial Food and Non-Agricultural Uses-PWC		199	99	65	50
Direct Water Application-using label restriction for MCL and 50% treatment area	700[2]	700[2]	104	75	70
Rice and Cranberry-PFAM	162	162	13.8	5.2	3.6
All SW Monitoring Data[3]	257	257	106	59.7	NC
All SW Monitoring Data 1 in 10 year at 90th percentile site	61	61	13	3	NC
SW Monitoring Data for Potential Watersheds Supporting CWSs[4] 1 in 10 year at 90th percentile site	35.09	35.09	13.47	2.82	NC

1-Concentrations of glyphosate have been normalized to acid equivalence because glyphosate is formulated as amine salts in end use products. The acid equivalence is the ratio of the molecular weight of the acid (grams/mole) to the molecular weight of the amine salt of glyphosate (grams/mole). This ratio was used to adjust the application rates in modeling. Additionally, monitoring data occurrence analyzed for glyphosate acid.

2- Represent the maximum label restricted concentration in glyphosate treated potable water. This concentration is equal to the OW Maximum Contaminate Level (MCL).

3-Data represent maximum concentrations of glyphosate in surface water monitoring data without a distributional assumption of the 1 in 10 year exposure concentration at a 90th percentile site. These are the observed glyphosate exposure concentration from all surface water monitoring data.

4-Concentrations represent 1 in 10 year concentration at a 90th percentile site for monitoring sites with watersheds ≥ 0.04 km^2.

Maximum observed and predicted glyphosate concentrations in ground water are shown in Table 2. Although the PWC modeling indicate no glyphosate breakthrough in groundwater during a 100-year simulation, ground water monitoring data indicate a very high peak (285 µg/L) and annual average concentration (20.6 µg/L) for glyphosate. The groundwater monitoring data with high glyphosate concentrations are associated with subsurface drains and, therefore, they are not representative of groundwater source drinking water. Typically, tile drain fields form preferential flow pathways into tile drains, which allows for a less torturous flow pathway when compared to advection-dispersion flow, as assumed in PWC modeling.

Table 2. Maximum EDWCS for Glyphosate in Groundwater

Assessment Process	Peak	Annual Average
	µg/L	
PRZM-GW Modeling	No breakthrough in GW	
Ground Water Monitoring	285	20.6

EFED recommends that the Health Effects Division (HED) use 700 µg/L for the 1 in 10 year daily peak, 104 µg/L for the 1 in 10 year 90-day average, 75 µg/L for the 1 in 10 year annual average, and 75 µg/L for the 30 year annual average in the dietary health risk assessment. These concentrations were derived from label restrictions for direct water applications of glyphosate on the maximum allowable glyphosate concentration (700 µg/L) at the intake of a drinking water system, as well as model estimated concentrations for the long-term average glyphosate concentrations.

Commercial Formulations and Residues of Concern

Several salts of glyphosate are currently marketed, as well as the acid, and are considered as the active ingredient in end-use products. The parent acid is the chemical species that exhibits herbicidal activity and is the actual chemical stressor considered in this risk assessment, unless otherwise specified.

In order to have comparable results, each salt is considered in terms of its glyphosate equivalent, (acid equivalent; a.e.), determined by multiplying the application rate by the acid equivalence ratio, defined as the ratio of the molecular weight of *N*-(phosphonomethyl)glycine to the molecular weight of the salt. Table 3 shows the salts of glyphosate that may be used as the source of the actual herbicide-active chemical species. For the purpose of this assessment, the acid and all salt species are referred to collectively as "glyphosate" throughout this document.

Table 3. Identification of Glyphosate and its Salts

Counter Cation	PC Code	CAS No.	Acid Equivalence Ratio
Glyphosate acid (no counter cation)	417300	1071-83-6	1
Isopropyl amine	103601	38641-94-0	0.74
Monoammonium	103604	114370-14-8	0.94
Diammonium	103607	69254-40-6	0.83
N-methylmethanamine	103608	34494-07-7	0.79
Potassium	103613	70901-12-1	0.81

The Health Effects Division determined that glyphosate([*N*-(phosphonomethyl)glycine) is the only residue of concern in the human health dietary exposure assessments.

Regulatory Criteria

The National Primary Drinking Water Regulations (NPDWR) have defined a Maximum Contaminate Level (MCL) for glyphosate (**https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations**). The MCL is 700 µg/L. This concentration represents a rolling average concentration for 4 consecutive 90-day sampling (quarterly) intervals.

Previous Drinking Water Assessments

Drinking water assessments have been conducted for a number of different terrestrial crop, terrestrial non-crop, and aquatic use patterns (D376484, D372055, D364549). The highest EDWCs were derived from the direct aquatic applications (D364549).

Use Statistics

Glyphosate is used as a non-selective foliar systemic herbicide in both aquatic and terrestrial environments on a wide variety of food and feed crops, non-food and non-feed crops and for other uses including forestry, greenhouse, non-crop, and residential. Based on agricultural usage data provided by the Biological and Economic Analysis Division (BEAD), on average, roughly 196,355,300 pounds of glyphosate are applied annually to agricultural crops (Table 4). Glyphosate usage is highest on soybeans, with annual average applications of 100,000,000 lbs a.i. applied (representing nearly 51% of the total use on agricultural crops). The crop with the highest average percent crop treated with glyphosate is soybeans (95%), followed by oranges (90%), and then almonds, cotton, grapefruit, and pistachios (85%).

Table 4. Screening Level Estimates of Agricultural Uses of Glyphosate

Crop	Pounds A.I.	Percent Crop Treated	
		Average	Maximum
Alfalfa	400,000	<2.5	5
Almonds	2,100,000	85	95
Apples	400,000	55	70
Apricots	10,000	60	80
Artichokes	1,000	10	15
Asparagus	30,000	55	70
Avocados	80,000	45	65
Barley	600,000	25	40
Beans, Green	70,000	15	25
Blueberries	10,000	20	25
Broccoli	3,000	<2.5	<2.5
Brussels Sprouts *	<500	N/C	N/C
Cabbage	20,000	10	25
Caneberries	3,000	10	25
Canola	500,000	65	80
Cantaloupes	20,000	10	25
Carrots	3,000	5	10
Cauliflower	1,000	<2.5	5
Celery	1,000	5	10
Cherries	200,000	65	85
Chicory*	<500	N/C	N/C
Corn	59,300,000	60	85
Cotton	18,300.000	85	95
Cucumbers	30,000	20	35
Dates	3,000	20	25
Dry Beans/Peas	600,000	25	45
Fallow	8,400,000	55	65
Figs	5,000	40	70
Garlic	4,000	10	25
Grapefruit	400,000	85	95
Grapes	1,400,000	70	80
Hazelnuts	30,000	65	90
Kiwifruit	2,000	30	40
Lemons	200,000	75	90
Lettuce	10,000	<2.5	10
Nectarines	20,000	45	70
Oats	100,000	5	10
Olives	20,000	45	50

Crop	Pounds A.I.	Percent Crop Treated	
		Average	Maximum
Onions	40,000	30	40
Oranges	3,200,000	90	95
Pasture	700,000	<1	<2.5
Peaches	100,000	55	70
Peanuts	300,000	20	35
Pears	100,000	65	90
Peas, Green	20,000	10	20
Pecans	400,000	35	45
Peppers	30,000	20	35
Pistachios	500,000	85	95
Plums/Prunes	200,000	65	80
Pluots*	1,000	N/C	N/C
Pomegranates*	40,000	N/C	N/C
Potatoes	80,000	10	15
Pumpkins	20,000	20	25
Rice	800,000	30	50
Sorghum	2,800,000	40	60
Soybeans	100,000,000	95	100
Spinach	2,000	<2.5	10
Squash	10,000	20	40
Strawberries	10,000	10	20
Sugar Beets	1,200,000	55	100
Sugarcane	300,000	45	50
Sunflowers	1,100,000	55	75
Sweet Corn	100,000	15	25
Tangelos	9,000	55	80
Tangerines	60,000	65	80
Tobacco	9,000	5	10
Tomatoes	100,000	35	45
Walnuts	600,000	75	85
Watermelons	30,000	15	25
Wheat	8,500,000	25	70

All numbers rounded.
<500 indicates less than 500 pounds of active ingredient.
<2.5 indicates less than 2.5 percent of crop is treated.
<1 indicates less than 1 percent of crop is treated.
* Based on CA DPR data only; N/C = not calculated, only lb a.i. available

The survey data included in the SLUA report does not differentiate between which exact chemical code(s) are included from the Case. Data years 2004-2012

SLUA data sources include:
USDA-NASS (United States Department of Agriculture's National Agricultural Statistics Service),
Private Pesticide Market Research, and California Department of Pesticide Regulation data.
These results reflect amalgamated data developed by the Agency and are releasable to the public.

As shown in Figure 1, based on U.S. Geological Survey (USGS) National Water Quality Assessment Program (NAWQA) data from 2011, glyphosate is used on agricultural crops across most of the U.S., but predominantly in California, Midwestern states, Arkansas, Tennessee, Mississippi, Louisiana, and Southeastern states from Maryland to Florida.

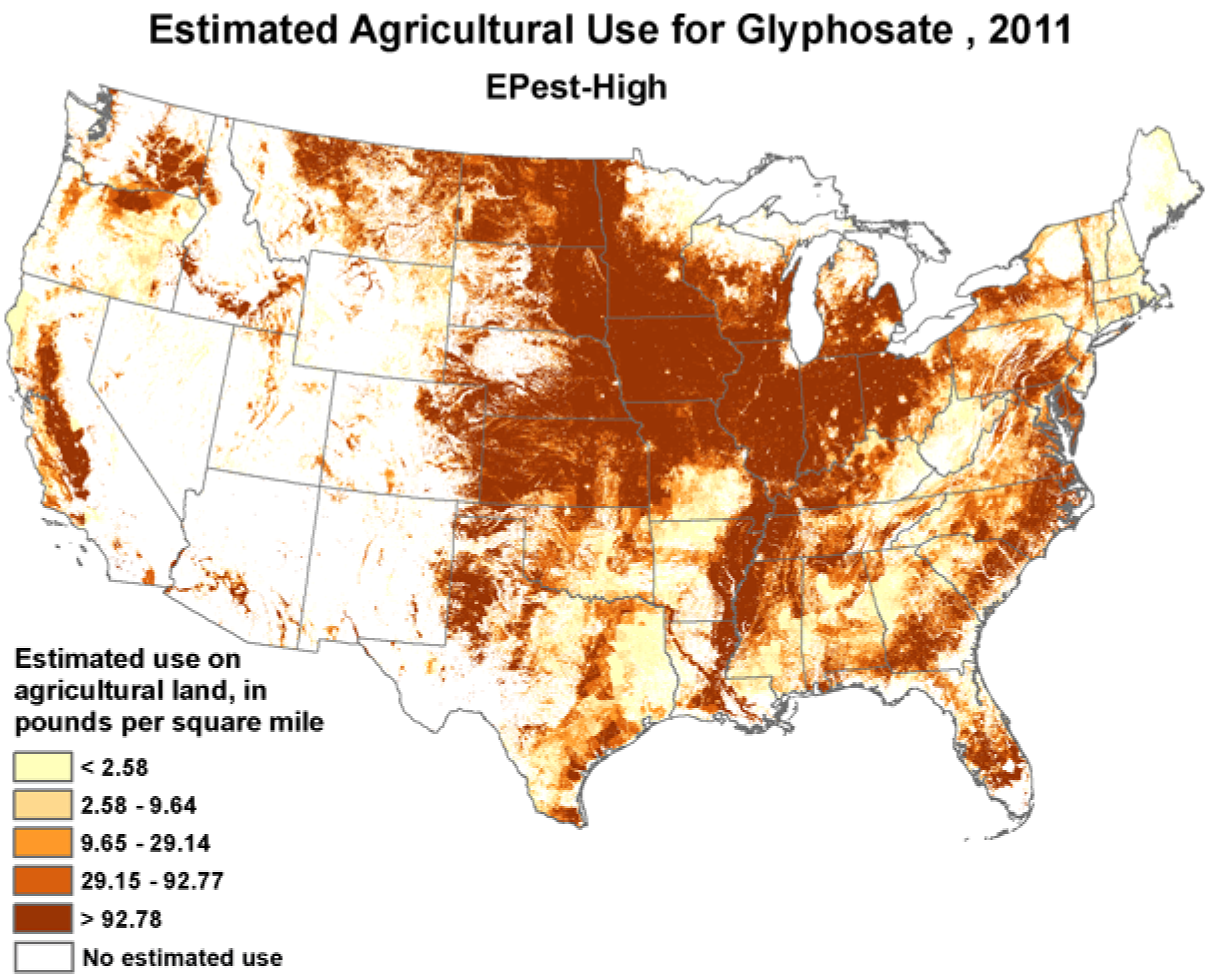

Figure 1. Map of Estimated Annual Agricultural Use of Glyphosate in 2011
(Source: http://water.usgs.gov/nawqa/pnsp/usage/maps/show_map.php?year=2011&map=GLYPHOSATE&hilo=L)

Application Methods and Rates

Target pests include a broad spectrum of emerged grass and broadleaf weeds, both annual and perennial. Glyphosate is formulated as water-dispersible granules (WG) (80% active ingredient), emulsifiable concentrate (EC) (13.4% - 36.5% active ingredient), water-dispersible liquids (L) (5% - 14.6% active ingredient), ready to use (RTU) (0.81% active ingredient), and soluble concentrate/solid (SC/S) (95.2% - 96.7% active ingredient). Application equipment includes aircraft and various ground equipment (boom sprayer, hand held hydraulic sprayer, hand held sprayer, high volume ground sprayer, hooded sprayer, hose-end sprayer, low volume ground sprayer, low volume sprayer, motor driven sprayer, product container, ready-to-use spray container, shielded applicator, sprayer, tank-type sprayer, wick applicator, and wiper applicator).

Application is via band treatment, broadcast, crack and crevice treatment, directed spray, edging treatment, ground spray, high volume spray (dilute), low volume spray (concentrate), perimeter treatment, soil broadcast treatment, spot treatment, spray, strip treatment, stump treatment, and wipe-on/wiper treatment. Single application rates are up to 8 pounds active ingredient (as acid equivalents)/acre (lb a.e./A), but are generally 1.55 lb a.e./A for aerial applications and 3.75 lb a.e./A for ground application. Maximum combined annual application rates are up to generally 6 to 8 lbs a.e./A. For some uses, the single application rates were calculated as up to 40 lbs a.e./A, however, these applications are intended for spot treatment or treatment over areas much smaller than an acre. In these cases, the application rate is also expressed in terms of the smaller coverage area.

The label data used in this assessment were derived label and use information compiled by the Joint Glyphosate Task Force (JGTF). The Agency requested that the JGTF submit label information to clarify non-specified information in the LUIS report (Memorandum attachments from Ms. Katie Miller, Administrator for the Joint Glyphosate Task Force, LLC. to Ms. Carissa Cyran, Chemical Review Manager in the Office of Pesticides Program. February 15, 2013, Regarding JGTF Submission of Data Matrix Sheet). The non-specified information clarified included maximum number of applications in a crop cycle, maximum number of applications per year, maximum application rate per year, and the minimum retreatment intervals. Table 5 and Table 6 show the maximum single application rates for glyphosate from the JGTF.

Table 5. Maximum Single Application Rates for Ground Applications of Glyphosate from the JGTF Use Matrix

Crop Group	Max Single App Rate (lb a.e./A)	Max Apps	Min Interval (days)	Max Annual App Rate Crop Cycle (lb a.e./A)	Max Combined Annual App Rate (lb a.e./A)
Round Ready 2 Yield Soybeans	3.75	3	10	3.75	6
Root Tuber Vegetables	3.75	3	7	6	6
Rangelands	0.38	6	7	2.25	2.25
Pome Fruits	3.75	10	7	8	8
Pastures	8	4	7	8	8
Oilseed Crops	3.75	3	7	6	6
Non-Food Tree Crops	8	30	7	8	8
Miscellaneous Tree Crops	3.75	10	7	8	8
Miscellaneous Crops	3.75	3	7	6	6
Legume Vegetables	3.75	6	7	6	6
Leafy Vegetables	3.75	6	7	6	6
Herbs and Spices	3.75	6	7	6	6
Grass/Turfgrass/Sod Production	3.75	3	7	6	6
Grain Sorghum	3.75	3	7	6	6
Fruiting Vegetables	3.75	6	7	6	6
Forestry	8	5	7	8	8

Crop Group	Max Single App Rate (lb a.e./A)	Max Apps	Min Interval (days)	Max Annual App Rate Crop Cycle (lb a.e./A)	Max Combined Annual App Rate (lb a.e./A)
Fallow	3.75	3	7	6	6
Cucurbits Vegetables/Fruit	3.75	6	7	6	6
Cotton	3.75	5	7	6	6
Corn (Field, Seed, Silage, Popcorn)	3.75	3	7	6	6
Conservation Reserve Program	3.75	3	7	6	6
Citrus Fruit Crop	3.75	10	7	8	8
Cereal and Grain Crop	3.75	3	7	6	6
Bulb Vegetables	3.75	6	7	6	6
Brassica Vegetable	3.75	6	7	6	6
Round-up Ready Flex Cotton	3.75	3	10	3.75	6
Round-up Ready Cotton	3.75	3	10	3.75	6
Round-up Ready Corn (GA-21)	3.75	3	10	3.75	6
Round-up Ready Corn 2 (NK603)	3.75	3	10	3.75	6
Round-up Ready Alfalfa	1.55	3	10	4.61	6
Round-up Ready Sugarbeets	3.75	3	10	3.75	6
Tropical/Subtropical Trees/Fruits	3.75	3	10	8	8
Tree Nut Crops	3.75	3	10	8	8
Sweet Corn	3.75	3	7	6	6
Sugar Cane	3.75	3	7	6	6
Stone Fruit	3.75	3	7	8	8
Round-Up Ready Canola(Winter Varieties)	1.55	3	10	1.55	6
Soybeans	3.75	3	7	6	6
Sweet Corn with Round-Up Ready 2 Technology	3.75	3	10	3.75	6
Round-Up Ready Canola (Spring Varieties)	1.55	3	10	1.55	6
Vine Crops	3.75	3	7	8	8
Non Crop	8	10	7	8	8
Aquatic	8	4	1	8	8
Alfalfa, Clover, and Other Forage Legume	3.75	3	7	6	6
Berry and Small Fruit Crops	3.75	3	7	8	8
Residential	40	12	7	40	40

Table 6. Maximum Single Application Rates for Aerial Applications of Glyphosate from the JGTF Use Matrix

Crop Group	Max Single App Rate (lb a.e./A)	Max Apps	Min Interval (days)	Max Annual App Rate Crop Cycle (lb a.e./A)	Max Combined Annual App Rate (lb a.e./A)
Round Ready 2 Yield Soybeans	1.55	3	10	3.75	6
Root Tuber Vegetables	1.55	3	7	4.65	6
Rangelands	0.38	6	7	2.25	2.25
Pome Fruits	1.55	3	7	4.65	8
Pastures	8	4	7	8	8
Oilseed Crops	1.55	3	7	4.65	6
Non-Food Tree Crops	8	3	7	4.65	8
Miscellaneous Tree Crops	1.55	3	7	4.65	8
Miscellaneous Crops	1.55	3	7	4.65	6
Legume Vegetables	1.55	6	7	4.65	6
Leafy Vegetables	1.55	6	7	4.65	6
Herbs and Spices	1.55	6	7	6	6
Grass/Turfgrass/Sod Production	1.55	3	7	4.65	6
Grain Sorghum	1.55	3	7	4.65	6
Fruiting Vegetables	1.55	6	7	4.65	6
Forestry	8	2	7	8	8
Fallow	1.55	3	7	4.65	6
Cucurbits Vegetables/Fruit	1.55	6	7	4.65	6
Cotton	1.55	3	7	4.65	6
Corn (Field, Seed, Silage, Popcorn)	1.55	3	7	4.65	6
Conservation Reserve Program	1.55	3	7	4.65	6
Citrus Fruit Crop	1.55	3	7	4.65	6
Cereal and Grain Crop	1.55	3	7	4.65	6
Bulb Vegetables	1.55	6	7	4.65	6
Brassica Vegetable	1.55	6	7	4.65	6
Round-up Ready Flex Cotton	1.55	3	10	3.75	6
Round-up Ready Flex Cotton	1.125	6	10	4.5	6
Round-up Ready Cotton	1.55	3	10	3.75	6
Round-up Ready Corn (GA-21)	1.55	3	10	3.75	6
Round-up Ready Corn 2 (NK603)	1.55	3	10	3.75	6
Round-up Ready Alfalfa	1.55	3	10	4.61	6
Round-up Ready Sugarbeets	1.55	3	10	3.75	6
Tropical/Subtropical Trees/Fruits	1.55	3	10	4.65	8
Tree Nut Crops	1.55	3	10	4.65	8
Sweet Corn	1.55	3	7	4.65	6

Crop Group	Max Single App Rate (lb a.e./A)	Max Apps	Min Interval (days)	Max Annual App Rate Crop Cycle (lb a.e./A)	Max Combined Annual App Rate (lb a.e./A)
Sugar Cane	2.25	3	7	6	6
Stone Fruit	1.55	3	7	4.65	8
Round-Up Ready Canola (Winter Varieties)	1.55	3	10	1.55	6
Soybeans	1.55	3	7	4.65	6
Sweet Corn with Round-Up Ready 2 Technology	1.55	3	10	3.75	6
Round-Up Ready Canola (Spring Varieties)	1.55	3	10	1.55	6
Vine Crops	1.55	3	7	4.65	8
Non Crop	8	10	7	8	8
Aquatic	8	4	1	8	8
Alfalfa, Clover, and Other Forage Legume	1.55	3	7	4.65	6
Berry and Small Fruit Crops	1.55	3	7	4.65	8

Environmental Fate Assessment

The glyphosate salts dissociate rapidly to form glyphosate acid and the counter ion. Because glyphosate acid will be a zwitterion (presence of both negative (anionic) and positive (cationic) electrostatic charges) in the environment, it is expected to speciate into dissociated species of glyphosate acid as well as glyphosate-metal complexes in soil, sediment, and aquatic environments. The environmental fate data for glyphosate, with the exception of a photodegradation study (MRID 44320643), did not address the impact of environmental fate processes on different species of glyphosate acid.

The major route of transformation of glyphosate identified in laboratory studies is microbial degradation (Table 7). In soils incubated under aerobic conditions, the half-life of glyphosate ranges from 1.8 to 109 days and in aerobic water-sediment systems is 14 - 518 days. However, anaerobic conditions limit the metabolism of glyphosate (half-life 199 - 208 days in anaerobic water-sediment systems).

In laboratory studies, glyphosate was not observed to break down by abiotic processes, such as hydrolysis, direct photolysis on soil, or photolysis in water at pH 7. In the field, soil dissipation half-lives for glyphosate were measured to be 1.4 to 142 days. The majority of terrestrial field dissipation studies showed glyphosate half-lives less than 25 days. Although the variability in glyphosate dissipation rates cannot be statistically correlated to any specific test site properties, dissipation half-lives tend to be higher at test sites in the central to northern United States. Along with significant mineralization to carbon dioxide, the major metabolite of glyphosate is aminomethylphosphonic acid (AMPA).

AMPA is a major degradation product from glyphosate. It was detected in all laboratory studies except for the abiotic hydrolysis studies. This degradation product is ionic because it retains the phosphonate and amine functional groups. Because of these functional groups, AMPA will form metal complexes with Ca^{2+}, Mg^{2+}, Mn^{2+}, Cu^{2+}, and Zn^{2+} (Popov, et al., 2001). Batch equilibrium data for AMPA indicate high sorption to soils. Freundlich sorption coefficients range from 10 to 509 with exponents (1/n) of .78 to 0.98. The laboratory and field dissipation data indicate that AMPA is substantially more persistent than glyphosate.

Table 7. Environmental Fate Data for Glyphosate

Study	Value	Major Degradates[1], Comments	MRID #
Abiotic Hydrolysis Half-life	Stable	None	00108192 44320642
Direct Aqueous Photolysis	Stable ($t_{1/2}$ = 216 days)	AMPA (6.6% of AR)	41689101 44320643
Soil Photolysis Half-life	Stable (for at least 30 days)	Degradation in dark control was equal to that in irradiated samples	44320645
Aerobic Soil Metabolism Half-life	1.8 days (sandy loam; 25°C) 2.6 days (silt loam; 25°C) 7.5 days (sandy loam; 25°C) 2.04 days (sandy loam; 25°C) 19.3 days (sandy loam;20°C) 27.4 days (scl loam; 20°C) 7.78 days (clay loam;20°C) 109 days (silt loam;20°C)	AMPA (24-32% of AR) CO_2 (53 to >70% of AR)	42372501 44320645 44125718 PMRA1161813 Al-Rajab and Schiavon, 2010
Anaerobic Aquatic Metabolism Half-life	208 days 203 days 199 days	AMPA (21.9-31.6% of AR) CO_2 (23-35% of AR) AMPA and glyphosate were detected in sediment at 1 year posttreatment	41723701 42372502 44125718
Aerobic Aquatic Metabolism Half-life	14.1 days (25°C) 267 days (20°C) 518 days (20°C)	AMPA (25% of applied AR) CO_2 (≥ 23% of applied AR)	41723601; 42372503 PMRA 161822

Study	Value				MRID #
Batch Equilibrium	*Soil*	K_F	*1/n*	K_{Foc}	44320646
	sand	64	0.75	22,000	
	sandy loam	9.4	0.72	1,600	
	sandy loam	90	0.76	5,000	
	silty clay loam	470	0.93	21,000	
	silty clay loam	700	0.94	33,000	
	Silty clay loam	62	0.90	3,172	00108192
	Silt	90	0.94	13,050	
	Sandy loam	70	0.95	5,075	
	Sandy loam	22	0.78	5,468	
	Sediment	175	1.0	20115	

Study	Value		MRID #
Terrestrial Field Dissipation Half-life	Glyph. / AMPA 1.7 d / 131 d (TX) 7.3 d / 119 d (OH) 8.3 d / 958 d (GA) 13 d / 896 d (CA) 17 d / 142 d (AZ) 25 d / 302 d (MN) 114 d / 240 d (NY) 142 d / no data (IA)	Bare ground studies. Glyphosate and AMPA were found predominantly in the 0 to 6 inch layers	42607501 42765001
	Glyph. / AMPA 2.79 d / 48d (CA) 31 d / ND (NC)	Bareground Studies Glyphosate and AMPA were found predominantly in the surface soil layers	44125719 44422201
	Glyph / AMPA 3.9 d / ND Bareground 1.4 d / ND Turf	Bareground and turf plots in MS Glyphosate and AMPA were found predominantly in the surface soil layers	44320648
	Glyph / AMPA 19 d / ND Bareground 12 d / ND Turf	Bareground and turf plots in CA Glyphosate and AMPA were found predominantly in the surface soil layers	44320649 44320650
Aquatic Field Dissipation Half-life	7.5 d – water 120 d- sediment	In a farm pond in Missouri. At 3 sites (OR, GA, MI), half-lives could not be calculated due to recharging events.	40881601
	Water: Dissipated rapidly immediately after treatment. Sediment: Glyphosate remained in pond sediments at ≥ 1 ppm at 1 year post treatment.	In ponds in Michigan and Oregon and a stream in Georgia Accumulation was higher in the pond than in the stream sediments	41552801
Forestry Dissipation	Foliage: < 1 day Ecosystem: Glyphosate: 100 d AMPA: 118 d	3.75 lb a.e./A, aerial application	41552801

[1] Major degradates are defined as those which reach >10% of the applied.

The available laboratory data indicate that both glyphosate and AMPA sorb strongly to soil. The formation of glyphosate-metal complexes promotes a high sorption affinity of glyphosate to Fe and Al oxide surfaces on soils and sediments (McBride, 1994; Popov, *et al*. 2001). AMPA is also expected to form similar metal-ligand complexes (Popov, *et al*. 2001). Freundlich partitioning coefficients (K_f) for glyphosate ranged from 9.4 to 479 with exponents of 0.72 to 1, which corresponding organic carbon partitioning coefficients (Kf_{oc}) of 1,600 to 33,000 mL/g_{oc}. Freundlich sorption coefficients for AMPA range from 10 to 509 with exponents (1/n) of 0.78 to 0.98. Because the Freundlich exponents for glyphosate and AMPA are not equal to 1, the sorption process is non-linear and, therefore, sorption coefficients are dependent on the concentration in soil solution or aquatic environments. Although this non-linearity in sorption is not captured in the exposure modeling, it is expected to reduce the exposure concentrations in aquatic exposure modeling.

Although the coefficient of variation for K_{foc} is less than the coefficient of variation for K_f, indicating that pesticide binding to the organic matter fraction of the soil may explain some of the variability among the adsorption coefficients, the physicochemical properties of glyphosate (ionic) and the propensity for glyphosate and AMPA to form metal-ligand complexes on surfaces of iron and aluminum oxides would suggest the Freundlich model is the most appropriate partitioning model. This model would account for sorption on both mineral and organic constituents in soils and sediments. Based on measured K_{oc} values, glyphosate is classified as slightly mobile to hardly mobile according to the FAO classification scheme and would not be expected to leach to groundwater or to move to surface water at high levels through dissolved runoff. However, glyphosate does have the potential to contaminate surface water from spray drift or transport of residues adsorbed to soil particles suspended in runoff. It is expected to be persistent in anaerobic sediments.

The potential for volatilization of glyphosate from soil and water is expected to be low due to the low vapor pressure and low Henry's Law constant. Several studies have shown both glyphosate and AMPA detections in rainwater near use locations. In most cases, these detections were found during the spraying season in the vicinity of local use areas and can be attributed to spray drift rather than to volatilization or long range transport (Baker *et al*., 2006; Quaghebeur *et al*., 2004). The highest concentrations were found in urban locations. At one site in Belgium that was 5 m from a spraying location in an urban parking lot, glyphosate was detected in rainwater for several months following a single application (Quaghebeur *et al*., 2004). Deposition was measured to be 205 µg a.i./m^2 at one week after spraying and 0.829 µg/m^2 two months after spraying. These data suggest that volatilization of glyphosate from hard surfaces is possible despite its low vapor pressure.

Surface Water Exposure Modeling

Drinking water assessments were conducted to assess EDWCs for terrestrial crop use sites, non-agricultural use sites, rice use sites, and direct application to water use sites. Each of these use sites require a different environmental fate modeling strategy for estimation of glyphosate concentrations in drinking water.

Environmental fate data parameters used in the modeling were selected from the available studies in general accordance with *Guidance for Selecting Input Parameters in Modeling the Environmental Fate and Transport of Pesticides*, Version 2.1, October 22, 2009. Environmental fate data used in glyphosate modeling are shown in Table 8.

Table 8. PWC Modeling Inputs for Glyphosate

PARAMETER	Measured VALUES	VALUE	COMMENT	SOURCE
Spray Drift Fraction	NA	No buffer-0.13 500 feet buffer-0.018 (AR and CA only)	Default fraction for no buffers simulations Calculated	AgDrift
Aerobic Soil Metabolism Half-life (days)	1.8days 2.6 days 7.5 days 2.0 days 13.6 days[b] 19.4 days[b] 5.5 days[b] 77.1 days[b]	29 days	Upper 90th percentile confidence bound of the mean half-life= 16.19+(1.415*25.37)/SQR(8) Average=16.19 SD=25.37 $T_{n-1,90}$ =1.415 n=8	MRID 44320645 MRID 44125718 MRID 42372501 PMRA 1161813 Al-Rajab and Schiavon, 2010
Organic Carbon Partition Coefficient (Koc) (mL/ goc)		157	Mean K_F[a]	MRID 44320646 MRID 00108192
Aerobic Aquatic Half-Life (days)	14 days 188 days[b] 366 days[b]	381 days	Upper 90th percentile confidence bound of the mean half-life= 189.7+(1.886*175.8)/SQR(3) Average=189.7 SD=175.8 $T_{n-1,90}$ =1.886 n=3	MRID 41723601 PMRA 1161822
Anaerobic Aquatic Half-Life (days)	208 days 203 days 199 days	208	Upper 90th percentile confidence bound of the mean half-life= 203.33+(1.886*4.509)/SQR(3) Average=203.33 SD=4.509 $T_{n-1,90}$ =1.886 n=3	MRID 41723701 MRID 42372502
Aqueous Photolysis half-life (days)		Stable	Represents photo-degradation rate at pH 7	MRID 41689101 MRID 44320643
Hydrolysis half-life (days)		Stable		MRID 00108192 MRID 44320642
Vapor Pressure (torr)	9.750E-10	9.750E-10	Vapor Pressure @ 25^{0}C	
Molecular Weight (g/mole)		169.08		Calculated
Water Solubility @ 25°C (mg/L)		12,000		Product Chemistry

a=Data derived according to Guidance of Selecting Input Parameters in Modeling Environmental Fate and Transport of Pesticides Version 2.1 (10/22/2009)
b=Half-lives corrected from 20^{o}C to 25^{o}C using Q10 temperature correction equation.

Terrestrial Crop and Non-Agricultural Terrestrial Use Sites

EDWCs in surface water from terrestrial and non-agricultural uses were estimated with PRZM5 and Variable Volume Water Model (VVWM) models in the operating platform of Pesticide Water Calculator (Version 1.52). PRZM5 simulates pesticide fate and transport as a result of leaching, direct spray drift, runoff and erosion from an agricultural field. The VVWM model simulates pesticide loading via runoff, erosion, and spray drift assuming a standard watershed of 172.8 ha that drains into an adjacent standard drinking water index reservoir of 5.26 ha, an average depth of 2.74 m. A more detailed description of the index reservoir (IR) watershed can be found at https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/development-and-use-index-reservoir-drinking-water. Simulations for drinking water used the index reservoir scenario in the VVWM, which is a surrogate for a drinking water source drawn from a surface water source (nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100JIT6.TXT). Weather and agricultural practices are simulated for 30 years so that the 1 in 10-year exceedance probability at the site can be estimated. The simulation was generated using the 30 years of meteorological data, encompassing the years from 1961 to 1990.

The EDWCs for surface water were multiplied by a percent crop area factor (PCA) of 1. Because glyphosate is used on multiple crops and non-agricultural areas, an all agricultural PCA of 1.0 was used to adjust EDWCs for the percentage of agricultural crops in a watershed (https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/development-community-water-system-drinking-water).

The modeling strategy used to estimate EDWCs for glyphosate included all crop and non-crop scenarios. This modeling approach was used because glyphosate can be used on most crops and non-agricultural use sites. Application rates of glyphosate used in modeling include 1) two applications at 3.75 lbs ae/A, 2) a single application at 8 lbs ae/A, and 3) a single application of 40 lbs ae/A. The application rate of 40 lbs ae/A is a calculated rate based on a residential spot treatment application rate and is expected to be highly conservative.

Pre-emergent applications were assessed assuming an application at 37 and 30 days before emergence at 3.75 lbs ae/A/application or 30 days before emergence at 8 lbs ae/A/application. Post-emergent applications were assessed assuming applications at 20 and 27 day after emergence at 3.75 lbs ae/A/application or 20 days after emergence at 8 lbs ae/A/application. The application date for the residential spot treatment of glyphosate was set to be May 1st because there is no clear emergence date for turf and residential areas. Aerial and ground applications were modeled. Default drift fractions were used to assess drift except for aerial glyphosate applications in CA scenarios (Brady, 2013[1]). Glyphosate labels in AR and CA require a 500 feet spray drift buffer for aerial applications of glyphosate. Drift fractions for the 500 feet spray drift buffer was estimated to be 0.018[2].

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1 Brady, December 13, 2013. Guidance on Modeling Offsite Deposition of Pesticides via Spray Drift for Ecological and Drinking Water Assessments. Environmental Fate and Effects Division, Office of Pesticide Programs.
2 Drift fraction calculation : ((area streams/area reservoir)*drift fraction for 500 feet buffer on a 4 meter wide stream) + drift fraction for 500 ft on an 82 meter wide reservoir. The equation used in calculation of drift fraction is as follows: ((6,000 m2/52,480 m2)*0.0183)+0.0156=0.0181.

The maximum EDWCs for Tier 1 simulations are shown in Table 9. The PWC output is shown in Appendix A. As expected, the highest EDWCs for terrestrial crop and non-agricultural uses is from the residential spot use expressed on an area calculated application rate of 40 lbs a.e./A in the Barton Springs Residential scenario. These EDWCs are expected to be very conservative due to scaling the spot treatment rate to a field application rate on lb a.e./A basis. More realistic EDWCs are expected from post and pre-emergent applications on terrestrial crops because of the defined use rates on field crops and the widespread use of glyphosate on terrestrial crops. The highest EDWCs (peak=206 µg/L) among the terrestrial crop scenarios is associated with an aerial application at an application rate of 8 lbs a.e./A in the MS cotton standard scenario.

EDWCs for glyphosate use on terrestrial crop and non-agricultural use sites are not expected to exceed 199 µg/L for the 1 in 10 year daily average peak concentration, 99 µg/L for the 1 in 10 year 90 day average concentration, 65 µg/L for the 1 in 10 year annual average concentration, and 50 µg/L for the 30 year annual average concentration.

Table 9. Tier I PWC Estimated Environmental Concentrations of Glyphosate in Surface Water from Terrestrial Crop and Non-Agriculture Use Sites

Application Method	Spray Drift Buffer (feet)	Single Application Rate (lb a.e./A)	EDWC				
			1 in 10 year				30 Year Annual Average
			Peak	Daily Average Peak	90 day Average	Annual Average	
			µg/L				
	Pre-emergent Application						
Aerial Spray	0	3.75[1]	176	171	89	58	45
	0	8	**206**	**199**	**99**	**65**	**50**
	500[3]	3.75[1]	123	121	74	52	29
	500[3]	8	125	123	80	57	32
Ground Spray	0	8	202	196	94	60	45
	Post-emergent Application						
Aerial Spray	0	3.75[1]	170	167	103	74	55
	0	8	179	175	104	76	56
	500[3]	3.75[1]	53	52	31	25	17
	500[3]	8	79	77.2	44	33	20
Ground Spray	0	8	175	196	98	71	51
	Residential Spot Treatment						
Ground Spray	0	40[2]	418	406	157	91	57

1-2 applications @ 7 day interval
2-Residential Spot Treatment- Application rates are expressed as lbs ae/A.
3-Spray Drift Buffer for CA and AR

Direct Applications to Aquatic Environments

Direct water applications of glyphosate are allowed to control of aquatic weeds. The EDWCs for direct water applications were calculated using the Pesticide Water Calculator (Version 1.52) and VVWM model.

Direct water applications were simulated in PWC for all available scenarios. This modeling approach considers the geographic variability in both aquatic degradation and reservoir flow rates. The modeling was conducted using single application rates of 3.75 and 8 lb a.e./A. The labels with direct aquatic uses do not specify a target concentration as the aquatic label application rates are expressed as lbs ae/A. Direct water applications were modeled in PWC by using the label application rate with a spray drift of application efficiency of 0 and drift fraction of 1.0. This modeling approach assumes that 100% of the pesticide application rate drifts into the reservoir. The glyphosate labels, however, recommend that no more than 50% of water area be treated to limit oxygen depletion from decaying aquatic vegetation.

The maximum EDWCs for direct water use simulations are shown in Table 10. The PWC output is shown in Appendix A. As expected, the highest EDWCs (peak=438 µg/L) for direct water applications are associated with the application of 8 lbs a.e./A in the MI asparagus and WAorchard scenarios. These EDWCs are expected to be conservative because they assume 100% of the reservoir area is treated with glyphosate. More realistic EDWCs require factoring in the label restriction for a maximum of 50% treated area in the waterbody for any direct water applications.

It is important to note the following label language regarding direct application to water: "*To make aquatic applications around and within ½ mile of active potable water intakes, the water intake must be turned off for a minimum period of 48 hours after the application. The water intake may be turned on prior to 48 hours if the glyphosate level in the intake water is below 0.7 parts per million as determined by laboratory analysis.*" This concentration is the USEPA maximum contaminate level (MCL) for glyphosate.

Based on label recommendations, EDWCs for direct water applications of glyphosate are not expected to exceed 700 µg/L in surface source drinking water. Because this concentration is greater than EDWCs from modeling, it represents the most conservative EDWCs from direct water applications.

Table 10. Predicted Glyphosate Concentrations from Direct Applications into the Index Reservoir

Single Application Rate (lb a.e./A)	Treated Area Assumption (100%)	EDWC				
		1 in 10 year				30 Year Annual Average
		Peak	Daily Average Peak	90 day Average	Annual Average	
		µg/L				
3.75	100	206	201	98	70	66
8	100	438	428	208	150	140
3.75	50	103	101	49	35	33
8	50	219	214	104	75	70

Aquatic Food Crop Uses (Rice and Cranberry)

EDWCs for glyphosate use on aquatic food crop use sites (rice and cranberry) were predicted using the PFAM model (version 2). Glyphosate is used in rice and wild rice as a pre-plant herbicide for control of red rice. The labels recommend a single glyphosate application of 0.375 to 1.5 lbs ae/A at 8 days prior to planting rice. For cranberries, glyphosate applications can be applied as a spot treatment around cranberry bogs or as a post-harvest application using a spot or wiper applications. The maximum specified application rate for cranberry is 3 lbs ae/A. Additionally, the label requires that only 10% of the bog is treated. For both the rice and cranberry uses, direct water applications of glyphosate are not allowed. Because the glyphosate labels for rice and cranberry restrict direct glyphosate applications to water, the Tier 1 rice model was not used.

PFAM modeling for rice was conducted using the drinking water standard scenarios for rice in CA and MO. These scenarios were designed to mimic a rice growing watershed draining to a community water system (CWS) intake. The cranberry scenarios for PFAM, however, have been designed for ecological exposure assessment. Therefore, the EDWCs for cranberry uses are expected to be highly conservative because they do not account for dilution and dissipation pathways between the treated field and the drinking water intake.

The maximum EDWCs for glyphosate use on rice and cranberry are shown in Table 11. The PFAM output is shown in Appendix B. The highest EDWCs are associated with the MO preflood no-hold scenario for glyphosate applications to rice. Although the cranberry modeling was conducted at a higher application rate than rice and represents edge of bog concentrations, the PFAM cranberry EDWCs are substantially lower than the PFAM rice EDWCs. A possible explanation is the difference in water management practices for rice and cranberry production.

EDWCs for glyphosate use on rice and cranberry are not expected to exceed 162 µg/L for the 1 in 10 year daily average peak concentration, 13.8 µg/L for the 1 in 10 year 90 day average concentration, 5.12 µg/L for the 1 in 10 year annual average concentration, and 3.6 µg/L for the 30 year annual average concentration.

Table 11. Predicted Glyphosate Concentrations from Applications to Rice and Cranberry Use Sites

Single Application Rate (lb a.e./A)	Crop	EDWC			
		1 in 10 year			30 Year Annual Average
		Daily Average	90 day Average	Annual Average	
		µg/L			
1.5	Rice	162	13.8	5.2	3.6
3.0	Cranberry	12.9	12.1	3.0	NR

1-NR=Not reported in PFAM output

Surface Water Monitoring Data

A search for available surface water monitoring data from 2014 to present for glyphosate and AMPA was conducted in the Water Quality Portal (accessed 4/18/2017), USGS NAWQA (accessed 1/4/2014), CADPR SWAMP (accessed 4/11/2017), CADPR SURF (accessed 4/11/2017), USDA PDP, and USGS-EPA Pilot Reservoir Monitoring Program, and the Washington Department Agriculture Salmonid Monitoring Program (accessed 6/12/2017). Additionally, open literature was also considered in this analysis.

The surface water monitoring data were analyzed on a site-year basis where each site-year combination is used to derive exposure endpoints. The surface water data were evaluated to ensure each observation had consistent concentration units (µg/L), defined detection limits, sampling station number, and sampling date. These data were evaluated using a computer program (Chemograph Generator 2.0.2) designed to derive sampling data on a site-year basis. Sampling data includes site identification, sample year, number of samples in a site-year, number of non-detects in a site-year, and relevant exposure concentrations, such as the daily peak, 90-day average, and annual average. Data points reported as the limit of quantification (LOQ) or limit of detection (LOD) were adjusted to 1/2 of LOD or LOQ, whichever is reported in the data. The daily peak concentrations represent the highest daily concentration for a site-year. Time weighted concentrations such as the 90-day average and annual average concentrations were derived using a forward "hot deck" stair-step imputation process from the first sampling date to the last sampling date in each site-year chemograph.

In order to adequately compare the monitoring data with model predictions of a 1 in 10 year concentration at a 90th percentile site, the monitoring data were analyzed using joint temporal-spatial distributional analysis. This analysis was completed using the site-year summary statistics from Chemograph Generator 2.0.2. All monitoring data were included in the analysis of daily peak concentrations. Monitoring data with 4 or more samples per year were used to calculate 90-day and annual average concentrations. The selected data for each appropriate endpoint (daily peak, 90 day-day average, and annual average) were log transformed to approximate a normal distribution. The assumption is that environmental monitoring data are commonly log-normally distributed. The average and standard deviation for each site were calculated using R commander (Version 3.03, 3/6/14**)**. These summary statistics were then used in the Student t approximation of a normal distribution to represent the 1 in 10 year value (90th percentile) based on lognormal average and standard deviation at each site. These transformed data were combined to determine the 90th percentile site. The calculated 1 in 10 year value at a 90th percentile site will be compared to the model predictions.

It is important to note that the monitoring data have not been corrected for bias due to low sampling frequency. However, glyphosate bias factors were generated from the single data set of USGS stream data with 2-day sampling frequency at sampling sites in MO for 2013 (Mahler et al., 2017). These bias factors provide some context on the extent of bias (underestimation) in the glyphosate occurrence concentrations. Bias factors were generated using the EXCEL program Chemograph Generator 2.0.2.

Glyphosate

Surface water monitoring data for glyphosate were derived from the Water Quality Portal, USGS NAWQA, CADEPA SWAMP, CADPR SURF, and Washington Department of Agriculture (WDA). Attributes of the general monitoring programs are shown in Table 12. The available monitoring data for glyphosate represent state and federal monitoring programs. The monitoring data represent a range of spatial and temporal distribution with the WQP, representing 20,466 site-years over 46 states to 1,638 site-years in single state (California). Most of the monitoring data represent glyphosate concentrations in dissolved or filtered surface water samples. For purposes of this analysis, dissolved glyphosate or glyphosate in filtered samples are equivalent.

NAWQA and USGS Stream monitoring data were the only monitoring programs to describe the major land use in the watershed of the sampling sites. The limits of detection (LOD) were generally low (<0.150 µg/L) for dissolved glyphosate concentrations. However, there were some monitoring data with high LODs (4-300 µg/L). These data were generally representative of older information (pre-2000).

Table 12. Attributes of Surface Water Monitoring Programs for Glyphosate

Monitoring Program Description	Years	Sites	States	Water Type[1]	Range of LOD µg/L
Water Quality Portal					
General Monitoring-Dissolved Water	18	1137	46	Dissolved	0-4 (0.02)[2]
General Monitoring-Total Water	23	442	3	Total	0-100 (10)
General Monitoring-Recoverable Water	5	35	6	Recoverable	5-10 (5)
USGS Streams					
2 Day Sample Frequency	1	5	1	Filtered	0.04
Weekly Sample Frequency – LC	1	27	9	Filtered	0.04
Weekly Sample Frequency– Elisia	1	100	12	Filtered	0.04
NAWQA					
All Sites	12	64	20	Filtered	0.02-.150 (0.1)
Agricultural Use Monitoring Sites	12	17	13	Filtered	0.02-.150 (0.1)
Urban Use Monitoring Sites	9	12	13	Filtered	0.02-.150 (0.1)
Mixed Use Monitoring Sites	9	17	15	Filtered	0.02-.150 (0.02)
Other Use Monitoring Sites	9	18	7	Filtered	0.02-.150 (0.02)
CA SWAMP					
CA Monitoring Sites	9	182	1	Filtered	1-300 (5)
CA SURF					
CA Monitoring Sites	16	291	1	Filtered	0.02-400 (5)
WDA					
Salmonid Monitoring Program	1	14	1	Total	0.008

1-Water Handling: Filtered is residues in filtered waters; Total is total residues detected in unfiltered sample; and Extractable is extracted residues from water sample.
2-Represents reported range of LOD or LOQ with (median)

Descriptive statistics for glyphosate occurrence in surface water are shown in Table 13. The median detection frequency ranged from 0 to 100%. A median detection frequency of 0% illustrates that 50% of the site-years had no glyphosate detections. In contrast, a median detection frequency of 100% illustrates that 50% of the site-years had glyphosate detections in every sample. This interpretation illustrates that glyphosate is commonly detected in surface waters. Although the ability to correlate detection frequency to land use is limited to the monitoring data from NAWQA, the highest median detection frequency (72.1%) was found in watersheds with undefined land use (i.e., mixed or other).

The highest glyphosate concentration in the monitoring data (257 µg/L) is from a Goshen Ditch sampling station (558GSDSP6) in the CA SURF database. This monitoring station is a sampling site in the irrigated lands monitoring program. Similar glyphosate concentrations (180 to 200 µg/L) were detected in the Drain 11@ Waisal Slough (53XXXD11) and Drain 14@ Lone Tree

Creek (544XXXD14) in CA. The highest concentration of glyphosate in the WQP monitoring program is 200 µg/L from a tributary in the Deep Hollow Lake watershed (USG 0728711610) near Sidon, MS. (https://archive.usgs.gov/archive /sites/ms.water.usgs.gov /projects/MDMSEA/index.html). The watershed of the tributary is comprised of 42.1 acres of soybean and cotton fields in conservation tillage and winter cover crops for Best Management Practices. The sampling site at the entrance of the tributary had a culvert with a weir. Similar concentrations of glyphosate (156 µg/L) also were observed in another tributary of the Deep Hollow Lake watershed (USGS-0728711620). The watershed of this tributary is comprised of 25.4 acres of soybean and cotton fields in conservation tillage. Although there are high glyphosate detections in surface water monitoring programs, the aforementioned sampling sites are not expected to be representative of drinking water intake locations.

Table 13. Maximum EDWCs for Glyphosate from Surface Water Monitoring Programs

Monitoring Program	Median Detection Frequency (%)	Peak	90-Day Average[1]	TW Annual Average[1]
		µg/L		
Water Quality Portal[2]				
Dissolved	50	200	87.4	57.8
Total	0	24.4	3.0	5.3
Recoverable	0	<LOD	<LOD	<LOD
USGS Streams				
2 Day Sample Frequency-Filtered	38.5	16.5	1.2	1.3
Weekly Sample Frequency – LC -Filtered	100	11.0	3.5	3.3
Weekly Sample Frequency– Elisia-Filtered	41.7	27.8	3.7	2.8
NAWQA[2]				
All Sites	61.5	73	31.3	6.1
Agricultural Use Monitoring Sites	56.5	73	31.3	4.0
Urban Use Monitoring Sites	38.9	5.9	1.6	0.9
Mixed Use Monitoring Sites	72.1	3.1	0.9	0.6
Other Use Monitoring Sites	72.1	38	7.3	6.1
CA SWAMP				
CA Monitoring Sites	0	200	106	59.7
CA SURF				
CA Monitoring Sites	0	257	106	59.7
WDA				
Salmonid Monitoring Program	100	1.5	NC[3]	NC

1-Represents site-years with 4 or more samples per year
2- Represent monitoring programs with monitoring sites capable of supporting a surface source community water system. Monitoring sites with dissolved glyphosate data and watershed areas greater or equal to 0.04 km2 are assumed to be capable of supporting a CWS. A watershed area of 0.04 km^2 represents a lower bound watershed area for a surface source drinking water.
3-Not calculated because there are only 2 samples per site-year.

Distributional analysis was conducted to provide a probabilistic estimate of the 1 in 10 glyphosate concentration at a 90th percentile use site from the monitoring data. Site-year descriptive statistics for non-bias factor adjusted monitoring data were used to estimate the 1 in 10 year glyphosate concentration at 90th percentile site. Table 14 shows the 1 in 10 year concentrations for dissolved glyphosate at a 90th percentile for monitoring sites with dissolved glyphosate concentrations data and watershed areas greater or equal to 0.04 km^2 from the WQP and NAWQA monitoring programs. These monitoring sites were selected in distributional analysis because their watersheds are comparable to or greater than a lower bound watershed area (0.04 km^2) for an actual surface source CWS. More importantly, the WQP and NAWQA monitoring data were used because most of the data are not routinely representative of non-drinking water source waters such as irrigation ditches, canals, and shallow streams. An assumption in determining the watershed area for individual monitoring sites is the linkage of monitoring site location to the National Hydrologic Database (NHD).

The distributional analysis indicates that daily maximum peak EDWCs from PWC modeling are comparable to the 95th site percentile in the NAWQA monitoring program and 99th site percentile in the WQP monitoring data. Additionally, the median (typical) EDWCs from PWC were generally comparable or higher than the 1 in 10 year glyphosate concentrations for the 90th percentile sites in the monitoring data. These data illustrate that the EDWCs from PWC modeling are reasonably conservative when compared to non-bias factor adjusted monitoring data.

Table 14. Comparison of glyphosate concentrations from non-bias factor adjusted surface water monitoring programs and EDWCs from PWC for Terrestrial Crop and Non-agricultural Uses

Monitoring Program	Exposure Endpoint	1 in 10 year Glyphosate Monitoring Concentration (µg/L)			1 in 10 year Glyphosate PWC Concentrations[1] (µg/L)		
		Site Percentile			Minimum	Median	Maximum
		90th	95th	99th			
WQP	Daily Peak	13.98	35.60	205.57	35.1	51.9	171
	90-Day Average	13.47	49.22	559.25	15.9	26.4	88.5
	Annual Average	2.82	6.01	24.90	5.4	14.7	45.2
NAWQA	Daily Peak	35.09	93.50	587.74	35.1	51.9	171
	90-Day Average	2.94	4.00	10.10	15.9	26.4	88.5
	Annual Average	0.98	1.46	3.10	5.4	14.7	45.2

1- PWC concentrations for two pre-emergent applications of 3.75 lb ae/A.

The bias factors for glyphosate show considerable variation (CV=64 to 129%) among the monitoring sites in the USGS stream monitoring program (Mahler et al., 2017) (Table 15). Although these bias factors were not factored into the distribution analysis, the bias factor adjustment of the monitoring data will inflate the differences between monitoring data and PWC modeling. The median sample frequency is 14 days in the WQP and NAWQA monitoring programs. These data suggest that bias factors for glyphosate could be 24.5 to 39.1X for daily peak glyphosate concentrations and 3.7X for 90-day average concentrations. Mahler et al., 2017 found that glyphosate concentrations from 2-day samples could be approximately 8 times higher than glyphosate concentrations from weekly samples. Using similar data, the BFs for 2-day peak concentrations could be underestimated from 12 to 19.5X lower for a 7-day sampling interval.

Although these data provide quantification on the potential extent of underestimation in glyphosate occurrence concentrations, there are insufficient data (≥100 site-years) to allow for spatial and temporal extrapolation of bias factors (US EPA, 2012).

Table 15. Bias factors estimated from USGS Small Stream Monitoring Data

Endpoint	Sampling Interval			
	7-day	14-day	21-day	28-day
Daily Peak	19.5±27.6	39.1±47.1	43.5±61	54.2±70.7
4-day average	12±15.4	24.5±25.7	25.9±38.8	33±37.3
90-day average	2.5±1.6	3.7±2.4	3.4±2.0	4.2±2.4

AMPA

Surface water monitoring data for AMPA were derived from the USGS NAWQA, CADEPA SWAMP, USGS Streams, and WDA. Attributes of the general monitoring programs are shown in Table 16. The available monitoring data for AMPA represent state and federal monitoring programs. The AMPA monitoring data represent a range of spatial and temporal dispersion with the WQP representing 846 site-years over 20 states to 180 site-years in a single state (California). Most of the monitoring data represent AMPA concentrations in dissolved or filtered surface water samples. NAWQA monitoring data was the only monitoring program to describe the major land use in the watershed of the sampling sites. The limits of detection (LOD) were generally low (<0.31 µg/L) for dissolved glyphosate concentrations. However, the CA SWAMP monitoring program had higher LODs (10 µg/L).

Table 16. Attributes of Surface Water Monitoring Programs for AMPA

Monitoring Program Description	Years	Sites	States	Water Type[1]	Range of LOD µg/L
USGS Streams					
Weekly Sample Frequency – LC	1	27	10	Filtered	0.02
NAWQA					
All Sites	13	65	20	Filtered	0.02-0.31 (0.1)
Agricultural Use Monitoring Sites	12	18	13	Filtered	0.02-0.31 (0.1)
Urban Use Monitoring Sites	9	7	7	Filtered	0.02-0.31 (0.1)
Mixed Use Monitoring Sites	10	18	15	Filtered	0.02-0.31 (0.1)
Other Use Monitoring Sites	9	19	6	Filtered	0.02-0.1 (0.1)
CA SWAMP					
CA Monitoring Sites	5	36	1	Filtered	10
WDA					
Salmonid Monitoring Program	1	14	1	Total	0.008

1-Water Handling: Filtered= Water samples filtered prior to chemical analysis; Total= Total residues detected in unfiltered sample; and Extractable-Extracted residues from water sample.
2-Zero was used as the LOD and LOQ

Descriptive statistics for AMPA occurrence in surface water are shown in Table 17. The median detection frequency for AMPA ranges from 83.4 to 100% with the exception of the CA SWAMP monitoring program. The high detection frequencies of AMPA were expected because it is more mobile and persistent than glyphosate. The highest median detection frequency (72.1%) was found in watersheds with undefined land use (i.e., mixed or other).

The highest AMPA concentration in the monitoring data (28 µg/L) is from a USGS sampling site on Bogue Phalia near Leland, MS (USGS 7288650). This site has a watershed area of

484 mile^2 with the major crop production in soybeans https://waterdata.usgs.gov/nwis/inventory/?site_no=07288650&agency_cd=USGS and Coupe et al, 2011).

Table 17. Maximum EDWCs for AMPA from Surface Water Monitoring Programs

Monitoring Program	Median Detection Frequency (%)	Peak	90-Day Average[1]	TW Annual Average[1]
		µg/L		
USGS Streams				
Weekly Sample Frequency – LC -Filtered	100	5.2	2.8	3.0
NAWQA				
All Sites	100	28	7.0	4.3
Agricultural Use Monitoring Sites	95.23	8.7	5.1	3.1
Urban Use Monitoring Sites	83.4	3.5	1.3	0.7
Mixed Use Monitoring Sites	100	4.4	1.5	1.0
Other Use Monitoring Sites	100	9.7	3.9	3.1
CA SWAMP				
CA Monitoring Sites	0	4.4	0.9	0.5
WDA				
Salmonid Monitoring Program	100	0.38	NC[2]	NC

1-Represents site-years with 4 or more samples per year
2-Not calculated because there are only 2 samples per site-year

Groundwater Modeling

Ground water concentrations are estimated using the PRZM-GW model in the Pesticide Water Calculator (Version 1.52). PRZM-GW uses leaching algorithms (tipping bucket) from the PRZM model to predict pesticide leaching into shallow groundwater on vulnerable sites (*i.e.*, sandy soils), with the shallow well located directly adjacent to the treated area. The model construct assumes that the aerobic soil metabolism rate decreases linearly to zero at a 1 meter depth in the surface soil, and that abiotic hydrolysis is the only degradation process deeper than 1 meter. Lateral flow is not considered in the modeling. Currently, six regionally-specific scenarios of vulnerable soils are used in the groundwater modeling. Detailed description, documentation, and direct links for running these models can be found in: https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/about-water-exposure-models-used-pesticide.

A modeling strategy using PWC to estimate EDWCs for glyphosate using all crop and non-crop scenarios was developed. The application rate used in modeling was 40 lbs ae/A. Although the application rate of 40 lbs ae/A is calculated from a residential spot treatment application rate, it is expected to provide the most conservative EDWCs in ground source drinking water. The application date for the residential spot treatment of glyphosate was set to be May 1st because there is no clear emergence date for turf and residential areas.

The Tier 1 simulation indicates that glyphosate is not expected to breakthrough into groundwater during a 100-year simulation. The PRZM-GW output is shown in Appendix C.

Glyphosate Groundwater Monitoring Data

Ground water monitoring data for glyphosate were derived from the Water Quality Portal and USGS NAWQA. Attributes of the general monitoring programs are shown in **Table 17**. The available monitoring data for glyphosate represent state and federal monitoring programs. The glyphosate monitoring data represent a range of spatial and temporal dispersion with the WQP representing 20,349 site-years over 30 states. Most of the monitoring data represent glyphosate concentrations in dissolved or filtered surface water samples. For purposes of this analysis, dissolved glyphosate or glyphosate in filtered samples are assumed to be equivalent. NAWQA monitoring data was the only monitoring program to describe the major land use in the watershed of the sampling sites. The limits of detection (LOD) were generally low (<0.6) µg/L) for dissolved glyphosate concentrations. However, LODs were higher (3 to 5 µg/L) for monitoring data for total and recoverable glyphosate fractions in groundwater.

Table 17. Attributes of Groundwater Monitoring Programs for Glyphosate

Monitoring Program Description	Years	Sites	States	Water Type[1]	Range of LOD µg/L
Water Quality Portal					
General Monitoring-Dissolved Water	17	1197	30	Dissolved	0.02-0.6 (0.02)
General Monitoring-Total Water	3	22	1	Total	3.0-3.1
General Monitoring-Recoverable Water	2	51	2	Recoverable	5.0
NAWQA					
All Sites	12	745	30	Filtered	0.02-0.15 (0.1)
Agricultural Use Monitoring Sites	9	294	18	Filtered	0.02-0.15 (0.1)
Urban Use Monitoring Sites	10	44	19	Filtered	0.02-0.15 (0.1)
Mixed Use Monitoring Sites	3	24	7	Filtered	0.02-.1 (0.1)
Other Use Monitoring Sites	9	23	13	Filtered	0.02-.1 (0.02)

1-Water Handling: Filtered is residues in filtered waters; Total is total residues detected in unfiltered sample; and Extractable is extracted residues from water sample.
2-Represents reported range of LOD or LOQ with (median)

Descriptive statistics for glyphosate occurrence in groundwater are shown in Table 18. The median detection frequency of glyphosate was < 0.1%. These data indicate that glyphosate is not typically detected in groundwater. Most of the monitoring sites had low peak concentrations (0.1-2.2 µg/L).

The highest glyphosate concentration (285 µg/L) in groundwater is from a subsurface drain in Hamilton County, IA (USGS 423232093351801), which is not representative of a drinking water intake location.

Table 18. Maximum EDWCs for Glyphosate from Groundwater Monitoring Programs

Monitoring Program	Median Detection Frequency (%)	Peak	TW Annual Average[1]
		µg/L	
Water Quality Portal			
Dissolved	0	280	22.77
Total	0	<LOD	<LOD
Recoverable	0	<LOD	<LOD
NAWQA			
All Sites	0	285	20.6
Agricultural Use Monitoring Sites	0	1.2	NE
Urban Use Monitoring Sites	0	2.2	0.3
Mixed Use Monitoring Sites	0	0.1	NE
Other Use Monitoring Sites	0	285	14

1-Represents sites with 4 or more samples per year

AMPA Groundwater Monitoring Data

Groundwater monitoring data for AMPA were derived from USGS NAWQA. Attributes of the general monitoring programs for AMPA are shown in Table 19. The available monitoring data for AMPA represent state and federal monitoring programs. The AMPA monitoring data represent a range of spatial and temporal distribution with the WQP representing 1164 site-years over 30 states. The monitoring data represent AMPA concentrations in filtered surface water samples. The limits of detection (LOD) were generally low (<0.31) µg/L) for dissolved AMPA concentrations.

Table 19.Attributes of Groundwater Monitoring Programs for AMPA

Monitoring Program Description	Years	Sites	States	Water Type[1]	Range of LOD µg/L
NAWQA					
All Sites	12	97	30	Filtered	0.02-.31 (0.1)
Agricultural Use Monitoring Sites	9	69	18	Filtered	0.02-.31 (0.1)
Urban Use Monitoring Sites	10	44	19	Filtered	0.02-.31 (0.1)
Mixed Use Monitoring Sites	4	18	8	Filtered	0.1
Other Use Monitoring Sites	10	24	14	Filtered	0.02-0.31 (0.02)

1-Water Handling: Filtered= Water samples filtered prior to chemical analysis; Total= Total residues detected in unfiltered sample; and Extractable-Extracted residues from water sample.
2-Zero was used as the LOD and LOQ

Descriptive statistics for AMPA occurrence in ground water are shown in Table 20. The median detection frequency of glyphosate was 0%. These data indicate that AMPA is not typically detected in groundwater. Peak AMPA concentrations in groundwater range from 1.4- 397 µg/L. The highest AMPA concentration (397 µg/L) in groundwater is from a site in IA (Coupe et al., 2011). Although there are high AMPA detections in groundwater monitoring programs, the aforementioned sampling site is not representative of a drinking water intake location.

Table 20. Maximum EDWCs for AMPA from Groundwater Monitoring Programs

Monitoring Program	Median Detection Frequency (%)	Peak	TW Annual Average[1]
		µg/L	
NAWQA			
All Sites	0	397	17
Agricultural Use Monitoring Sites	0	1.4	0.2
Urban Use Monitoring Sites	0	37	5.3
Mixed Use Monitoring Sites	0	<LOD	<LOD
Other Use Monitoring Sites	0	397	17

<u>Open Literature</u>

The USGS conducted studies to assess glyphosate and AMPA concentrations in surface water as well as wastewater effluent from treatment plants.

A total of 154 water samples were collected by the U.S. Geological Survey during a 2002 study in nine Midwestern States (Illinois, Indiana, Iowa, Kansas, Minnesota, Missouri, Nebraska, Ohio, and Wisconsin) (Scribner *et al*., 2003 and Lee *et al*., 2001), where glyphosate is extensively used on corn. Glyphosate was detected in 36 percent of the samples, while its metabolite AMPA was detected in 69 percent of the samples. The highest measured concentration of glyphosate was 8.7 µg/L. The highest AMPA concentration was 3.6 µg/L.

Treated effluent samples were collected from 10 wastewater treatment plants (WWTPs) in Arizona, Colorado, Georgia, Iowa, Minnesota, Nevada, New Jersey, New York, and South Dakota to study the occurrence of glyphosate and AMPA (Kolpin *et al*., 2006). Stream samples were collected upstream and downstream of the 10 WWTPs. Two reference streams were also sampled. The results document the apparent contribution of WWTP effluent to stream concentrations of glyphosate and AMPA, with roughly a two-fold increase in their frequencies of detection between stream samples collected upstream and those collected downstream of the WWTPs. Thus, urban use of glyphosate contributes to glyphosate and AMPA concentrations in streams in the United States.

Glyphosate or its degradate AMPA were commonly detected in the stream and WWTP effluent samples, being present in 67.5% of the 40 samples collected. Concentrations were generally low, although nine detections of AMPA (maximum concentration=3.9 µg/L) and three detections of glyphosate (maximum concentration=2.2 µg/L) exceeded 1 µg/L. AMPA was detected much more frequently (67.5%) than glyphosate (17.5%).

Both AMPA and glyphosate had the greatest frequency of detection in the WWTP effluent samples, with roughly a two-fold increase in the frequency of detection for both AMPA and glyphosate between stream samples located upstream and those located downstream of the WWTPs.

It should be noted, however, that AMPA can also be derived from the degradation of phosphonic acids (such as EDTMP and DTPMP) in detergents. Thus, part of the AMPA detections from this study could be potentially derived from a detergent source. Other components of detergents, such as 4-nonylphenol diethoxylate and 4-nonylphenol monoethoxylate were also measured in the samples collected for this study. However, AMPA was always present in samples that had detections of glyphosate, which suggests that at least part of the AMPA concentrations in this study were derived from the degradation of glyphosate.

From 2003 to 2008, Coupe *et al*, 2011 conducted surface water monitoring of glyphosate and AMPA in agricultural surface waters in MS, IA, IN, and France. This monitoring was targeted to watersheds with a high percentage of agricultural crops (68 to ~100% basin in agriculture). The major crops in the watershed were soybeans, corn, cotton, rice, and grapes (France only). For the larger surface water bodies in the United States, samples were taken bimonthly during most of the year with weekly sampling during the growing season from April to August. Additionally, some samples were collected during selected storm events. Monitoring in France and some smaller basins in the U.S. were taken using an automatic sampler. Filtered water samples were analyzed using HPLC/MS. The reporting levels were 0.02 µg/L for samples from the United States and 0.1 µg/L for the French samples. Detection frequencies of glyphosate and AMPA ranged from 59 to 100% and 92 to 100%, respectively. The maximum concentration of glyphosate was 430 µg/L (median 380 µg/L) at an overland flow site in the Sugar Creek, IN monitoring site from May 19-21, 2004. The maximum concentration of AMPA was 29 µg/L (median 26 µg/L) at the overland flow site.

Mahler, et al. 2017 conducted a Midwest Stream Quality Assessment (MSQA) on 100 sites of shallow streams (<1 meter deep) across the U.S. Midwestern Corn Belt. The land use within the sample sites was 54% row crops, 11% pasture and hay, 8% urban land use, and the remainder in woodlands and grasslands. The highest detections of glyphosate (63%) were from urban watersheds. The maximum glyphosate concentration from weekly samples was 27.8 µg/L (median 1.68 µg/L). The maximum glyphosate concentration from 2-day sampling intervals was 35.2 µg/L.

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Coupe, R.H., S.J. P.D. Capel, and C.Gregoire. 2012. Fate and transport of glyphosate and aminomethylphosphonic acid in surface waters of agricultural basins. Pesticide Management Science. Volume 68, Pages 16-30.

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APPENDIX A. Terrestrial Crop and Non-Agricultural Terrestrial Use Sites

Variable Volume Water Model, Version 1.02000000000000

****
Performed on: 5/ 4/2017 at 16:28

Peak 1-in-10.0 = 206. ppb
Chronic 1-in-10.0 = 42.3 ppb
Simulation Avg = 25.1 ppb
4-d avg 1-in-10.0 = 183. ppb
21-d avg 1-in-10.0 = 134. ppb
60-d avg 1-in-10.0 = 101. ppb
90-d avg 1-in-10.0 = 87.7 ppb
1-d avg 1-in-10.0 = 199. ppb
Benthic Pore Water Peak 1-in-10.0 = 80.2 ppb
Benthic Pore Water 21-d avg 1-in-10.0 = 79.6 ppb
Benthic Conversion Factor = 157. -Pore water (ug/L) to (total mass, ug)/(dry sed mass,kg)
Benthic Mass Fraction in Pore Water = 0.235E-02

YEAR	Peak	4-day	21-day	60-day	90-day	Yearly Avg	Benthic Pk	Benthic 21-day
1	4.37E+01	3.74E+01	2.56E+01	2.04E+01	1.89E+01	9.72E+00	1.65E+01	1.63E+01
2	1.57E+02	1.44E+02	1.08E+02	7.77E+01	6.70E+01	3.08E+01	6.32E+01	6.26E+01
3	5.52E+01	4.88E+01	3.62E+01	3.29E+01	2.98E+01	1.81E+01	2.89E+01	2.86E+01
4	1.42E+02	1.29E+02	1.07E+02	8.14E+01	7.04E+01	3.33E+01	6.61E+01	6.55E+01
5	5.61E+01	4.98E+01	3.57E+01	2.48E+01	2.17E+01	1.36E+01	2.09E+01	2.09E+01
6	7.00E+01	6.33E+01	5.26E+01	4.43E+01	3.92E+01	2.03E+01	3.84E+01	3.80E+01
7	8.27E+01	7.52E+01	5.86E+01	4.63E+01	4.15E+01	2.33E+01	4.21E+01	4.18E+01
8	1.19E+02	1.07E+02	8.36E+01	6.64E+01	5.91E+01	2.99E+01	5.49E+01	5.44E+01
9	1.35E+02	1.21E+02	8.81E+01	6.37E+01	5.58E+01	2.90E+01	5.53E+01	5.49E+01
10	5.44E+01	4.80E+01	3.69E+01	3.30E+01	2.99E+01	1.72E+01	2.90E+01	2.87E+01
11	9.90E+01	8.85E+01	7.27E+01	5.78E+01	5.06E+01	2.57E+01	4.99E+01	4.95E+01
12	5.91E+01	5.37E+01	4.57E+01	3.55E+01	3.30E+01	1.88E+01	3.37E+01	3.34E+01
13	1.42E+02	1.31E+02	9.45E+01	7.02E+01	6.16E+01	3.00E+01	5.93E+01	5.86E+01
14	1.45E+02	1.29E+02	9.47E+01	6.76E+01	5.94E+01	3.09E+01	5.70E+01	5.67E+01
15	7.13E+01	6.58E+01	5.66E+01	4.66E+01	4.33E+01	2.46E+01	4.36E+01	4.31E+01
16	6.18E+01	5.66E+01	4.63E+01	3.81E+01	3.43E+01	2.03E+01	3.59E+01	3.55E+01
17	1.69E+02	1.49E+02	1.08E+02	7.98E+01	6.91E+01	3.29E+01	6.44E+01	6.39E+01
18	6.85E+01	6.47E+01	5.63E+01	4.65E+01	4.35E+01	2.44E+01	4.45E+01	4.41E+01
19	2.10E+02	1.87E+02	1.37E+02	1.03E+02	8.96E+01	4.33E+01	8.17E+01	8.11E+01
20	2.18E+02	2.02E+02	1.50E+02	1.06E+02	9.14E+01	4.53E+01	8.71E+01	8.64E+01
21	6.68E+01	6.03E+01	4.49E+01	3.64E+01	3.58E+01	2.27E+01	3.62E+01	3.57E+01
22	1.10E+02	9.78E+01	7.36E+01	5.26E+01	4.68E+01	2.48E+01	4.59E+01	4.55E+01
23	2.37E+02	2.19E+02	1.70E+02	1.18E+02	1.02E+02	4.82E+01	9.23E+01	9.15E+01
24	8.13E+01	7.27E+01	5.64E+01	5.02E+01	4.58E+01	2.71E+01	4.47E+01	4.45E+01
25	5.30E+01	4.68E+01	3.65E+01	2.70E+01	2.35E+01	1.37E+01	2.18E+01	2.16E+01
26	4.83E+01	4.27E+01	3.64E+01	2.83E+01	2.51E+01	1.44E+01	2.64E+01	2.61E+01
27	4.97E+01	4.44E+01	2.94E+01	2.61E+01	2.47E+01	1.40E+01	2.29E+01	2.27E+01
28	1.37E+02	1.21E+02	8.15E+01	6.29E+01	5.44E+01	2.57E+01	5.05E+01	5.01E+01
29	7.31E+01	6.74E+01	5.46E+01	4.39E+01	3.99E+01	2.27E+01	4.00E+01	3.97E+01
30	5.61E+01	5.17E+01	4.16E+01	3.62E+01	3.39E+01	1.91E+01	3.41E+01	3.36E+01

****
Effective compartment halflives averaged over simulation duration:

washout halflife (days) = 48.1966144835075
water col metab halflife (days) = 560.436578988054
zero hydrolysis 0
zero photolysis 0
volatile halflife (days) = 15373857038.0289
total water col halflife (days) = 44.3800074522735

zero burial 0
benthic metab halflife (days) = 306.313158027487
zero benthic hydrolysis 0
total benthic halflife (days) = 306.313158027487
****
Fractional Contribution of Transport Processes to Waterbody & Total Mass (kg):

Due to Runoff = 0.1158 119.1

Due to Erosion = 0.6985 718.2
Due to Drift = 0.1857 190.9
****
Flow in/out Characteristics of Waterbody:
Average Daily Runoff Into Waterbody (m3/s) = 2.398982023910145E-002
Baseflow Into Waterbody (m3/s) = 0.000000000000000E+000
Average Daily Flow Out of Waterbody (m3/s) = 2.398982023910173E-002
****
Inputs:
3925. = oc partitioning coefficient
381.0 = water column half Life
25.00 = reference temp for water column degradation
208.2 = benthic Half Life
25.00 = Reference temp for benthic degradation
2.000 = Q ten value
0.000 = photolysis half life
0.000 = reference latitude for photolysis study
0.000 = hydrolysis half life
169.1 = molecular wt
0.9750E-09 = vapor pressure
0.1200E+05 = solubility
0.1728E+07 = field area
0.5260E+05 = water body area
2.740 = initial depth
2.740 = maximum depth
3 1=vvwm, 2=usepa pond, 3 = usepa reservoir, 4 = const vol no flow, 5 = const vol w/flow
F T = burial, else no burial
0.1000E-07 = mass transfer coefficient
0.5000 = PRBEN
0.5000E-01 = benthic compartment depth
0.5000 = benthic porosity
1.350 = benthic bulk density
0.4000E-01 = OC frcation in benthic sediment
5.000 = DOC in benthic compartment
0.6000E-02 = benthic biomass
1.190 = DFAC
30.00 = SS
0.5000E-02 = chlorophyll
0.4000E-01 = OC frcation in water column SS
5.000 = DOC in water column
0.4000 = biomass in water column
FRACTION AREA CROPPED = 1.00000000000000

Direct Applications to Aquatic Environments

<u>MIasparagusSTD scenario</u>

Variable Volume Water Model, Version 1.02000000000000

****
Performed on: 5/ 4/2017 at 16:37

Peak 1-in-10.0 = 577. ppb
Chronic 1-in-10.0 = 168. ppb
Simulation Avg = 152. ppb
4-d avg 1-in-10.0 = 507. ppb
21-d avg 1-in-10.0 = 349. ppb
60-d avg 1-in-10.0 = 254. ppb
90-d avg 1-in-10.0 = 229. ppb
1-d avg 1-in-10.0 = 558. ppb
Benthic Pore Water Peak 1-in-10.0 = 193. ppb
Benthic Pore Water 21-d avg 1-in-10.0 = 192. ppb
Benthic Conversion Factor = 157. -Pore water (ug/L) to (total mass, ug)/(dry sed mass,kg)
Benthic Mass Fraction in Pore Water = 0.235E-02

YEAR Peak 4-day 21-day 60-day 90-day Yearly Avg Benthic Pk Benthic 21-day

1	4.44E+02	3.73E+02	2.17E+02	1.26E+02	1.05E+02	4.65E+01	6.65E+01	6.63E+01
2	4.90E+02	4.19E+02	2.62E+02	1.69E+02	1.47E+02	8.75E+01	1.09E+02	1.08E+02
3	5.19E+02	4.48E+02	2.91E+02	1.98E+02	1.75E+02	1.15E+02	1.38E+02	1.37E+02
4	5.37E+02	4.66E+02	3.09E+02	2.14E+02	1.91E+02	1.30E+02	1.54E+02	1.53E+02
5	5.49E+02	4.78E+02	3.20E+02	2.25E+02	2.01E+02	1.41E+02	1.65E+02	1.64E+02
6	5.56E+02	4.86E+02	3.29E+02	2.34E+02	2.10E+02	1.48E+02	1.74E+02	1.73E+02
7	5.62E+02	4.91E+02	3.34E+02	2.39E+02	2.15E+02	1.53E+02	1.79E+02	1.78E+02
8	5.65E+02	4.94E+02	3.37E+02	2.42E+02	2.18E+02	1.57E+02	1.82E+02	1.81E+02
9	5.68E+02	4.97E+02	3.40E+02	2.45E+02	2.21E+02	1.59E+02	1.85E+02	1.84E+02
10	5.71E+02	5.00E+02	3.42E+02	2.46E+02	2.22E+02	1.60E+02	1.86E+02	1.85E+02
11	5.70E+02	5.00E+02	3.42E+02	2.47E+02	2.23E+02	1.61E+02	1.87E+02	1.86E+02
12	5.72E+02	5.01E+02	3.43E+02	2.48E+02	2.24E+02	1.62E+02	1.87E+02	1.86E+02
13	5.74E+02	5.03E+02	3.45E+02	2.50E+02	2.26E+02	1.64E+02	1.90E+02	1.90E+02
14	5.73E+02	5.02E+02	3.45E+02	2.50E+02	2.26E+02	1.64E+02	1.90E+02	1.89E+02
15	5.76E+02	5.05E+02	3.47E+02	2.52E+02	2.27E+02	1.65E+02	1.91E+02	1.90E+02
16	5.72E+02	5.01E+02	3.43E+02	2.48E+02	2.24E+02	1.63E+02	1.88E+02	1.87E+02
17	5.75E+02	5.04E+02	3.45E+02	2.50E+02	2.25E+02	1.64E+02	1.89E+02	1.88E+02
18	5.75E+02	5.04E+02	3.46E+02	2.51E+02	2.26E+02	1.65E+02	1.90E+02	1.89E+02
19	5.76E+02	5.05E+02	3.48E+02	2.53E+02	2.29E+02	1.67E+02	1.92E+02	1.92E+02
20	5.78E+02	5.07E+02	3.50E+02	2.55E+02	2.30E+02	1.68E+02	1.94E+02	1.93E+02
21	5.78E+02	5.07E+02	3.49E+02	2.54E+02	2.29E+02	1.68E+02	1.94E+02	1.93E+02
22	5.79E+02	5.07E+02	3.49E+02	2.54E+02	2.30E+02	1.68E+02	1.93E+02	1.92E+02
23	5.76E+02	5.05E+02	3.47E+02	2.53E+02	2.28E+02	1.65E+02	1.93E+02	1.92E+02
24	5.72E+02	5.02E+02	3.44E+02	2.49E+02	2.25E+02	1.63E+02	1.89E+02	1.88E+02
25	5.72E+02	5.00E+02	3.42E+02	2.47E+02	2.23E+02	1.62E+02	1.86E+02	1.86E+02
26	5.72E+02	5.00E+02	3.43E+02	2.47E+02	2.23E+02	1.62E+02	1.87E+02	1.86E+02
27	5.71E+02	5.00E+02	3.42E+02	2.45E+02	2.20E+02	1.59E+02	1.85E+02	1.84E+02
28	5.68E+02	4.97E+02	3.39E+02	2.43E+02	2.18E+02	1.56E+02	1.83E+02	1.82E+02
29	5.66E+02	4.95E+02	3.37E+02	2.42E+02	2.18E+02	1.57E+02	1.82E+02	1.81E+02
30	5.69E+02	4.98E+02	3.40E+02	2.45E+02	2.21E+02	1.60E+02	1.85E+02	1.84E+02

****

Effective compartment halflives averaged over simulation duration:

zero washout 0
water col metab halflife (days) = 972.604153253890
zero hydrolysis 0
zero photolysis 0
volatile halflife (days) = 10193410081.3359
total water col halflife (days) = 972.604060452880

zero burial 0
benthic metab halflife (days) = 531.588159773203
zero benthic hydrolysis 0
total benthic halflife (days) = 531.588159773203
****

Fractional Contribution of Transport Processes to Waterbody & Total Mass (kg):

Due to Runoff = 0.0000 0.000
Due to Erosion = 0.0000 0.000
Due to Drift = 1.0000 268.8
****

Flow in/out Characteristics of Waterbody:
Average Daily Runoff Into Waterbody (m3/s) = 5.349566875959242E-005
Baseflow Into Waterbody (m3/s) = 0.000000000000000E+000
Average Daily Flow Out of Waterbody (m3/s) = 5.349566875959118E-005
****

Inputs:
3925. = oc partitioning coefficient
381.0 = water column half Life
25.00 = reference temp for water column degradation
208.2 = benthic Half Life
25.00 = Reference temp for benthic degradation
2.000 = Q ten value
0.000 = photolysis half life
0.000 = reference latitude for photolysis study
0.000 = hydrolysis half life
169.1 = molecular wt
0.9750E-09 = vapor pressure
0.1200E+05 = solubility
0.1000E+06 = field area

0.1000E+05 = water body area
2.000 = initial depth
2.000 = maximum depth
2 1=vvwm, 2=usepa pond, 3 = usepa reservoir, 4 = const vol no flow, 5 = const vol w/flow
F T = burial, else no burial
0.1000E-07 = mass transfer coefficient
0.5000 = PRBEN
0.5000E-01 = benthic compartment depth
0.5000 = benthic porosity
1.350 = benthic bulk density
0.4000E-01 = OC frcation in benthic sediment
5.000 = DOC in benthic compartment
0.6000E-02 = benthic biomass
1.190 = DFAC
30.00 = SS
0.5000E-02 = chlorophyll
0.4000E-01 = OC frcation in water column SS
5.000 = DOC in water column
0.4000 = biomass in water column
FRACTION AREA CROPPED = 1.00000000000000

WAorchardsSTD scenario

Variable Volume Water Model, Version 1.02000000000000

****
Performed on: 5/ 4/2017 at 16:36

Peak 1-in-10.0 = 438. ppb
Chronic 1-in-10.0 = 150. ppb
Simulation Avg = 140. ppb
4-d avg 1-in-10.0 = 399. ppb
21-d avg 1-in-10.0 = 300. ppb
60-d avg 1-in-10.0 = 228. ppb
90-d avg 1-in-10.0 = 208. ppb
1-d avg 1-in-10.0 = 427. ppb
Benthic Pore Water Peak 1-in-10.0 = 173. ppb
Benthic Pore Water 21-d avg 1-in-10.0 = 173. ppb
Benthic Conversion Factor = 157. -Pore water (ug/L) to (total mass, ug)/(dry sed mass,kg)
Benthic Mass Fraction in Pore Water = 0.235E-02

YEAR	Peak	4-day	21-day	60-day	90-day	Yearly Avg	Benthic Pk	Benthic 21-day
1	3.24E+02	2.85E+02	1.87E+02	1.16E+02	9.84E+01	5.37E+01	6.32E+01	6.31E+01
2	3.65E+02	3.26E+02	2.28E+02	1.57E+02	1.38E+02	8.97E+01	1.03E+02	1.03E+02
3	3.93E+02	3.54E+02	2.55E+02	1.83E+02	1.65E+02	1.13E+02	1.29E+02	1.29E+02
4	4.09E+02	3.70E+02	2.71E+02	1.99E+02	1.81E+02	1.28E+02	1.45E+02	1.45E+02
5	4.24E+02	3.85E+02	2.86E+02	2.14E+02	1.95E+02	1.39E+02	1.59E+02	1.59E+02
6	4.29E+02	3.90E+02	2.91E+02	2.19E+02	2.00E+02	1.43E+02	1.64E+02	1.64E+02
7	4.29E+02	3.90E+02	2.91E+02	2.18E+02	2.00E+02	1.42E+02	1.64E+02	1.64E+02
8	4.27E+02	3.88E+02	2.90E+02	2.17E+02	1.98E+02	1.42E+02	1.62E+02	1.62E+02
9	4.32E+02	3.93E+02	2.95E+02	2.22E+02	2.03E+02	1.45E+02	1.68E+02	1.68E+02
10	4.33E+02	3.94E+02	2.95E+02	2.23E+02	2.04E+02	1.46E+02	1.68E+02	1.68E+02
11	4.32E+02	3.93E+02	2.95E+02	2.22E+02	2.03E+02	1.46E+02	1.68E+02	1.68E+02
12	4.34E+02	3.95E+02	2.96E+02	2.24E+02	2.05E+02	1.47E+02	1.69E+02	1.69E+02
13	4.35E+02	3.96E+02	2.97E+02	2.25E+02	2.05E+02	1.47E+02	1.70E+02	1.70E+02
14	4.33E+02	3.94E+02	2.95E+02	2.23E+02	2.04E+02	1.47E+02	1.68E+02	1.68E+02
15	4.33E+02	3.94E+02	2.96E+02	2.23E+02	2.04E+02	1.47E+02	1.69E+02	1.69E+02
16	4.34E+02	3.95E+02	2.97E+02	2.24E+02	2.05E+02	1.49E+02	1.70E+02	1.70E+02
17	4.38E+02	3.99E+02	3.00E+02	2.28E+02	2.08E+02	1.50E+02	1.73E+02	1.73E+02
18	4.35E+02	3.96E+02	2.98E+02	2.25E+02	2.05E+02	1.48E+02	1.70E+02	1.70E+02
19	4.38E+02	3.99E+02	3.00E+02	2.27E+02	2.08E+02	1.49E+02	1.73E+02	1.72E+02
20	4.34E+02	3.95E+02	2.96E+02	2.24E+02	2.04E+02	1.47E+02	1.69E+02	1.69E+02
21	4.33E+02	3.94E+02	2.96E+02	2.23E+02	2.03E+02	1.46E+02	1.68E+02	1.67E+02
22	4.33E+02	3.94E+02	2.95E+02	2.23E+02	2.04E+02	1.47E+02	1.68E+02	1.68E+02
23	4.35E+02	3.96E+02	2.97E+02	2.24E+02	2.05E+02	1.48E+02	1.69E+02	1.69E+02
24	4.35E+02	3.96E+02	2.97E+02	2.25E+02	2.05E+02	1.49E+02	1.70E+02	1.69E+02
25	4.39E+02	4.00E+02	3.01E+02	2.29E+02	2.09E+02	1.51E+02	1.74E+02	1.74E+02
26	4.40E+02	4.01E+02	3.02E+02	2.29E+02	2.10E+02	1.52E+02	1.74E+02	1.74E+02

27	4.38E+02	3.99E+02	3.00E+02	2.27E+02	2.08E+02	1.50E+02	1.73E+02	1.72E+02
28	4.36E+02	3.97E+02	2.99E+02	2.26E+02	2.07E+02	1.50E+02	1.71E+02	1.71E+02
29	4.37E+02	3.98E+02	2.99E+02	2.27E+02	2.08E+02	1.50E+02	1.72E+02	1.72E+02
30	4.37E+02	3.98E+02	2.99E+02	2.26E+02	2.07E+02	1.49E+02	1.72E+02	1.71E+02

****

Effective compartment halflives averaged over simulation duration:

washout halflife (days) = 4842.69650906671
water col metab halflife (days) = 912.130844512108
zero hydrolysis 0
zero photolysis 0
volatile halflife (days) = 17022237093.2060
total water col halflife (days) = 767.559543659740

zero burial 0
benthic metab halflife (days) = 498.535766564833
zero benthic hydrolysis 0
total benthic halflife (days) = 498.535766564833
****

Fractional Contribution of Transport Processes to Waterbody & Total Mass (kg):

Due to Runoff = 0.0000 0.000
Due to Erosion = 0.0000 0.000
Due to Drift = 1.0000 1414.
****

Flow in/out Characteristics of Waterbody:
Average Daily Runoff Into Waterbody (m3/s) = 2.387570882106416E-004
Baseflow Into Waterbody (m3/s) = 0.000000000000000E+000
Average Daily Flow Out of Waterbody (m3/s) = 2.387570882106397E-004
****

Inputs:
3925. = oc partitioning coefficient
381.0 = water column half Life
25.00 = reference temp for water column degradation
208.2 = benthic Half Life
25.00 = Reference temp for benthic degradation
2.000 = Q ten value
0.000 = photolysis half life
0.000 = reference latitude for photolysis study
0.000 = hydrolysis half life
169.1 = molecular wt
0.9750E-09 = vapor pressure
0.1200E+05 = solubility
0.1728E+07 = field area
0.5260E+05 = water body area
2.740 = initial depth
2.740 = maximum depth
3 1=vvwm, 2=usepa pond, 3 = usepa reservoir, 4 = const vol no flow, 5 = const vol w/flow
F T = burial, else no burial
0.1000E-07 = mass transfer coefficient
0.5000 = PRBEN
0.5000E-01 = benthic compartment depth
0.5000 = benthic porosity
1.350 = benthic bulk density
0.4000E-01 = OC frcation in benthic sediment
5.000 = DOC in benthic compartment
0.6000E-02 = benthic biomass
1.190 = DFAC
30.00 = SS
0.5000E-02 = chlorophyll
0.4000E-01 = OC frcation in water column SS
5.000 = DOC in water column
0.4000 = biomass in water column
FRACTION AREA CROPPED = 1.00000000000000

APPENDIX B. PFAM Aquatic Food Crop Uses (Rice and Cranberry)

DW CA Preflood nohold Rice Scenario

```
******************************************************************************
 Pesticide in Flooded Applications (PFAM)
 Version 2
 6/15/2017 1:00:11 PM
 Variable Volume Water Model: PFAM Compatible    1.01000000000000
 Performed on:  6/15/2017  at 13: 0
 MIXING CELL, Width =    194.0  Depth=     5.1  Length =     40.0
 Parent
******************************************************************************
1-day avg 1-in-10 (ppb) =     162.
4-day avg 1-in-10  =     65.2
21-day avg 1-in-10 =     31.9
60-day avg 1-in-10 =     18.8
90-day avg 1-in-10 =     13.8
Chronic 1-in-10    =     5.12
Overall Average    =     3.62
 **************************************************************************
 Effective compartment halflives averaged over simulation duration:

 washout halflife (days) =           1.139782804254377E-003
 water col metab halflife (days) =      686.891795253106
 hydrolysis halflife (days)  =         103542641.722930
 photolysis halflife (days)  =         25930523373.8510
 volatile halflife (days)  =          28063375434.6205
 total water col halflife (days) =     1.139780912964687E-003

 zero burial
 benthic metab halflife (days) =       375.428733447524
 benthic hydrolysis halflife (days) =   169658242568.335
 total benthic halflife (days) =       375.428732616756
 **************************************************************************

Mass Fraction Due to Drift =  0.892E-02
```

MA cranberry Scenario

```
  Pesticide in Flooded Applications (PFAM)
 Version 2
 5/19/2017 11:28:33 AM
******* Summary of Paddy Concentration Rankings ********

*********************************************************
**************  Analysis for Parent        *************
Max released concentration (ppb) =  0.173E+05
Index for max concentration      =       4687

 1-in-10 Year Return Concentrations:
********* WATER COLUMN CONCENTRATION (ug/L) ************
Water Column Peak              =   13.5
Water Column 1-day Avg         =   12.9
Water Column 4-day Avg         =   12.9
Water Column 21-day Avg        =   12.6
Water Column 60-day Avg        =   12.4
Water Column 90-day Avg        =   12.1
Water Column 365-day Avg       =   3.00

****** BENTHIC PORE WATER (ug/L) Concentration *********
Benthic Pore Water  Peak       =   31.9
Benthic Pore Water 4-day Avg    =   31.3
Benthic Pore Water 21-day Avg   =   28.0
Benthic Pore Water 60-day Avg   =   22.5
Benthic Pore Water 90-day Avg   =   19.3
 Benthic Pore Water 365-day Avg  =   10.1
```

******* BENTHIC TOTAL CONCENTRATION (Mass/Dry Mass) ********
Benthic Total Conc. Peak = 0.502E+04
Benthic Total Conc. 4-day Avg = 0.492E+04
Benthic Total Conc. 21-day Avg = 0.441E+04
Benthic Total Conc. 60-day Avg = 0.354E+04
Benthic Total Conc. 90-day Avg = 0.304E+04
Benthic Total Conc. 365-day Avg = 0.159E+04
****

APPENDIX C. PRZM-GW Output for Residential Spot Treatment Use (40 lbs ae /A)

**** Parent **

GW Run ID	Peak	Breakthru	Thruput	PostBT Avg	Sim Avg
Delmarva_PWC_+0	6.5223E-29	-999999	0.02867823	-999999	6.775729E-30
FL potato_ForQA_+0	1.9012E-21	-999999	0.07528269	-999999	3.324455E-22
FLCitrus_PWC_+0	2.0027E-20	-999999	0.05396811	-999999	3.228578E-21
GA peanuts_ForQA_+0	8.9863E-34	-999999	0.03971326	-999999	5.149908E-35
NCCotton_PWC_+0	1.0738E-31	-999999	0.02014195	-999999	1.154074E-32
WI_corn_ForQA_+0	6.31285E-42	-999999	0.01438171	-999999	3.433181E-43