V. Cumulative Risk from Carbamate Pesticides in Drinking Water

The Food Quality Protection Act (FQPA) of 1996 requires the Agency to assess the risks from different pesticides having a common mechanism of action, focusing on the likelihood that a person will be concurrently exposed to multiple pesticides from multiple sources (food, drinking water, and residential uses). Ideally, data to support the drinking water portion of this exposure would provide information on multiple pesticides, and their transformation products, collected from sufficient drinking water sources throughout the U.S. and at a sufficient frequency to reflect the spatial and temporal patterns of pesticide occurrence in water. The great diversity of geographic-, climatic-, and time-dependent factors that affect pesticide contamination in water creates unique challenges in characterizing drinking water exposure. The Office of Pesticide Programs (OPP) must rely on both available monitoring data and modeling to develop sufficient data for use in the exposure assessment.

Because of similarities in use (both groups are insecticides), hazard endpoints (acute – short term – endpoints), and exposure requirements (estimates of peak concentrations and time-series distributions), the Agency will use the same methods for estimating surface water exposure in the carbamate drinking water assessment as it did for the organophosphate (OP) cumulative risk assessment (CRA). These methods have already been presented to the FIFRA Science Advisory Panel (FIFRA SAP, 2002). This case study provides a summary of those methods used in the OP CRA as they apply specifically to the N-methyl carbamates included in this cumulative assessment group. In addition to being found in surface water, the carbamates are likely to reach ground-water sources of drinking water. In order to assess the potential impacts of carbamate residues in ground water on the drinking water assessment, OPP is evaluating the capability of three ground water models to estimate carbamate concentrations. This evaluation is presented to the SAP as a separate document.

This case study provides preliminary results of estimated drinking water exposures from surface water in the southeastern US. Based on an assessment of carbamate use patterns and relative runoff vulnerabilities of the US, the Agency expects these drinking water exposures to represent the high-end of anticipated cumulative carbamate exposures in surface water sources of drinking water.

A. Problem Formulation

The approach for assessing drinking water exposure accounts for the fact that pesticide concentrations found in drinking water are not random, but are in large part determined by the amount, method, timing and location of pesticide application, the physical characteristics of the watersheds and/or aquifers in which the community water supplies (CWS) or private wells are located, and other environmental factors (such as rainfall) which cause the pesticide to move from the location where it was applied. The choice of data and tools to estimate the drinking water exposure component of cumulative exposure depends upon both the questions to be answered and the expected exposure in water.

1. Drinking Water Exposure Estimates Required for the Carbamate Cumulative Assessment

For the N-methyl carbamate group, the toxicity endpoint of concern results from short-term exposure (acute effects). To adequately characterize the potential impacts of pesticide residues in drinking water, the estimated residue concentrations need to reflect a sufficient reporting frequency in time to capture peak concentrations. Because pesticide loads tend to move in relatively quick pulses in flowing water, the frequency sufficient to reliably capture peak concentrations is on the order of daily sampling.

The drinking water exposure assessment needs to account for the potential for any or all of the carbamates included in the cumulative assessment group (Table 1) to occur together in drinking water sources. To realistically estimate exposures, the assessment must take into account those factors (crop uses, pest pressures, timing of application, etc.) which determine whether more than one carbamate pesticide can occur together in time and place. Although multiple carbamate pesticides may be registered for use on the same site, they may not necessarily be used at the same time. While monitoring data could provide real-time estimates of co-occurrence, it needs to be able to account for all of the potential carbamates used in the monitoring area, be of sufficient frequency to reflect the pulse nature of pesticide exposures, and span sufficient years to capture the yearly variability in use and weather patterns.

Table 1. N-methyl carbamate use patterns and availability of national monitoring data

Pesticide	Use pattern likely to result in water exposure?	Availability of national water monitoring data?
Chemical A	Yes (agricultural and residential uses)	Yes: NAWQA, Reservoir monitoring
Chemical B	Yes (agricultural uses)	Yes: NAWQA, Reservoir monitoring; state monitoring
Chemical C	Yes (agricultural uses)	Yes: NAWQA, Reservoir monitoring
Chemical D	Yes (agricultural uses)	No
Chemical E	Yes (agricultural uses)	Yes: NAWQA, Reservoir monitoring
Chemical F	Yes (agricultural uses)	Yes: NAWQA, Reservoir monitoring; state monitoring
Chemical G	No (indoor uses)	Some limited NAWQA monitoring
Chemical H	Limited impact due to limited use	Some limited NAWQA monitoring
Chemical I	Yes (agricultural uses)	No
Chemical J	Limited impact due to indoor uses, limited outdoor use	No

In order to meet the FQPA requirement of “reasonable certainty of no harm”, the drinking water exposure assessment must balance between reflecting actual use in the field and accounting for year-to-year variations

due to weather, fluctuating pest pressures, and other use / environmental factors in order to provide a realistic potential high-end exposure.

2. Nature of Carbamate Exposure in Drinking Water Sources

This section briefly summarizes the nature of expected carbamate exposure in drinking water sources based in individual chemical assessments (aggregate exposure), available water monitoring data, and published literature on the potential impact of conventional drinking water treatment processes on carbamates in water.

Re-registration eligibility documents (REDs) or Interim REDs (IREDs) are available for five of the pesticides included in the carbamate cumulative assessment group (available on the USEPA OPP web site at http://cfpub.epa.gov/oppref/rereg/status.cfm?show=rereg); risk assessments are underway for three additional carbamates. These individual assessments indicate that seven of the carbamates listed in Table 1 – Chemicals A, B, C, D, E, F, and I – have the potential to reach drinking water sources based on use and chemical fate and transport properties. All seven are likely to reach surface water sources of drinking water via runoff or sediment transport, and have been detected in monitoring studies. Two carbamates – Chemicals B and F – are likely to reach and persist in ground water sources of drinking water, especially in shallow aquifers. This has been confirmed in a number of monitoring studies. Three other carbamates – Chemicals A, C, and E – may also reach ground water, but are not likely to persist. Detections of these chemicals in ground water are infrequent.

The most extensive source of national water monitoring data for pesticides is the US Geological Survey (USGS) National Water Quality Assessment (NAWQA) program, which includes seven of the carbamates in its list of pesticides (Table 2). The NAWQA program focuses on ambient water rather than drinking water sources, is not specifically targeted to pesticide use areas, and are not sampled frequently enough to provide reliable estimates of peak pesticide concentrations. However, the program does provide a good understanding on a national level of the expected occurrence of pesticides in flowing water bodies that may be representative of drinking water sources. The monitoring data are better indicators of the nature of occurrence of pesticides with widespread use rather than pesticides that are limited to a few crops or pests. A detailed description of the pesticide monitoring component of the NAWQA program is available on the NAWQA Pesticide National Synthesis Project (PNSP) web site (http://ca.water.usgs.gov/pnsp/).

A summary of the first cycle of NAWQA monitoring from 1991 to 2001 indicates that the seven carbamate pesticides included in the monitoring study were not frequently detected in the NAWQA study units (Table 2). Chemicals A and F were the most frequently detected

carbamate pesticides in streams and ground water, reflecting the broader use patterns of these particular insecticides. In most instances, maximum reported detections of the carbamates were in the single parts per billion or sub-parts per billion range. OPP obtained carbamate-specific monitoring data through the NAWQA Data Warehouse (a link is available from the PNSP web site referenced above), current through November 5, 2004. While these data have not been analyzed for this case study, a limited, preliminary evaluation noted reported concentrations as high as 25 to 35 ug/l for Chemicals A, E, and F.

As expected, co-occurrence of carbamates in the monitored water samples reflects use patterns. Chemicals A and F are the most common carbamates occurring together in the NAWQA sampling; up to three different carbamates have been detected in the same surface water samples in the NAWQA study units. Although less commonly observed, more than one carbamate was also detected in a small number of ground water samples.

Table 2. Summary of carbamate detections in the USGS NAWQA study, 1991-2001 (provisional data published by USGS in 2003).

Pesticide	Agricultural Land Use			Mixed Land Use			*Urban Land Use*		
	% detect	Max conc, ug/L	95th %ile conc	% detect	Max conc, ug/L	95th %ile conc	% detect	Max conc, ug/L	*95th %ile conc*
Surface Water Monitoring 1									
Chemical A	9.2%	5.2	nd	15.4%	0.5	nd	43.8%	5.2	*0.3*
Chemical B	0.2%	0.5	nd	0%	Nd	nd	0%	nd	*nd*
Chemical C	0.8%	0.2	nd	0%	Nd	nd	0%	nd	*nd*
Chemical E	1.6%	0.7	nd	0.3%	0.3	nd	0%	nd	*nd*
Chemical F	9.6%	7.0	0.04	3.3%	0.7	nd	2.1%	0.1	*nd*
Chemical G	0.2%	0.1	nd	0.2%	0.2	nd	0.2%	0.3	*nd*
Chemical H	0.1%	0.1	nd	0%	Nd	nd	0%	nd	*nd*
Ground Water Monitoring 2									
Chemical A	0.4%	0.02	nd	0.8%	0.5	nd	1.6%	0.03	*nd*
Chemical B	0.3%	1.8	nd	0.1%	0.1	nd	0%	nd	*nd*
Chemical C	0.8%	2.1	nd	0.1%	0.03	nd	0.2%	0.3	*nd*
Chemical E	0.1%	0.04	nd	0.1%	0.1	nd	0.2%	0.4	*nd*
Chemical F	1.6%	1.3	nd	0.4%	0.2	nd	0.7%	0.09	*nd*
Chemical G	0.1%	0.06	nd	0.1%	0.06	nd	0.2%	0.3	*nd*
Chemical H	0%	nd	nd	0.1%	0.03	nd	0%	nd	*nd*

1 Martin et al, 2003; http://ca.water.usgs.gov/pnsp/pestsw/Pest-SW_2001_Text.html
2 Koplin & Martin, 2003; http://ca.water.usgs.gov/pnsp/pestgw/Pest-GW_2001_Text.html

NAWQA and other surface-water monitoring programs show that pesticide concentrations in surface water are highly variable in location and in time. This is particularly true for insecticides, such as the carbamates, where usage is often in response to specific pest pressures, which are likely to be concentrated in some areas but not in others and in some years but not necessarily every year. In addition to variable use patterns, carbamate concentrations in surface water are influenced by

local soil, hydrology, and weather patterns and by the timing of rainfall events in relation to use.

While Chemical B has not been detected frequently or in high concentrations in ground water in the NAWQA program, extensive monitoring by others (the registrant, state and local governments, universities) shows widespread contamination of ground water where Chemical B has been used. In the aggregate exposure assessment for Chemical B (IRED scheduled for 2006), OPP contrasted the entire body of ground water monitoring data, much of which occurred during the late 1980s, with monitoring data since 1990 (Table 3). During that time, label changes were incorporated to restrict use from certain areas.

While the extent of Chemical B contamination in ground water is less today than it was in previous decades, it is also less well characterized in most areas. In addition, total Chemical B residues (primarily the transformation products) can persist in ground water for years or decades after use. Twenty years after Chemical B use on Long Island, NY, was halted, Chemical B residues are still the most frequently detected pesticide compounds in ground water (Suffolk County Dept. of Health Services, 2000).

Table 3. Summary of Chemical B detections in ground water monitoring data collected from available ground water monitoring data.

Region	All ground water monitoring			Monitoring data since 1990		
	max conc (ug/L)	95th %ile (ug/L)	70th %ile (ug/L)	max conc (ug/L)	95th %ile (ug/L)	70th %ile (ug/L)
Northwest	183	58.7	1.0	2.1	0.8	0.6
Southwest	44	22.8	7.8	7.2	7.1	6.7
Northern Great Plains	65	46.3	7.9	65	52.9	9.5
Lower Midwest	N/A	N/A	N/A	N/A	N/A	N/A
North-central	111	38	10	83	24.2	6.8
Northeast	187.2	40.1	13.4	187.2	24.5	8.0
Southeast and Mid-south	602	27.7	5.3	21	20.3	3.6
Florida	55.2	25	8.3	55.2	25.6	8.5

A similarly extensive body of ground water monitoring data exists for Chemical F. Like Chemical B, the extent of monitoring for Chemical F in ground water has decreased in recent years, so current impacts are not as well documented. However, several inferences can be drawn from the body of studies. Targeted ground water monitoring studies show a clear pattern of Chemical F movement into ground water, with maximum detections in the same range as that reported for Chemical B. Because transport to ground water typically takes longer than transport to surface water, measured concentrations of Chemical F in ground water may represent usage that occurred years before the samples were collected. As with Chemical B, Chemical F will also persist in ground water for long periods of time after use has been discontinued. This is particularly true for slightly acidic to acidic ground water because Chemical F is stable to

hydrolysis (the major route of degradation in ground water) at pH values of 6.0 or less.

EPA' s preliminary review of available scientific and technical literature indicates that conventional water treatment processes such as coagulation, sedimentation, and conventional filtration generally do not affect removal or transformation of most pesticides, including the N-methyl carbamates. While powdered activated carbon (PAC), granular activated carbon (GAC), and reverse osmosis can be effective in removing many pesticides, they are not widely used in community water systems (CWS). Chemical softening processes can facilitate chemical transformations of some pesticides, including those carbamates that hydrolyze rapidly at alkaline pH values. However, softening is not employed at every CWS. These results were published in the Federal Register in October 2001, along with an interim policy for considering the impacts of drinking water treatment in drinking water exposure assessments under FQPA (USEPA, 2001). The registrant has submitted studies on the effect of drinking water treatment on Chemical E and Chemical C; these studies have not been reviewed for this case study. For the cumulative assessment, the Agency will qualitatively consider the impacts of conventional drinking water treatment on specific carbamate pesticides in CWS water supplies. However, the Agency must also consider raw water concentrations for private ground water wells since these private wells generally do not include any form of treatment.

3. Summary

The goal of the drinking water exposure assessment is to provide estimates of distributions of carbamate residues (concentrations in drinking water) for use in probabilistic exposure assessment that account for:

- ❑ daily and seasonal variations in residues over time due to time of application(s) and runoff/leaching events (surface water concentrations are expected to be more variable in time than ground water concentrations)

- ❑ year-to-year variations due to weather patterns, pest pressures, and use

- ❑ variability in residues from place to place, resulting from the source and nature of drinking water and from the regional / local factors (soil, geology, hydrology, climate, crops, pest pressures, usage) that affect the vulnerability of those sources

- ❑ the potential for co-occurrence of more than one carbamate in location and time only when this is likely to happen

B. Analysis Plan

Risk is a function of both hazard and exposure, and estimation of the exposure portion for drinking water requires data on concentrations of the pesticides in the drinking water and consumption of drinking water for different demographic populations on a daily basis. Drinking water is locally derived and concentrations of pesticides in source water fluctuate over time and location for a variety of reasons. Pesticide residues in water fluctuate daily, seasonally, and yearly as a result of the timing of the pesticide application, the vulnerability of the watershed to pesticide runoff, spray drift and leaching, and changes in the weather. Changes in concentrations also result from the method of application, the location and characteristics of the sites where a pesticide is used, the climate, and the type and degree of pest pressure.

Given the data needs and the number of variables that can affect the outcome of the predictive model, it is apparent that the development of daily distributions of concentrations of co-occurring carbamates in drinking water for various regions of the US is far-reaching in scope and complexity. While monitoring data provide a picture of the expected occurrence of carbamate pesticides in drinking water, the data alone are not sufficient for use in the cumulative drinking water exposure assessment. This section describes the planned approach to estimate cumulative carbamate residues in drinking water using models and evaluating the estimates against available monitoring data.

Based on the needs of the probabilistic cumulative exposure assessment and the information gained from an assessment of monitoring data, OPP designed a drinking water assessment that provides multiple years of daily residue concentrations from drinking water sources in eight regions across the country. Because of similarities between the N-methyl carbamates and the organophosphate (OP) pesticides with regard to hazard endpoints and expected occurrence in surface water, the Agency will use the same approach it used in the OP CRA for estimating drinking water exposure from surface water. Unlike the OP pesticides, the carbamate pesticides have been detected in ground water sources of drinking water. Thus, the Agency is developing methods to estimate carbamate residues in ground water sources of drinking water.

1. Estimating Carbamate Exposure in Surface Water Sources of Drinking Water

While the available monitoring studies provide a profile of carbamate occurrence in water, the same limitations identified in the OP CRA also preclude basing the carbamate cumulative water exposure assessment solely on monitoring:

- The monitoring studies were not designed to characterize daily concentration profiles and are not robust enough to provide daily distributions; the frequency is not sufficient to capture peak or near-peak concentrations

- ❑ The studies have not been conducted over a period of time sufficient to characterize year-to-year fluctuations due to weather, use, pest pressures, etc.

- ❑ While the NAWQA study units coincide with a number of high carbamate-use areas, not all of the major carbamate use areas have monitoring data

- ❑ Lack of monitoring for some compounds make it difficult to completely assess co-occurrence

- ❑ Monitoring provides a snapshot in time and does not reflect recent mitigation actions, such as lower application rates and fewer applications or cancellation of certain uses or chemicals, initiated for individual chemicals during the risk management phase.

As with the OP CRA, OPP is using available monitoring (particularly the USGS NAWQA and Reservoir Monitoring studies, state monitoring programs, and industry-conducted studies) in the carbamate cumulative drinking water assessment. Because the NAWQA monitoring covers a number of areas of the country, it can help characterize the spatial variation in exposures and identify potential areas of concern. Taken in context with known carbamate usage, weather patterns, and soil/hydrologic conditions, monitoring will be used to evaluate modeled exposure estimates.

In a case study for the OP CRA, the Agency used a developmental version of the USGS Watershed Regression for Pesticides (WARP) model to estimate concentrations of two OP pesticides in drinking water sources. The panel noted that shortcomings in the available data (particularly pesticide usage) and in the model's estimation capabilities (described below) limited the Agency's ability to use the WARP model presented to them in the cumulative exposure assessment for multiple pesticides (FIFRA SAP, 2000).

Since then, the USGS has completed development of the WARP model for atrazine (Larson et al, 2004). While the USGS is currently working on a multi-pesticide model and is investigating potential methods for estimating peak concentrations and providing temporal distributions of pesticide concentrations in water, those improvements are not ready yet. In its current state, the WARP model cannot address the requirements of the carbamate CRA:

- ❑ In present state of development (published model for atrazine), WARP is not yet capable of estimating concentrations for multiple chemicals (though a multiple chemical model is being evaluated)

- ❑ Because it is a regression model, it carries a number of the same limitations as monitoring data

- ❑ The model falls short of peak estimates because it is intended to estimate up to the 95th percentile annual concentration, which means that roughly 18 days out of every year will have greater concentrations

- ❑ Does not provide a daily distribution and, thus, cannot adequately separate estimated concentrations that are not likely to occur together in time.

Therefore, as with the OP CRA, the Agency will estimate the daily drinking water exposure from surface water sources using the simulation models PRZM (Pesticide Root Zone Model) and EXAMS (EXposure Analysis Modeling System). PRZM/EXAMS modeling using a drinking water reservoir allows the Agency to:

- ❑ Account for potential co-occurrence of carbamates by modeling all uses in a region/area

- ❑ Combine daily time series over multiple years (using 30 years of recorded weather data) to account for year-to-year variations in weather and to separate peak concentrations that are not likely to occur together

- ❑ Can estimate peak concentrations (on a daily time step); adjustments to pesticide use inputs (“typical” rates, frequencies) can reflect estimated concentrations in a “typical” year

- ❑ Model vulnerable surface water sources in regions to reflect spatial variations in crops, use, weather, soil, hydrology

- ❑ Adjust for crop area, acres treated

2. Estimating Carbamate Exposure in Ground Water Sources of Drinking Water

As noted in the problem formulation, a number of the carbamates included in this assessment have been detected in ground water. For the same reasons mentioned above for surface water, the existing body of ground water monitoring is not sufficient to serve as the basis for cumulative ground water exposure estimates. Monitoring does indicate that more than one carbamate may occur together in ground-water. While carbamate concentrations in ground water are affected by pesticide use, rainfall, and soil conditions, the response time between an application / leaching event and detection in ground water is not as rapid as it is for surface water. Thus, carbamate concentrations are less likely to fluctuate

as drastically in ground water as they do in surface water and less frequent time steps may be adequate to characterize ground water exposures. However, carbamate residues are likely to linger for longer periods in ground water, particularly in slightly acidic to acidic ground waters where the carbamates tend to be more persistent. Cumulative exposure is likely to reflect past as well as current uses.

The Agency uses the Screening Concentrations In GROund Water (SCI-GROW) model in its initial screening estimates of individual pesticide concentrations in ground water sources of drinking water (a description of the model is available through the OPP Water Models web site at http://www.epa.gov/oppefed1/models/water/index.htm). Pesticide concentrations estimated by SCI-GROW represent high-end exposure values because the model is based on ground-water monitoring studies which were conducted by applying pesticides at maximum allowed rates and frequency to vulnerable sites (i.e., shallow aquifers, sandy, permeable soils, and substantial rainfall and/or irrigation to maximize leaching). The model provides a single estimated concentration which is used for both short-term and longer-term exposures. This model does not provide time-series estimates and is not designed to estimate concentrations other than the peak estimates it provides.

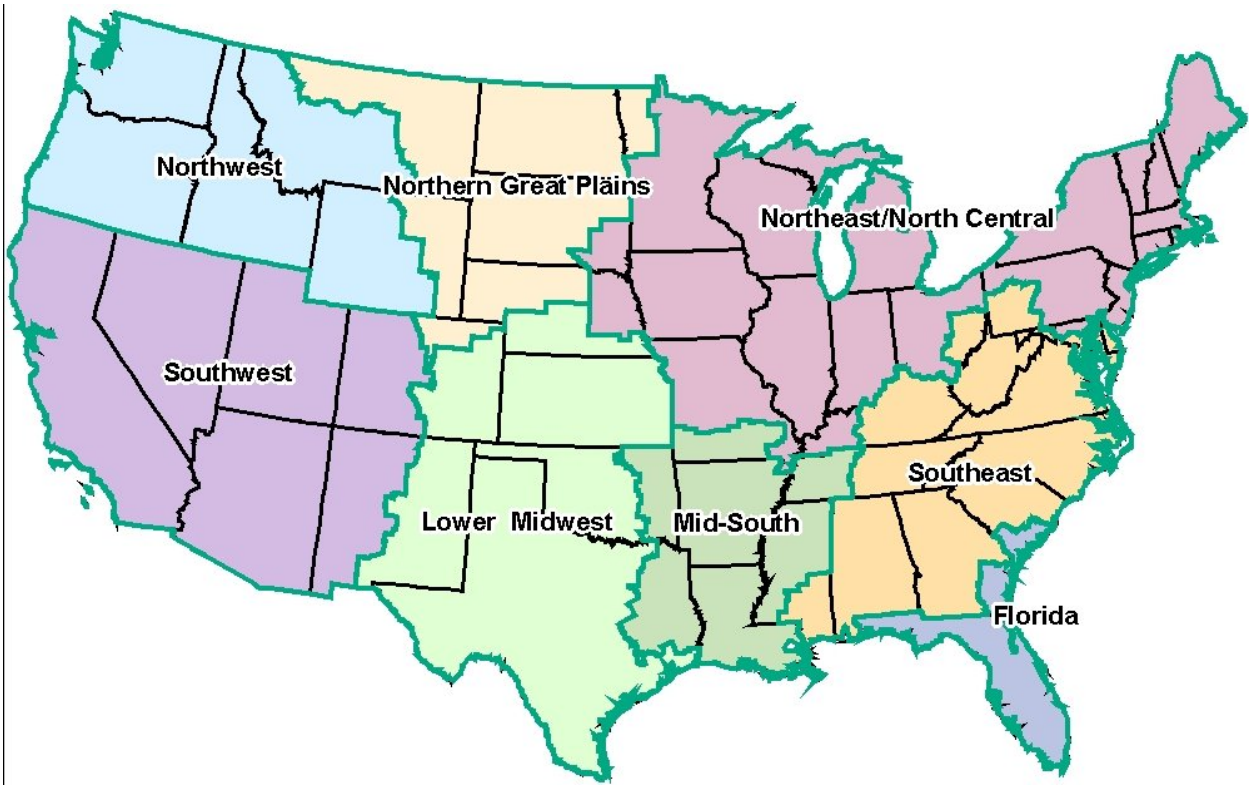
Currently, EPA does not have a more refined ground water model for estimating pesticide exposures in ground water sources of drinking water. Recently, the USGS evaluated the capabilities of a number of existing ground water models. Based in the results, EPA considered three models – LEACHM, RZWQM, and PRZM – for predicting ground water concentrations. EPA has evaluated the USGS comparisons and the data requirements of these models, in addition to evaluations done by the FIFRA Environmental Model Validation Task Force in order to select a model for use in the carbamate CRA. This evaluation is being presented to the SAP in Session 3 for consideration and feedback.

3. Regional Screening Approach for Drinking Water Exposure Assessment

As with the OP CRA, the Agency is using a regional approach as a first step in addressing the impacts of regional and localized variability in site, environmental, and management practices that affect pesticide concentrations in water. OPP adapted a modification of the USDA Farm Resource Region map (Heimlich, 2000) as a framework for focusing the cumulative assessment (Figure 1). By providing general groupings according to similarities in key environmental factors affecting runoff and leaching, such as precipitation, irrigation practices, and soil types, these farm resource regions provide a framework for identifying one or more locations which represent an area of the greatest concern for drinking water exposure in each region. In this way, the Agency chose a set of locations to represent drinking water sources throughout the US.

Within the regions, drinking water exposure will vary locally due to pesticide use, agricultural practices, nature and vulnerability of drinking water sources, and weather patterns. Thus, the water exposure assessment focused on one or more specific geographic areas within each region in a manner that would be realistically protective of all sites within the region. OPP selected locations in each region where carbamates in drinking water sources are likely to be of greatest concern based on total carbamate use and vulnerability of the drinking water sources. If carbamate levels in water from these vulnerable sites are not major contributors to the total regional cumulative exposure, then the Agency can reasonably conclude that drinking water exposures will not be a concern in other, less vulnerable, portions of the region. If drinking water exposure from one or more of these vulnerable sites is a significant contributor to the total cumulative exposure, then additional assessments may be necessary to characterize the extent of the potential exposure.

Figure 1. Carbamate cumulative risk assessment regions for drinking water exposure assessment.



C. Analysis Methods

A detailed description of the methods used for estimating cumulative pesticide concentrations in surface water sources of drinking water can be found in the Water OP Cumulative Risk document for the OP CRA (USEPA OPP,

2002). This section provides a brief description of the methods of analysis in order to provide context for understanding case study results.

1. N-methyl Carbamate Properties

The predicted persistence and movement of each of the carbamate pesticides in the environment are based on environmental fate and transport studies submitted by the pesticide registrants as a requirement of registration and/or re-registration. Inputs for the water models are based on the individual chemical assessments. Model inputs have not been provided for this case study since the focus of the study is on the methods for cumulative exposure assessment and not the individual chemical properties. Such inputs will be documented in the preliminary risk assessment.

2. Identifying Regional Exposure Scenarios

The selection of a specific location for regional drinking water assessments involves several steps. First, OPP identified the high carbamate usage areas within each region. To account for the differences in toxicities among the carbamates, OPP adjusted the county-level estimates of pounds of each carbamate by their respective relative potency factors before summing the total pounds of carbamate use. Thus, the adjusted usage map reflects the areas of greatest use of the most potent of the carbamates.

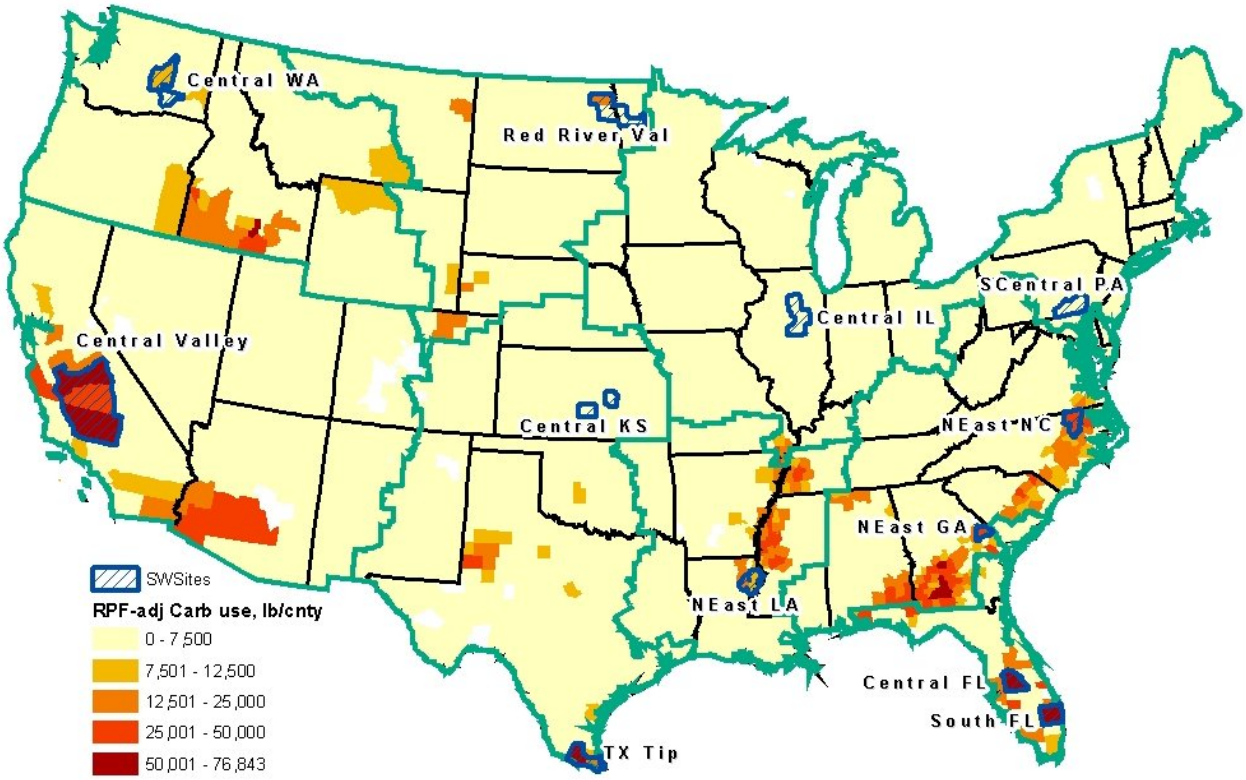
Next, OPP identified the types of drinking water sources in each high usage area. The Agency used a spatial dataset that describes water use for all the counties in the continental US (USGS, 1998) to determine the dominant source of drinking water – (1) public supply served by surface water, (2) public supply served by ground water, or (3) domestic self-supplied drinking water (primarily private wells). The Agency focused its regional assessments on high carbamate usage areas that coincided with either surface-water or ground-water sources of drinking water.

The final step in choosing a location is to assess the vulnerability of drinking water sources within the high usage area within the region. For surface water sources of drinking water, OPP compared relative vulnerabilities of the areas based on average-annual runoff, average 2-month runoff (beginning of the growing season), and average soil loss, as developed by the USDA Natural Resources Conservation Service (Kellogg et al, 1997). For ground water sources of drinking water, OPP compared relative ground water vulnerabilities of the high carbamate use areas based on a variety of sources, including Nolan et al (2002), USGS NAWQA reports, and USGS Ground Water Atlases.

Figure 2 shows the locations of the regional surface water exposure scenarios selected for the carbamate drinking water exposure

assessment. The Central FL site also serves as the initial ground water exposure scenario location. Data was collected from each county- or multi-county area to represent the cropping patterns, carbamate usage, soil, hydrologic, and weather conditions for the surface watersheds or aquifers associated with the drinking water supplies.

Figure 2. Locations of the regional surface water exposure sites for the carbamate cumulative assessment



3. Regional Usage

The regional exposure areas of interest consist of multi-county areas that encompass the vulnerable drinking water source in high carbamate use areas. OPP collected information on the target crops, estimated carbamate usage, and timing of application for these multi-county areas.

The drinking water exposure assessments require information on crop use, pounds applied, application rate, number of applications, percent of crop treated, and application timing. Much of this information is not easily available or does not exist at the geographic scale needed for the exposure assessment. OPP used the best available information to provide the best regional estimates for the carbamate pesticide-crop combinations that actually occur in scenario areas. Because county-level pesticide usage data is based on surveys and is uneven in quality, OPP created county clusters that surrounded the initial scenario areas shown in

Figure 2. The Agency also used multiple data sources and multiple years of data to improve the robustness of the use data.

For each regional scenario site, OPP used USDA National Agricultural Statistics Service (USDA NASS) and Doane's databases to estimate usage (acres planted, total pounds used, percent of crop treated, application rate, and number of applications) for each carbamate and crop reported in the use cluster. Usage was averaged for the years 1998 through 2002. The Agency identified those carbamate-crop uses that accounted for at least 95% of the total carbamate usage in the scenario area.

Usage data (application rates, frequency, area treated) represent the mean for the area over the 5-year period. As noted in the characterization section, this will result in underestimates of those times when more intense pest pressures result in higher rates and/or greater acres treated and in overestimates for those times when pest pressures are minimal or absent. As with the OP CRA, the Agency plans to conduct sensitivity analyses to characterize the uncertainty based on using average usage data.

Once the crop / chemical combinations were identified in a given area, OPP used USDA crop profiles and typical planting/harvesting dates and various other sources to identify most likely windows of application for each carbamate use. Typically, all the carbamates discussed here target multiple pests or ones that can occur multiple times during a given crop's growing season, so applications often occur over a broad time period. For the case study, OPP systematically selected the beginning of the most active window for the initial application date of each carbamate. Where multiple applications were identified, the Agency spread those evenly over the most active window.

4. Surface Water Exposure Assessment

For each of the regional surface water exposure scenarios, EPA used its paired PRZM and EXAMS models for an index, or reference, reservoir to estimate a distribution of daily drinking water concentrations that could be used for multiple chemicals over several years of predictions across the country. PRZM-EXAMS estimates concentrations in a small drinking water reservoir in a primarily agricultural watershed. PRZM-EXAMS has the capability of predicting water concentrations over a number of years based on collected historical weather data for the sites which are being modeled. A detailed description of the models is available from the OPP Water Models web site (http://www.epa.gov/oppefed1/models/water/index.htm).

The PRZM component of the model is designed to predict the concentration of a pesticide dissolved in runoff waters and carried on

entrained sediments from the field where a pesticide has been applied into an adjacent surface water body. Inputs to the model include specific soil properties (organic matter, water holding capacity, bulk density), site characteristics (slope, surface roughness, field geometry), pesticide application parameters (application rate, frequency, spray drift, application depth, application efficiency, application methods), agricultural management practices (erosion parameters influences by tillage practices, irrigation, crop rotation sequences), and pesticide environmental fate and transport properties (aerobic soil metabolism half-life, soil:water partitioning coefficients, foliar degradation and dissipation rates, and vapor pressure). The input parameters are specific for each carbamate-crop scenario in each region.

In addition to the pesticide-specific environmental fate properties and usage information described above, PRZM uses values for soil properties, site characteristics, and weather data that are specific to the regions of the exposure assessments. For instance, in the eastern North Carolina exposure site representing the Southeast region of the US, the cotton, peanut, and tobacco scenarios consist of properties for soils on which the crops are grown in the coastal plain of North Carolina. The weather data used in the simulations come from 30 years of weather collected at a NOAA weather station in Raleigh/Durham, just west of the scenario area.

The EXAMS component of the model is used to simulate environmental fate and transport processes of pesticides in surface water, including abiotic and biotic degradation, sediment:water partitioning, and volatilization. Currently, OPP is using an index reservoir as the benchmark surface water body for drinking water exposure assessments. The reservoir, based on Shipman City Lake in IL, is a 5.3-hectare reservoir (reserve normal capacity of 144,000 m3) with a 172.8-hectare (427 acre) watershed.

The PRZM-EXAMS model is used in individual chemical aggregate assessments to predict a reasonable high end screening concentration. This is done by using health-protective assumptions (maximum label application rates, 100% of the crop is treated, national percent crop area estimate) in order to determine whether the Agency can reliably conclude a reasonable certainty of no harm from pesticide exposures in drinking water. However, the cumulative assessment focuses on the probability or likelihood of concurrent exposure to multiple pesticides from food, water, and residential use. It is unlikely that the exposure to the highest (peak) concentrations for multiple carbamates in a use area will occur at the same time. Thus, the cumulative assessment uses average application rates, average numbers of applications, and estimates of acres treated. The implications of these assumptions are discussed in the risk characterization section.

PRZM is a field-scale model, while the cumulative water assessment focuses on watershed-scale impacts (i.e., the contributions of multiple carbamate uses on multiple crops occurring in multiple fields in a watershed). As with the OP CRA, the Agency used PRZM to model multiple fields in a watershed. While this approach provides a more realistic depiction of multiple chemical usage in a watershed, it still has limitations. PRZM can simulate multiple fields, but provides no spatial context for those fields. It also assumes that the runoff from each of those fields goes into the reservoir.

To adapt PRZM for this watershed approach, OPP must adjust the estimated pesticide concentrations generated for each crop-carbamate combination to account for the portion of the watershed that is treated by a particular carbamate. This was done with a cumulative adjustment factor (CAF) in a three step process:

(1) The carbamate-crop combination was modeled with PRZM/EXAMS, using the region-specific usage, application timing, soil, site, and weather data. The result is a time-series of daily pesticide concentrations in a reservoir spanning a 30-year period.

(2) Each daily concentration is adjusted by the fraction of the watershed that is in the crop being modeled. This is done by dividing the acres of crop grown in the multi-county region by the total acres in that region (percent crop area).

(3) The daily concentrations are then adjusted by the fraction of acres of the crop treated by the particular carbamate. This is done by dividing the acres of crop treated by the total crop acres in the multi-county region (percent crop treated).

The resulting CAF-adjusted concentrations for each crop-carbamate combination must be converted to a concentration equivalent for an index chemical. Once this is done, the concentrations can be combined into a single set of daily cumulative concentrations (spanning multiple years) for each region. The concentrations were normalized to an index equivalent by multiplying each of the daily concentrations by the relative potency factor (RPF) for the respective carbamate pesticide. This normalized output for each crop-carbamate combination was summed day by day to give a single time series of potential combined water residues for the region. The resulting carbamate cumulative drinking water exposure is provided as a cumulative daily time series over 30 years.

In summary, within each region, a residue file was generated by PRZM-EXAMS for each crop-carbamate combination which was reported in the county or counties selected for assessment. This day-by-day residue file was modified by the CAF specific to that crop-carbamate combination and the relative potency factor for that pesticide. Then, the

modified residue files for all crop-carbamate combinations for that location were summed across days to give a distribution of combined daily residues in drinking water.

5. Ground Water Exposure Assessment

EPA is evaluating three models for use in the carbamate cumulative risk assessment to estimate carbamate concentrations in ground water sources of drinking water. Based on the results of the evaluation (presented to this SAP in a separate session) and recommendations of the SAP, the Agency will use one of the models to estimate potential exposure of carbamates in drinking water derived from ground water.

In addition to the criteria EPA used to evaluate the suitability of the models for estimating pesticide concentrations in ground water (comparisons to monitoring, availability of inputs for the model, ease of use, maintenance, etc.), the models must also address the needs of the cumulative exposure assessment. Despite some differences in the nature of pesticide exposure in ground water as compared to surface water, the requirements of a ground water exposure assessment are similar. These requirements will be addressed in the ground water exposure assessment as follows:

- **Variations in Residues Over Time:** Pesticide residues in ground water are likely to fluctuate less drastically than residues in surface water; however, the model estimates will need to provide a concentration time series.

- **Variations in Residues Over Location:** As with the surface water assessment, EPA will focus on regional ground water sources of drinking water that are expected to be among the most vulnerable to carbamate contamination based on soil, geology, hydrology, climate, crops, pest pressures, and usage. For the preliminary assessment, EPA focused on central Florida, based on carbamate use, drinking water source, and expected aquifer vulnerability.

- **Co-occurrence:** USGS monitoring shows that co-occurrence of carbamates, though infrequent, does occur in ground water. Therefore, EPA will estimate ground water concentrations for multiple carbamate pesticides in ground water as their use is reflected in the regional ground water sites.

Unlike surface water exposure, in which pesticide residues dissipate quickly because of flow, the ground water exposure assessment needs to address background residues present from previous use. As noted, available monitoring shows that Chemical B and Chemical F can persist in slightly acidic to acidic ground water for years after use has been reduced or eliminated. The Agency is considering three possible approaches:

- ❑ at one extreme, assume no background residues (drinking water exposures would reflect only what is estimated by modeling), i.e, all residues in GW are “fresh”;

- ❑ at the other extreme, assume a baseline background concentration (based on available monitoring), with model estimates as additions and no decline;

- ❑ in between, include the background levels with model estimates, but provide an estimate of decline in residues over time (estimate based on long-term trends in monitoring)

The resulting cumulative distributions from ground water will be converted to an index chemical based on the relative potency (RPF) and, then summed for a cumulative ground water distribution.

D. Carbamate Cumulative Drinking Water Exposures: Case Study Results

For this case study, EPA focused the drinking water exposure assessment on the southeastern US, covered by the Florida, Southeast, and Mid-south regions (Figure 3). EPA estimated carbamate cumulative distributions in surface water from five sites in the three regions (Figure 3 and Table 4), based on total carbamate usage (adjusted for relative potency), location of surface water intakes of drinking water, and relative vulnerabilities of those intake watersheds to runoff. Because the distribution from the northeastern North Carolina site had the highest concentrations and frequencies of pulse loads, OPP used that distribution in the cumulative exposure assessment in this case study. Thus, the case study would reflect the impacts of drinking water exposure (surface water sources) from the most vulnerable scenario modeled in the mid-south and southeastern portion of the country.

1. Description of the Regions and Site Assessment Areas

The Southeast region includes the eastern coastal plain, piedmont, and Appalachian ridge and plateaus, extending from the Delmarva Peninsula south to the gulf coast of Alabama and Mississippi. The dominant carbamate use in this area occurs along the coastal plain from southeastern Virginia to southeastern Alabama (Figure 3). The dominant carbamate uses in the region are on cotton, peanuts, tobacco, and pecans (Table 4).

The Florida region encompasses all of Florida, and extends through coastal Georgia into southernmost South Carolina. The high-use areas are in southern Florida, around Palm Beach County and to the south, and in central Florida, around Polk County (Figure 3). In central Florida, the

dominant carbamate uses are on citrus; in southern Florida, the dominant uses are on citrus, sweet corn, sugarcane, and vegetables (Table 4).

The Mid-south region includes the lower Mississippi River valley from southern Missouri southward and the Ozark Mountain regions. The high-use areas occur on either side of the Mississippi River, in western Tennessee, eastern Arkansas, northeastern Louisiana, and northwestern Mississippi (Figure 3). The dominant use in this region is on cotton, corn, and sorghum (Table 4).

Figure 3. Southeast, Florida, and Mid-south Regions with carbamate usage and location of drinking water exposure sites.

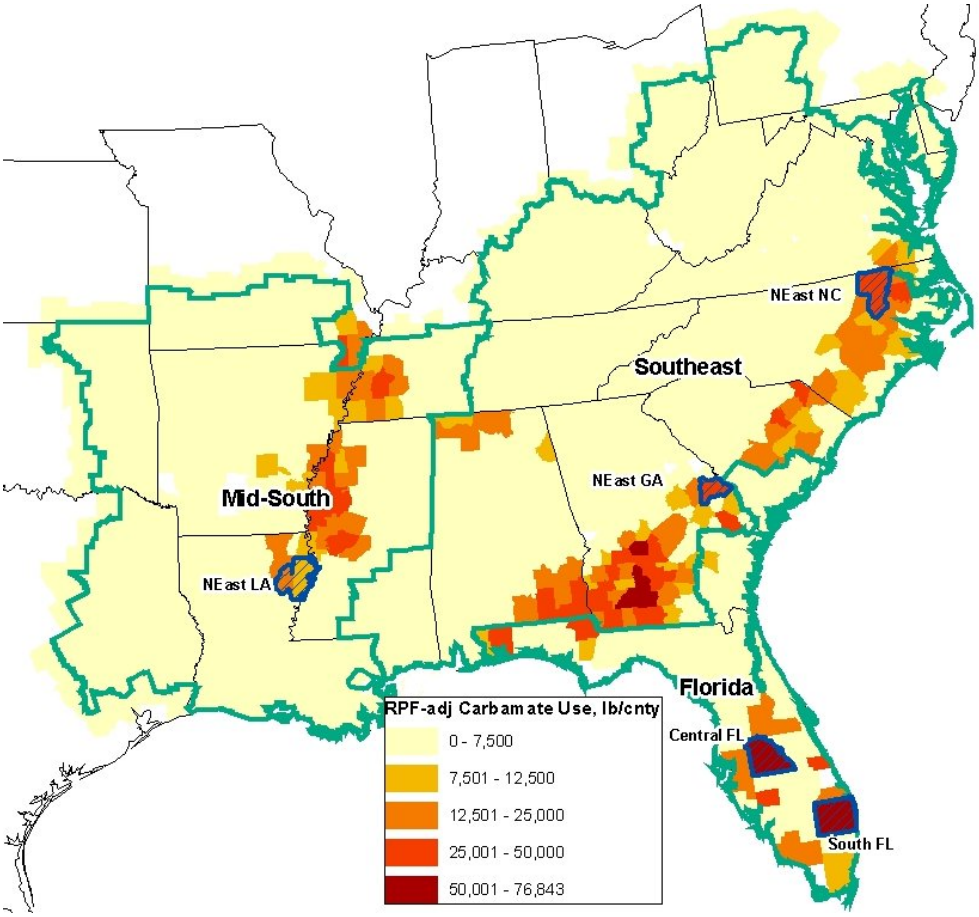


Table 4. Regional drinking water exposure sites and dominant carbamate uses.

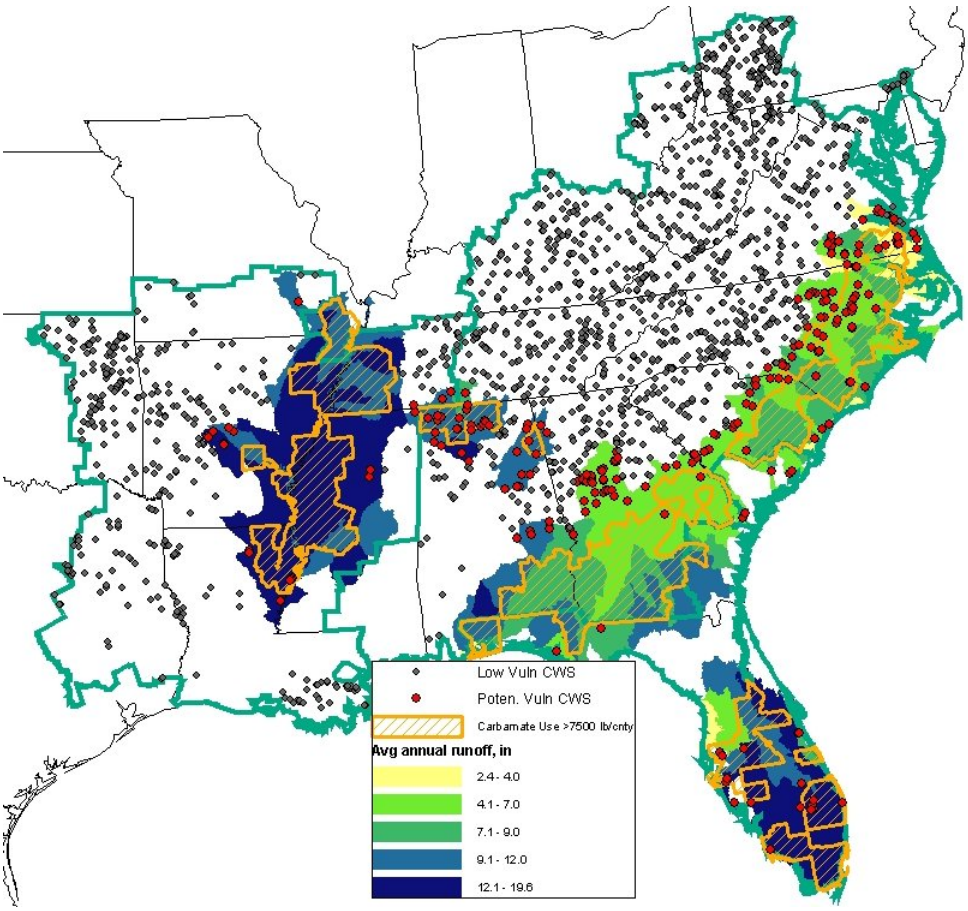
Region	Exposure scenario sites	Dominant carbamate use crops	Dominant carbamates
Southeast	Northeast NC (SW), eastern GA (SW)	Cotton, peanuts, tobacco, pecans	Chemicals A, B, C
Florida	South FL (SW), central FL (SW, GW)	Citrus, sweet corn, sugarcane, cucumber, pepper	Chemicals A, B, C, E, F, I
Mid-south	Northeast LA (SW)	Cotton, corn, sorghum	Chemicals B, C, F, I

The predominance of surface water sources of drinking water in the Southeast, Florida, and Mid-south regions occur where total carbamate use is low (Figure 4). Surface water intakes within the high carbamate use areas of the Southeast region are largely confined to the western side of the coastal plain, with more intakes to the north, in Virginia, North Carolina and South Carolina. The watersheds that are most vulnerable to runoff in the high carbamate use area tend to occur in areas where ground water is the dominant source of drinking water. EPA selected sites in northeastern North Carolina and eastern Georgia to represent the northern and southern ends of the high carbamate use areas in the coastal plain that coincide with surface water sources of drinking water.

Few surface water sources of drinking water occur in the Florida Region. However, the surface water intakes in central and southern Florida are located in high carbamate-use areas that are particularly vulnerable to runoff (Figure 4). EPA selected two sites in Florida where surface water intakes occurred in high-runoff, high carbamate use areas. The central FL site represented dominantly citrus uses; at the southern FL site, carbamate use on vegetables, citrus, sugarcane, and sweet corn accounted for more than 95 percent of agricultural usage of carbamate pesticides.

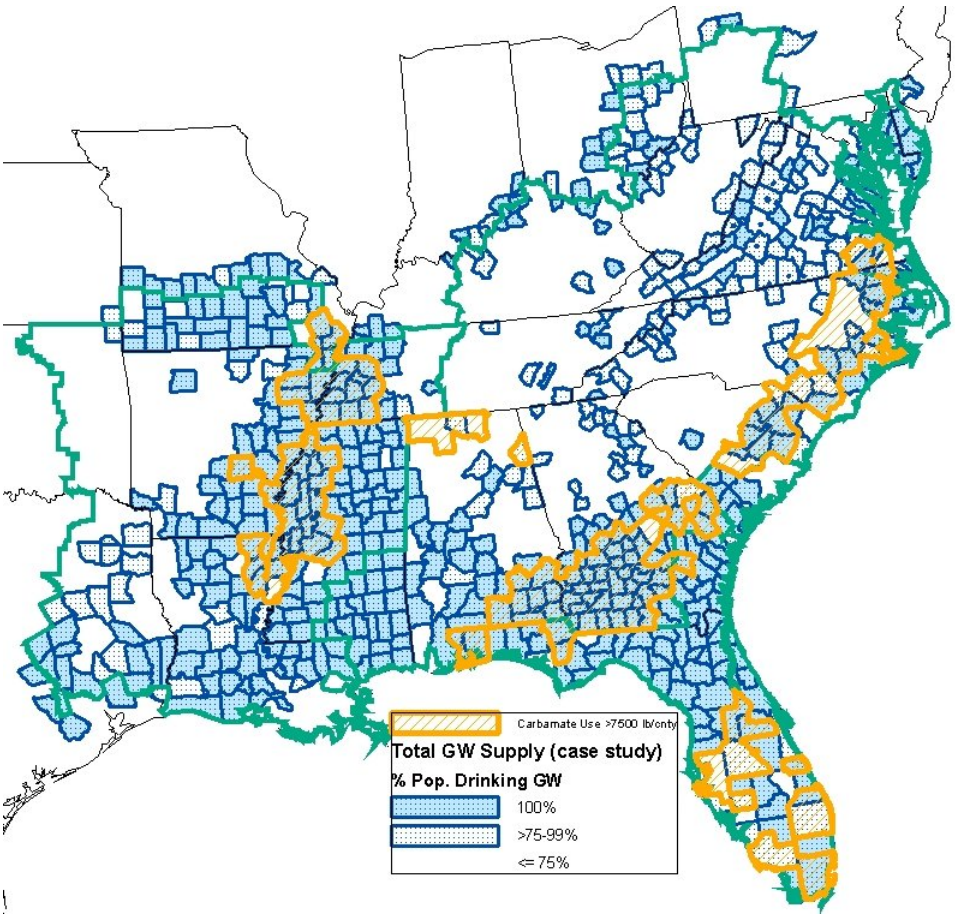
The high use area of the Mid-south has few surface water intakes, but includes the most vulnerable runoff watersheds. The Agency chose a high-use, high-runoff site in northeast Louisiana, where the intakes are surrounded by crops, with cotton, corn, and sorghum representing the dominant carbamate uses. Transport of pesticides in surface water here is complicated by levees on the Mississippi River and a system of drainage canals.

Figure 4. Location of surface water intakes in relation to carbamate usage and runoff vulnerability in the southeastern US.



The majority of the population living in the high carbamate use areas of the Southeast, Florida, and Mid-south regions obtains drinking water from ground water sources (Figure 5). In many of the counties in the high use areas, most of the drinking water comes through public ground water supplies, particularly in the Mid-south and Florida regions. In general, private wells tend to be more vulnerable to pesticide contamination than public supply wells because they are more likely to be shallower, tap into the surficial aquifers, and receive no treatment. However, the vulnerability of aquifers supplying drinking water vary greatly across and within the regions.

Figure 5. Location of high carbamate use areas in relation to predominant ground water sources of drinking water.



The high carbamate use areas in the Southeast and Florida regions overlay three major aquifers:

(1) A surficial aquifer consisting of beds of sand and shells, sand and gravel that provides drinking water in southeastern Georgia and coastal South Carolina (http://capp.water.usgs.gov/gwa/ch_g/jpeg/G008.jpeg). It also provides drinking water for private supplies in these states and Florida. Domestic wells in this aquifer are likely to be more vulnerable to pesticide contamination than wells extending into the protected, underlying aquifers.

(2) the Floridan aquifer, a highly productive carbonate rock (e.g. limestone) aquifer which is an important source of drinking water in Alabama, Georgia, South Carolina and Florida (USGS Hydrologic Investigations Atlas 730-G). In some places, the recharge areas of the Floridan aquifer can be highly vulnerable karst regions while, in areas such as southeastern Georgia, the Floridan is confined by at least 100 feet of fine sediments, which reduces the likelihood of direct contamination from the surface (NAWQA Apalachicola-

Chattahoochee-Flint River Basin study report and http://capp.water.usgs.gov/gwa/ch_g/jpeg/G055.jpeg).

(3) The Southeastern Coastal Plain aquifer is most important as a drinking water source in the inner Coastal Plain. It is separated from the overlying Floridan by a clayey confining unit in Alabama and western Georgia, which serves to retard recharge and potential contamination from the Floridan aquifer and the surface (http://capp.water.usgs.gov/gwa/ch_g/jpeg/G008.jpeg).

Ground water is also an important source of drinking water in the high carbamate use areas of coastal Virginia and North Carolina, where layers of sand are separated by clay and silt confining units into eleven aquifers. Domestic wells drawing from the unconfined surficial aquifer will be the most vulnerable to contamination. Domestic or public supply wells drawing from deeper confined aquifers are less so.

Ground water is the major source of drinking water for a significant part of the Mid-south region, north of Baton Rouge, LA, and south of western Tennessee. Ground water is derived predominantly from confined or semi-confined aquifers which underlie the entire Mississippi embayment. Significant amounts of water are also drawn from younger alluvium which occurs at the surface or under 10 to 50 feet of relatively recently deposited silt and clay. Although the alluvial aquifer is mostly used for irrigation, there is some domestic use for drinking water. The structure of the aquifer system, and the presence of multiple confining layers, reduces the likelihood of drinking-water contamination for large sections of the Mid-south region. In general, while carbamate contamination is possible, ground-water contamination with pesticides is less likely in this region than in most of the rest of the nation.

Based on total carbamate use, general aquifer characteristics, and information on relative vulnerability of the surficial aquifers to contamination from agricultural chemicals (Nolan et al, 2002), EPA selected the central Florida area (around Polk County) to use in its evaluation of ground water models for use in estimating drinking water concentrations for the carbamate cumulative case study. The results are discussed in a separate document presented to the SAP on the results of that evaluation.

2. Estimated Cumulative Distribution in Surface Water

The Agency estimated drinking water concentrations for individual carbamate pesticides and for the cumulative carbamate load (reflecting concentrations of an index chemical) for the five surface water scenario sites in the three regions included in this case study. The greatest estimated cumulative carbamate concentrations in drinking water were predicted for the northeastern NC site in the Southeast region (Table 5).

Table 5. Predicted percentile concentrations of individual carbamates and RPF-adjusted cumulative distributions in the surface water scenario sites.

Scenario site	Chemical	Crops	Concentration in ug/L 1					
			Max	99th	95th	90th	75th	50th
Southeast/ Northeast NC	B	Cotton, peanuts	1.5	0.6	0.3	0.1	0.05	0.02
	Cumulative Exposure		190	78	34	18	6.6	2.0
Southeast/ Eastern GA	A	Pecans	0.05	0.01	0.004	0.002	<0.001	<0.001
	B	Cotton, peanuts	0.4	0.2	0.09	0.04	0.01	0.003
	Cumulative Exposure		54	29	11	5.5	1.4	0.4
Florida/ South FL	B	Citrus	0.02	0.01	0.003	0.002	<0.001	<0.001
	C	Pepper, citrus, cucumber	0.1	0.02	0.006	0.003	0.001	<0.001
	E	Sweet corn, pepper, cucumber	0.6	0.3	0.2	0.1	0.07	0.03
	F	Sweet corn, sugarcane, cucumber	0.8	0.2	0.08	0.04	0.007	0.001
	I	Sweet corn	0.06	0.007	0.003	0.001	<0.001	<0.001
	Cumulative Exposure		26	6.8	3.6	2.4	1.1	0.4
Florida/ Central FL	A	Citrus	0.1	0.03	0.009	0.005	<0.001	<0.001
	B	Citrus	0.5	0.2	0.09	0.04	0.01	0.004
	C	Citrus	0.05	0.008	0.002	<0.001	<0.001	<0.001
	Cumulative Exposure		66	29	11	5.5	1.9	0.5
Mid-south / Northeast LA	B	Cotton	0.8	0.4	0.09	0.04	0.007	0.001
	E	Cotton	0.4	0.1	0.04	0.02	0.006	0.002
	F	Cotton, corn, sorghum	0.3	0.2	0.07	0.04	0.01	0.002
	I	Cotton	0.08	0.03	0.007	0.001	<0.001	<0.001
	Cumulative Exposure		103	48	12	5.1	1.3	0.2

1 Concentrations for individual chemicals are not adjusted for relative potencies while the cumulative exposure concentrations have been adjusted to index chemical concentrations.

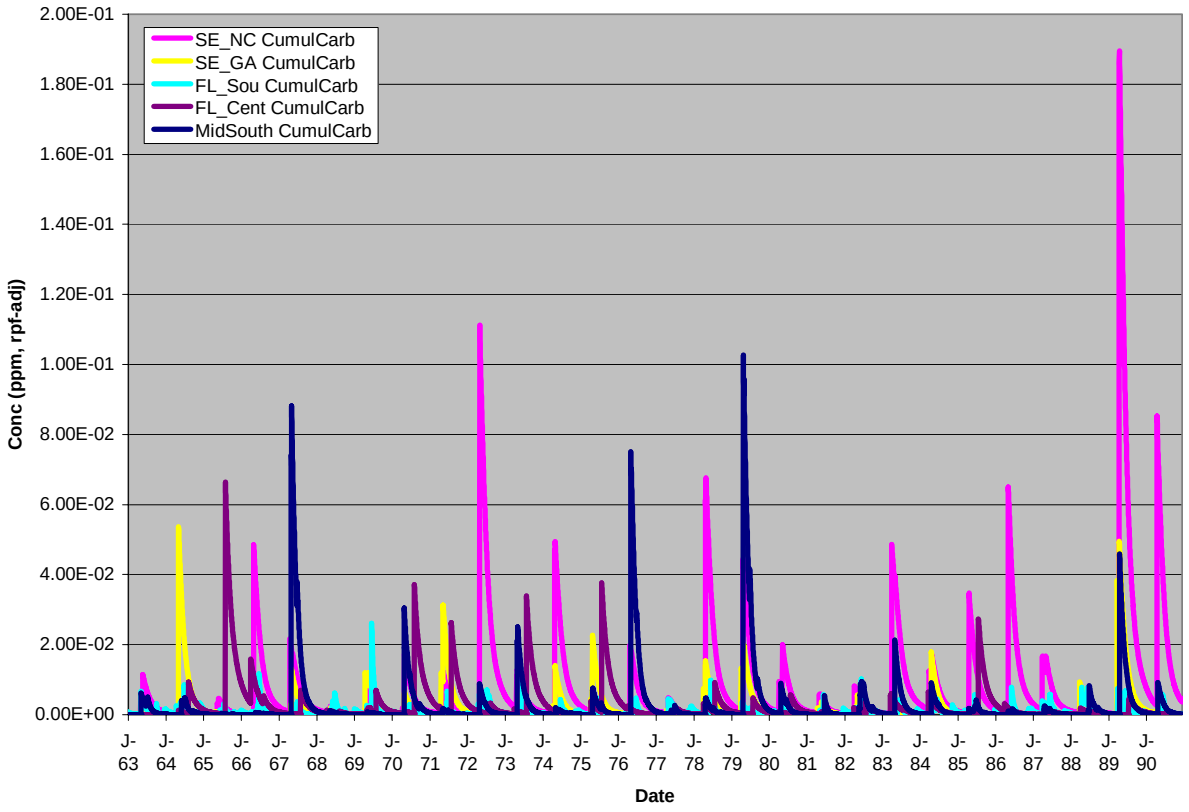
The concentrations in Table 5 for the individual carbamates represent the estimated combined exposure from all of the crops modeled for that particular pesticide. Individual carbamate exposures have not been adjusted for relative potency while the cumulative carbamate exposure in each region reflects the relative potency adjusted concentrations.

Estimated concentrations of the individual carbamate pesticides in each of the regional surface water scenario sites were in the sub-parts per billion

range. Only Chemical B reached a maximum concentration in the single parts per billion in the northeast NC site.

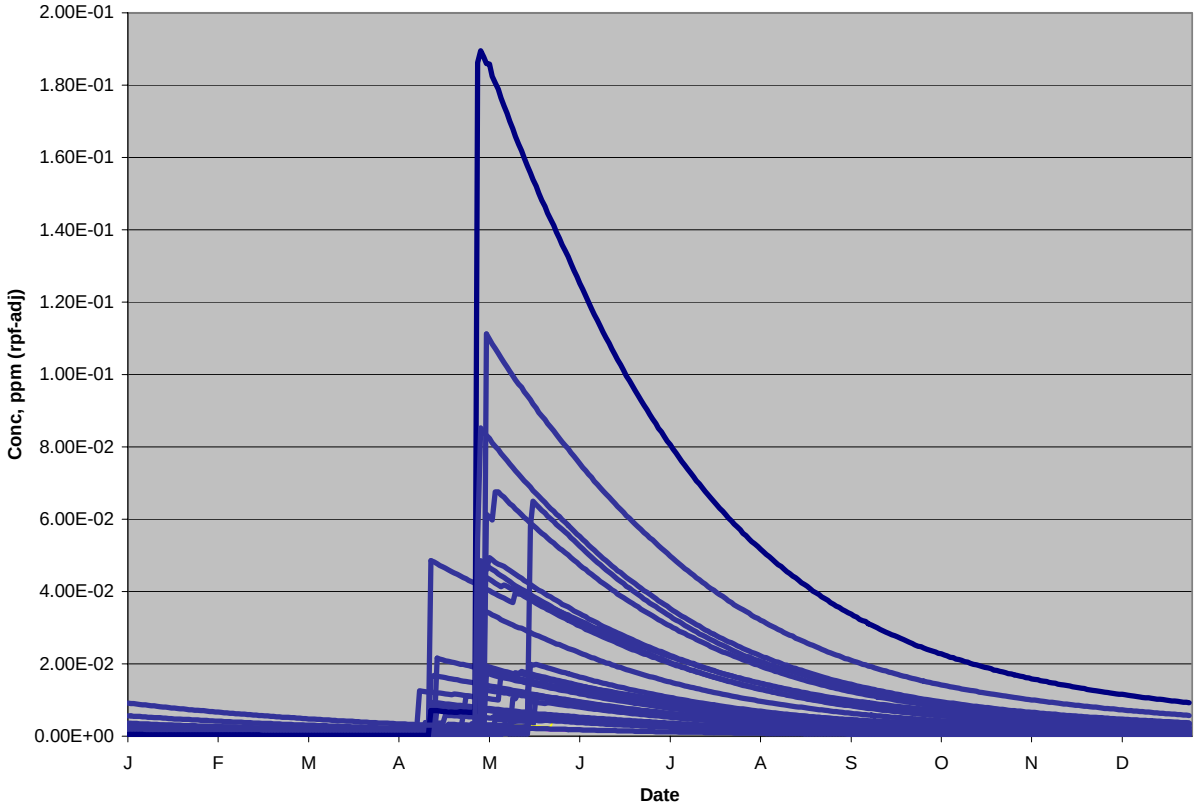
Figure 6 illustrates the year-to-year variability in predicted cumulative carbamate concentrations in surface water sources of drinking water. For the exposure assessment, pesticide usage (amount, frequency, timing) was held constant so the variations reflect the range in variability in pesticide concentrations based on weather patterns over time.

Figure 6. Estimated cumulative carbamate distribution in surface water at the five regional scenario sites.



The seasonal trend of pesticide exposure for the northeastern NC scenario site is illustrated in Figure 7. The aggregated cumulative exposure to humans will reflect this seasonal pattern, with the greatest exposures from drinking water occurring in late spring and summer (May-July), dropping to negligible levels during the rest of the year.

Figure 7. Seasonal trend in cumulative carbamate concentrations in surface water in the Southeast Region (30 years of weather). Each line represents the time series over a single year.



3. Estimated Cumulative Distribution in Ground Water

The estimated cumulative carbamate distribution in ground water will be derived using one of the models presented in a separate document submitted to the SAP. Depending on the recommendations of the SAP, EPA will use one or more of the models discussed in the evaluation paper to generate estimated concentrations over time for combined carbamates in ground water sources of drinking water.

E. Characterization of Drinking Water Exposures in the Case Study

The regional water exposure assessments are designed to represent exposures from typical carbamate usage conditions at one of the more vulnerable surface watersheds in the region. Each regional assessment focuses on areas where combined carbamate exposure is likely to be among the highest within the region as a result of total carbamate usage, adjusted for relative potencies, and vulnerability of the drinking water sources. In this manner, OPP is confident that if the regional cumulative risk assessment finds that exposure in water is not a significant contributor to the overall carbamate exposure, it will not be a significant contributor in less vulnerable areas in the region. However,

because the assessment is based on typical usage, it is not a high-end estimate of pesticide exposure at that vulnerable site.

In this case study, the surface water exposure site in northeastern North Carolina had the highest predicted carbamate cumulative concentrations of the five sites for which predicted concentrations were generated. When the drinking water component was combined with the food and residential exposure routes in the cumulative assessment, the highest seasonal exposures from surface water sources of drinking water were approximately an order of magnitude less than those estimated for food or for the total carbamate exposure from all routes. For most of the year, predicted exposures from drinking water were much lower.

Although a detailed comparison of the estimated concentrations from individual carbamates with available monitoring has not been done for this case study, very preliminary comparisons indicate that this assessment is by no means worst case or unrealistic. The estimated peak concentrations for Chemicals B, C, and E were similar to the maximum detections reported in the USGS NAWQA program. Estimated peaks for Chemicals A and F were roughly an order of magnitude less than the maximum reported detections from NAWQA. A more extensive comparison of estimated carbamate concentrations with monitoring data will be conducted for the preliminary carbamate cumulative risk assessment to be released in 2005.

The discussion that follows characterizes the results of the regional water exposure distributions, and identifies assumptions and approaches to the assessment that might impact the level of certainty in the results.

1. What Each Regional Site Represents

Each region in the assessment is represented by a geographic area with the highest apparent potential for cumulative exposure to carbamates in drinking water. This was done by identifying drinking water source in each geographic area where relatively high usage of multiple carbamate pesticides coincided with watershed or aquifer properties that would facilitate the movement of pesticides to the drinking water source.

Because the selection process took into account the relative potencies of the carbamates pesticides, the sites used for the initial drinking water exposure estimates are biased toward the areas in which the more toxic carbamates are used. Since the purpose of the assessment is to identify the impact from multiple carbamates occurring in water in the same area, the area(s) selected for the assessment do not necessarily represent the highest exposure of a single chemical, but rather the highest multiple carbamate exposure within the region. Since pesticide use may vary from year to year and cropping and usage patterns may change, some areas in other parts of the region may have greater water exposure in a given year.

2. What the Models Represent

For the surface water sources of drinking water, OPP used PRZM/EXAMS to predict pesticide concentrations in a small reservoir. This modeling approach makes certain assumptions regarding the nature of the drinking water source, the watershed, and year-to-year variability.

The reservoir used for the exposure assessment is based on the specific geometry (watershed and reservoir size) of an actual reservoir (Shipman City) in the Midwestern US. As such, it may best represent potential transport to similar drinking water sources in high rainfall areas such as the midwest and eastern U.S. It may not so well represent reservoirs in drier parts of the west, where inflow and outflow are artificially managed. In addition, while the reservoir scenario will not necessarily reflect short pulses of higher concentrations found in flowing rivers and streams, long-term average concentrations in a reservoir may be greater than in streams because of differences in the residence time for water in these water bodies.

PRZM is not a basin-scale model, but a field-scale model which estimates edge-of-field pesticide loads in runoff from a 172.8-hectare watershed into a 5.3-hectare reservoir (144,000 m3 volume) simulated by EXAMS. PRZM does not explicitly account for the relative contributions of each field to the reservoir. OPP used a cumulative adjustment factor (a combination of the regional percentage of the total watershed area in crops with carbamate uses and the percentage of acres treated by each carbamate on each crop) to adjust the resulting reservoir concentrations calculated by EXAMS. Further information on the assumptions involved in applying Percent Crop Area (PCA) factors for drinking water assessments of individual pesticides can be found in the science policy paper, "Applying a Percent Crop Area Adjustment to Tier 2 Surface Water Model Estimates for Pesticide Drinking Water Exposure Estimates" (USEPA, 2000).

PRZM does not account for location in the watershed: all fields are assumed to be uniformly distributed within the watershed, with runoff going directly into the reservoir. Each crop use simulated in PRZM assumes that the entire area of the watershed planted in the crop consists of a single soil. In each of the regions, OPP used actual soil data from local soils on which the crops are grown. When possible, the soil selected for each scenario was a benchmark soil that was prone to runoff (classified as hydrologic group "C" or "D" soils). While OPP attempted to simulate soils that might be prone to runoff, the emphasis in developing the scenarios was to choose important local soils for which sufficient data are available, and which are know to be used to grow the crops of interest. These soils may not represent those most prone to runoff, but afford reasonable certainty that the simulation represents local soil conditions. While an assessment using a single soil assumes that each part of the

watershed will be equally vulnerable to runoff, areas of higher and lower runoff vulnerability will exist in an actual watershed.

Because the application rates, frequencies, and timing are held constant, the PRZM/ EXAMS simulations over multiple years evaluate the impact of the variability in precipitation on the amount of pesticide that reaches surface water. Because weather data spanning 30 years is available for many locations across the country, PRZM/ EXAMS can account for pesticide runoff from a wide range of weather patterns not otherwise possible with monitoring studies that span relatively few years. The age of the data (1961 to 1990) limits OPP's ability to compare of the modeling output to more recent monitoring data.

Weather data files for PRZM are available for weather stations across the country. The weather station nearest to the county or counties used for the simulations was chosen for the cumulative assessment. To the extent that precipitation in these counties over the period of record might have been greater or less than that recorded at the nearest weather station, runoff for that area may have been over- or underestimated by PRZM.

3. What the usage information represents

Typical application rates and frequencies for each carbamate pesticide on each crop were generated by taking the average (spanning multiple years) of agricultural chemical usage surveys. This assumes that all applications were made at this typical or average rate and that frequencies of applications were constant year to year. The assessment considered only yearly variations in weather, and not variations in application rates. Thus, using these typical application rates and frequencies may underestimate water concentrations in years when pest pressure is higher than in our reported years and may overestimate in years when lower amounts of pesticide is used. The usage data was generally not sufficient to conduct a probabilistic assessment over a distribution of actual application rates.

In the OP cumulative risk assessment, the agency compared cumulative OP distributions estimated using the average application rates with those estimated using maximum label rates. The difference in estimated cumulative distributions between all typical and all maximum rates ranged from no difference in all but the lowest percentiles in Florida to a factor of 2 to 4 times greater at the higher percentiles (95th and above) in the Southeast and Mid-south Regions (USEPA OPP, 2002). EPA plans to conduct a similar comparison for the carbamate assessment.

The regional percent crop area (PCA) factors are based on a large area: the size of the hydrologic units (average > 1000 square miles) used

generally span multiple counties and may contain several watersheds that supply drinking water intakes. These regional PCAs represent the aggregation of crop areas from county-level NASS data and assume that the cropping area is uniformly distributed. However, cropping intensity is variable and smaller watersheds, including those capable of supporting drinking water supplies, may have a much higher percentage of crop land than the rest of the large basin.

The typical application rates and percent acres treated are derived from state-level data and assume uniform use practices across the state. Indeed, an uneven distribution of application rates and percent acres treated is expected in response to differing pest pressures. This assumption will underestimate areas where pest pressures may dictate a higher percentage of acres treated in a given year; similarly, it will overestimate areas where low pest pressures will require fewer acre treatments.

OPP used crop profiles and other relative crop production publications to establish a window for the application date of the pesticide on a particular crop. This window doesn't necessarily reflect the range over which a pesticide will be applied in a particular year, but captures the year-to-year variation in the application dates over time. Thus, in any given year, the timing of application may be clustered within a shorter time-frame than suggested by the application window. However, because of weather and other environmental factors, the timing of intensive pest pressure and/or pesticide application may vary across the window.

The date of application can have an effect on the predicted concentrations generated by PRZM/EXAMS, depending on how near in time the pesticide application coincides with rainfall events in any given year. OPP evaluated the impact varying the dates of application across the application window on the OP cumulative distribution (US EPA OPP, 2002). The impact of varying dates of application was most evident at the extremes in the distributions. The ratio in maximum concentrations between the lowest and highest estimates was a factor of 5 to 6. For 99th and lower percentiles, the differences were not as dramatic, with the ratio between lowest and highest values generally two or less. This analysis only looked at the cumulative OP distribution and did not evaluate variations in individual chemical distributions.

In the absence of data to show otherwise, OPP assumed that all of the pesticide applied on a particular crop is done on the same date. While this may be an unreasonable assumption for a large watershed, it is not unrealistic for the size of the watershed used in this assessment. This assumption may result in higher peaks, but similar overall average concentrations than if applications are spread out over time. The resulting estimate of exposure may result in a small overestimation bias in the results that will be greater in large than in small watersheds.

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