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II.D. Appendices: Drinking Water Exposure

7. Ground Water Exposure Assessment

Based on the February 2005 SAP, the Agency revised the groundwater modeling effort to incorporate recommendations regarding model scenario set up and evaluations against monitoring data. The major modeling change relates to the way groundwater concentrations are calculated. Previously, OPP proposed to use only unsaturated zone pore water concentrations, as this was a readily available output from the models. In this revision, OPP has made modifications to the model scenario set up in order to capture spatially averaged saturated zone concentrations. In this way, the models should deliver more reasonable estimates of concentrations that may be found in drinking water in rural private wells. This altered conceptualization, as well as other details of the scenarios, is described in the sections that follow.

Preliminary results of the model output are given, and where possible this output is compared to monitoring data.

A. Groundwater Scenario Model Overview

Figure II.D.7.1 depicts the conceptualization of the groundwater scenario which evolved from the advice of the February 2005 SAP. In this conceptualization, the pesticide is applied to the soil surface (or plant canopy) and precipitation or irrigation drive pesticide through the soil profile and into a saturated zone. Transport processes are simulated with three models—PRZM, RZWQM, and LEACHP—with each model performing the simulation calculations differently (FIFRA SAP, 2005). Particulars of the model setups used to perform these calculations are described below.

All models simulated a shallow unconfined aquifer with a water table at 3.5 m below the surface. Well screen length was assumed to be 1 m, starting at the water table and extending to 4.5 m. The well concentration was calculated as the average pore water concentration across the length of the screen. The models were set up to deliver the average pore water concentration in the 'saturated' soil profile from 3.5 to 4.5 m. This was accomplished by means depending upon the models' capabilities, as described later.

The well depth was chosen to ensure reasonable conservativeness in the assessment and acceptable runtimes in the models. Furthermore, as some preliminary simulations have shown, well depth does not have a critical influence in these proposed scenarios. This is because the predominant means of degradation occurs in the top 1 meter of the profile (see below), and dispersion effects that would be influenced by depth are considerably damped by using the 1-m spatially averaged concentration for output.

The models consider that degradation rates change through the soil profile. In general it should be expected that faster degradation occurs in the top of the profile and

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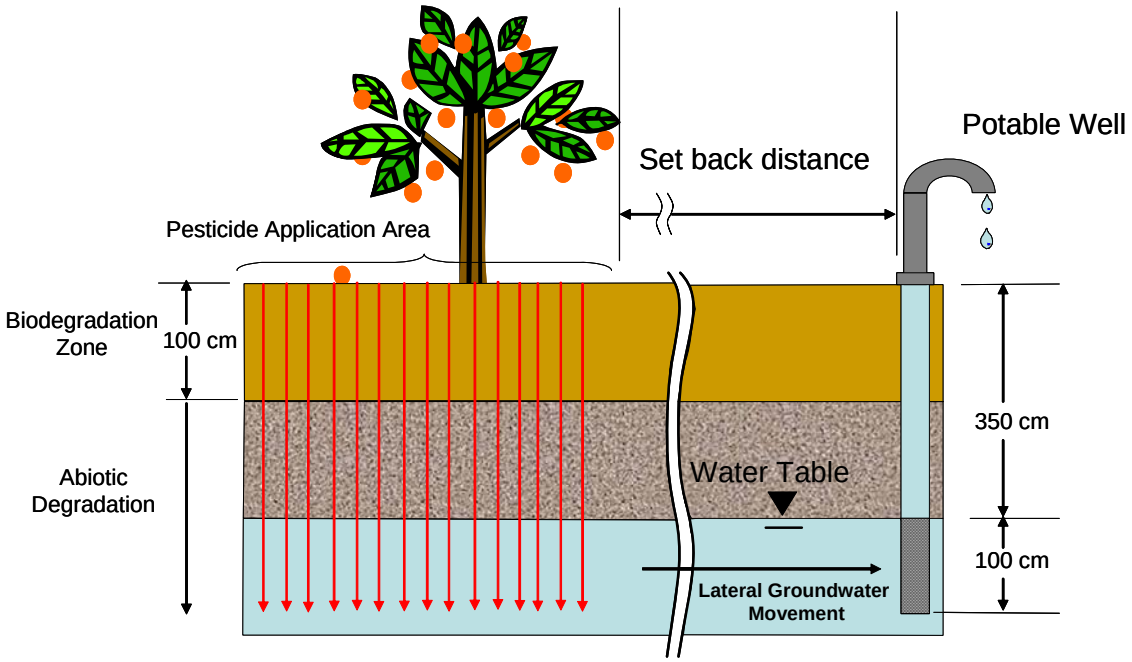
decreases at lower depths. OPP used the pesticide aerobic soil metabolism rate for the top 25 cm, and a linearly declining rate with depth to 1 m, below which only abiotic processes were in effect. The pesticide may degrade in the upper reaches of the soil profile by both abiotic and biotic processes and in the lower reaches and aquifer by abiotic processes only (Figure II.D.7.2). This is consistent with the default arrangement in the RZWQM model and is roughly equivalent to configurations used by Health Canada and the European FOCUS group (see section on FOCUS below). Also, temperature and soil water content (as they affect degradation) can be accounted for in LEACHP and RZWQM, but this function does not currently appear to be operating correctly in PRZM.

For some pesticides, well setbacks (Figure II.D.7.1) are specified by state or federal regulations. For such cases, the additional travel time for a pesticide to reach a drinking water well and the degradation that occurs during that time is taken into consideration by a plug flow model, as described later.

II.D.7. 1 - Depiction of general groundwater scenario concept for estimating pesticide concentrations in drinking water.



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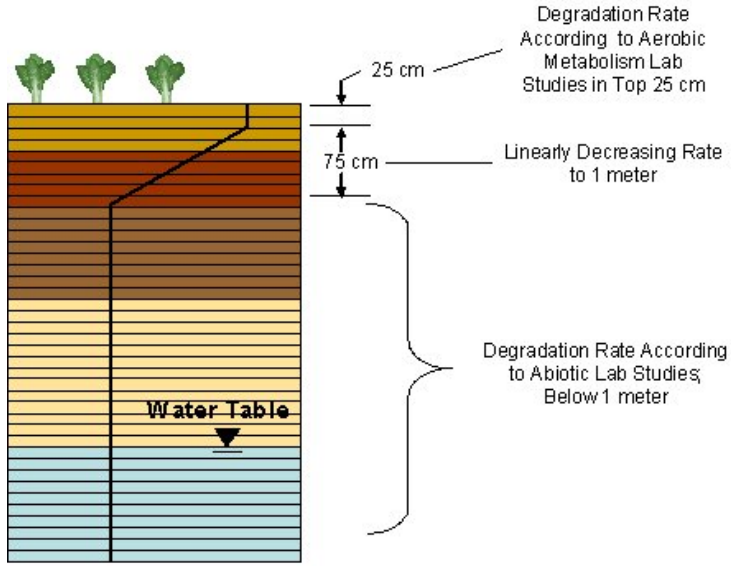
II.D.7. 2 - Conceptual model illustrating pesticide degradation through the soil and vadose zone.



B. Implementation of the Models

With the exception of LEACHP, the application of a fixed saturated zone is beyond the usual application of these models. Thus some background investigations were required for these models to be parameterized for the conceptual model. This section describes the unique manners in which each of these models was parameterized in order to fit this conceptualization.

1. PRZM

Although PRZM was not originally developed to simulate saturated conditions, a review of the model's structure and coding showed that saturated conditions could be effectively simulated by redefining the field capacity parameter. Soil compartments in PRZM are maintained at "field capacity" unless losses occur by evapotranspiration. Below the zone of evapotranspiration (which occurs at the bottom of the defined root zone), PRZM maintains water at field capacity. Thus, a saturated zone can be created in PRZM by setting the field capacity parameter (called THEFC in PRZM) to equal the porosity. By doing this, a constant water table can be created (Figure II.D.7.3). Output concentrations are taken as the spatial average over the depth from the top of the saturated zone (at 3.5 m below soil surface) to 1 meter below the water table. Depending on rainfall and evapotranspiration characteristics of the particular scenario, this spatial averaging effectively represents temporal averaging of from 6 months to greater than one year (i.e., 1 meter of water infiltrating into the water table takes from 6 months for Florida citrus scenario to greater than a year for Washington potato scenario).

Irrigation, when required by a scenario, is handled according to recent OPP guidance on PRZM irrigation (memo from D. Young and M. Corbin to the OPP Water

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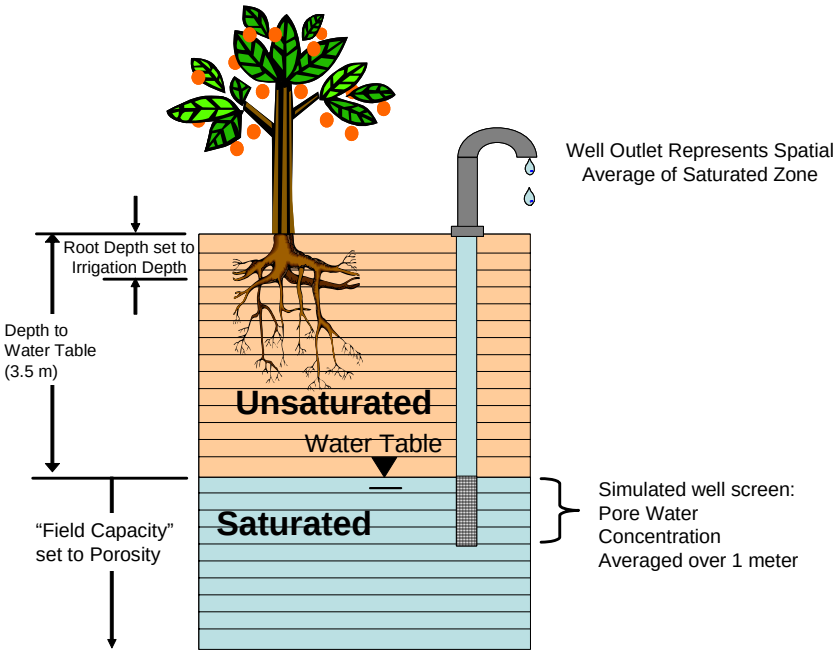
Quality Tech Team, July 2005). This guidance suggests that PRZM has only two appropriate ways to handle irrigation—either above the canopy or beneath the canopy. Other forms of irrigation listed in the PRZM manual were deemed inappropriate due to hydrologic improbabilities. In addition, because the quantity of irrigation water is coupled to root zone depth in PRZM, rooting depths were set to irrigation depths rather than actual rooting depths. This is especially important for deep-rooting orchard crops for which irrigation water is only applied to satisfy water demand in the upper most soil layers (otherwise, if rooting depth were set to 2 meters as in citrus irrigation, water would be unrealistically applied to satisfy the entire 2 meter depth).

II.D.7. 3 - PRZM scenario to simulate a fixed water table. Note the two unique adjustments to PRZM groundwater scenarios: 1) "Field capacity" set to porosity to simulate a saturated zone, and 2) root depth set to irrigation depth to ensure proper irrigation.



2. RZWQM

The current version of RZWQM, like PRZM, was not designed to handle a constant depth saturated zone (although USDA is currently revising RZWQM to handle this condition). Therefore, OPP set up tile drains and head gates to mimic a near-constant water table depth. This is shown in Figure II.D.7.4. In developing the scenarios, the tile drain spacing, lateral conductivity, and drain diameter were adjusted so that a water table formed just above the head gate, thereby giving some flow out of the drain at all times. Concentrations out of the drain are calculated in RZWQM by taking the average concentration of the overlying saturated zone (from tile drain to top of water table). This method of calculation is fortuitous in that this is the concentration that one would expect from a well screened from the water table to 1 meter below the water table. This is especially fortuitous because RZWQM does not offer any other simple means to calculate spatially averaged concentrations. We note that USDA-ARS has not completely agreed with manipulation of RZWQM in this way, but they have not discounted it. The set up is

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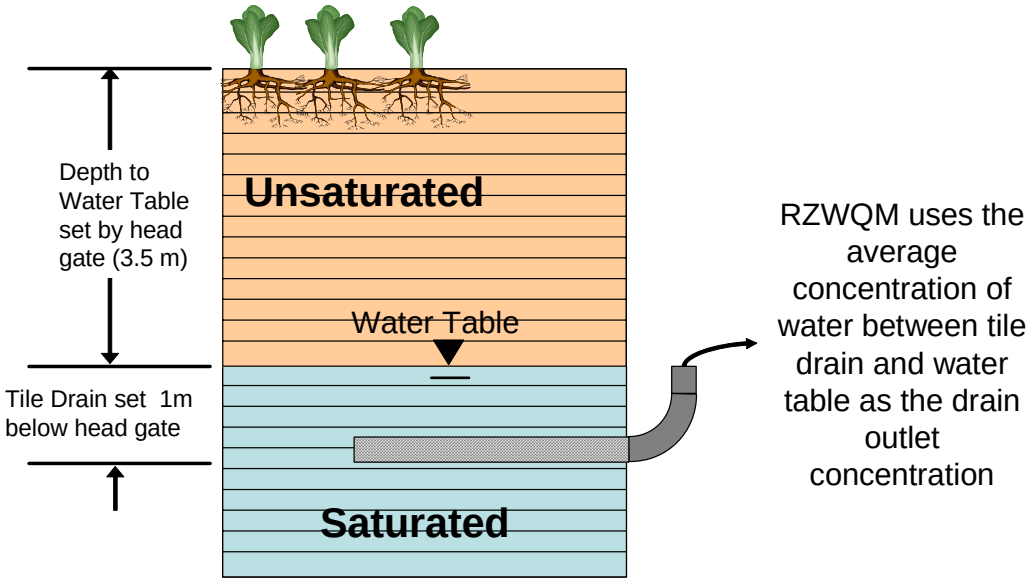
currently being evaluated by USDA-ARS, and it is likely that ARS will be able to modify RZWQM to handle a fixed water table condition.

Irrigation in RZWQM is handled much the same as in PRZM, in that root zone depth is the depth at which soil moisture depletion is considered. Root zone depth was set equal to the desired depth of irrigation, as it was in PRZM.

II.D.7. 4 - Formation of relatively constant water table in RZWQM using tile drains and head gate. Note that tile drains and head gates do not actually represent their physical usage, but rather are implemented as a means to control the lower boundary condition.



3. LEACHP

Unlike the other models, LEACHP allows for a constant water table depth as a part of its normal functioning. Thus no special manipulations were required in this regard.

LEACHP uses the Richard's equation to simulate water movement. Five options are available to estimate soil water retention (water content vs. matric potential) and hydraulic conductivity (water content vs. hydraulic conductivity). The method used is option 5 (Rawls and Brakensiek, 1985) which is based upon US soils, and considers as independent variables particle size distribution (percent sand, silt and clay), soil organic matter, and, soil bulk density.

The automatic irrigation option was used. A *name.sch file which requires the depth where the soil water sensor is located (100 mm), the threshold matric potential (-100 kaP) which triggers irrigation, and the replenishment depth (100 cm) was created.

4. Well Setbacks

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In some cases, well setbacks are required by federal or state regulations. These setback requirements specify the nearest distance to a well that a pesticide can be applied. For such cases, the additional travel time to the well allows for additional degradation. Reductions in concentration are calculated in these assessments by a plug flow approximation as follows:

$$\frac{C}{C_0} = \exp\left(-\frac{L}{v}k\right)$$

where C = concentration at well [mass/volume]
C_0= concentration at point of application [mass/volume]
L = well setback distance [length]
v = lateral groundwater velocity [length/time]
k = degradation rate in aquifer [$time^{-1}$]

The travel time of the groundwater used in these scenarios is much shorter than travel time would be if only the pumping-induced gradient (cone of depression) of a private drinking well was considered. OPP made conservative estimates regarding natural, topographically/stratigraphically-driven groundwater lateral velocities (e.g., velocities determined by elevation head and hydraulic conductivity of the substrate). As an example, consider the travel time through a setback for unretarded chemicals without regard to additional head induced by well pumping, which can be estimated by

$$t_n = \frac{r}{v}$$

where r = setback radius
v = natural lateral groundwater velocity
t_n = travel time of unretarded solute due to natural gradient

The travel time of an unretarded chemical when only pumping-induced hydraulic gradient is considered is determined from (see for example USEPA 1993):

$$t_w = \frac{r^2 \pi \theta L_s}{Q}$$

where θ= aquifer porosity
L_s= screened length of well
Q = flow rate
t_w = travel time of unretarded solute

For setback estimations, OPP assumed a high lateral velocity of 0.15 m/day, which is the typical high end velocity that Russell et al. (1987) reported in the Central Ridge of Florida. For a 50-ft setback, travel time is about 100 days due to the natural topographic gradient (elevation head). To determine the well-induced travel time (caused by gradient changes due to well drawdown), OPP assumed that a typical family uses 101 gallons per day (0.28 m^3/day) (American Water Works Association estimate), a 1-m screened well, and a porosity of 30%. For a 50 foot setback, the well-induced travel time

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is 570 days; the natural gradient travel is 17% of the well-induced travel time, which is well within any reasonable expectation of the error within such calculations. For 1000-foot setbacks, the natural gradient travel time is less than 1% of the well-induced travel time. Thus OPP neglected the velocity effects caused by private rural wells because of their insignificance.

C. Standard Generic Scenarios

OPP developed four groundwater scenarios for the Carbamate Cumulative assessment (Florida citrus, Georgia peanuts, North Carolina cotton, and Washington potato), and applied a consistent set of rules to establish a protocol. This selection process primarily involved selection of the soil characteristics, selection of the weather, and selection of appropriate crop management practices.

The most appropriate soils for each crop were selected by consulting the USDA Soil Data Mart (http://soildatamart.nrcs.usda.gov/). In cases where crops were likely to be grown on multiple soils in a region, the most vulnerable of the likely soils were chosen, as characterized by the soils hydrologic group (A, B, C, or D), hydraulic conductivity, and organic matter content. Soil properties were taken from the Soils Data Mart and transformed into appropriate input parameters for each of the models.

Weather inputs were selected to represent the weather in closest proximity to the scenario location. In the case of RZWQM, weather was generated from CLIGEN, which is an integral part of RZWQM. For PRZM and LEACHM, 30 years of historical data was used as obtained from the EPA Office of Research and Development (http://www.epa.gov/ceampubl/tools/metdata/index.htm).

Specific management practices that might affect pesticide transport were included in the models in those cases where the practices were likely to significantly affect pesticide transport. Significant practices that were included were the pesticide application method and the application of irrigation water. Variations in tillage practices were ignored in the development of these scenarios, as characterization and parameterization of such practices are difficult and would be speculative. Irrigation and pesticide application practices were developed for the models after consultation with agricultural extension agents, review of open literature, and pesticide label information.

For this carbamate cumulative assessment, the four scenarios developed by OPP (described in section 1D of the main document – see above) were intended to represent high carbamate use in areas of high groundwater vulnerability, and are discussed below.

1. Florida Citrus

Most citrus production occurs on Florida's Central Ridge. Polk County is typical of the Ridge and has the highest acreage (101,000 acres in year 2000) in citrus production in Florida (Obreza and Collins 2002). Groundwater in this region is particularly

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vulnerable to pesticide contamination due to the high water table and sandy soils with low organic matter content. For these reasons, OPP chose the Polk County area as representative of a typical highly vulnerable Florida citrus area. Figure II.D.7.5 shows the approximate vicinity of the Florida citrus scenario. Additionally, the choice of this location is benefited by the availability of several ground water studies (e.g., Jones et al. 1987; Hornsby et al., 1990, FL DEP 2005, USGS 2005), which will allow some evaluation of the scenario modeling performance.

II.D.7. 5- Location of FL citrus scenario. The circle indicates the approximate vicinity.

a. Soil

Citrus grows in the Entisols on the Florida Ridge which are characteristically low in organic matter content and drain water quickly. Typical soil series used for citrus production in Polk County are Candler, Tavares, and Astatula (Obreza and Collins, 2002). These soils are predominantly sand (>97%) and have a low organic matter content (0.5 to 2 percent; US Soils data mart). In mature citrus groves, organic content is even lower (0.5 to 1 percent; Obreza and Collins, 2002). Some salient features of these soils are given in Table II.D.7.1. These soils are all in the Hydrologic Group A, meaning there is negligible runoff.

Table II.D.7.1. Soil Properties Candler Series

Soil Series	Horizon2 (cm)	Texture	Sand1	Silt1	Clay1	Saturated Hydraulic Conductivity 1 in/hr	Organic matter1 (%)	Field Capacity1	Moist Bulk Density2	Avail. Water Capacity (in/in)	pH

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Table II.D.7.1. Soil Properties Candler Series

Soil Series	Horizon2 (cm)	Texture	Sand1	Silt1	Clay1	Saturated Hydraulic Conductivity 1 in/hr	Organic matter1 (%)	Field Capacity1	Moist Bulk Density2	Avail. Water Capacity (in/in)	pH
Candler	0 -80	Sand	97.5	1.25	1.25	6-50	0.5 - 1.0	0.025-0.058	1.35-1.55	0.04-0.08	4.5-6
Tavares	0-8	Sand	97	1.5	1.5	7-39	0.5-1.0	0.025-0.05	1.25-1.6	0.05-0.10	3.6-6
	8-80	Sand	97	1.5	1.5	7-39	0-0.5	--	1.40-1.70	0.02-0.05	3.6-6
Astatula	0-7	Sand	98.5	0.75	0.75	9-85	0.5-1.0	0.025-0.05	1.25-1.55	0.04-0.10	4.5-6.5
	7-80	Sand	98.5	0.75	0.75	9-85	0-0.5	--	1.45-1.60	0.02-0.05	4.5-6.5

[1]Obreza and Collins, 2002
[2]USDA Soils Data Mart

b. Irrigation

Central Ridge has relatively high rainfall (~50 inches/year), but irrigation is necessary because of high drainage of the characteristic sandy soils on the Central Ridge. Because of the high sand fraction and the associated low water holding capacity, irrigation water management is difficult. As a result, microirrigation is commonly used, supplying only enough water to satisfy the tree demand (Smajstra and Harman, 2002; Parsons and Morgan, 2004). Microirrigation typically supplies 10-20 gallons/hour spread out over a 10- to 18-ft area, with durations of about 4 hours. Typically, microirrigation is set to satisfy water in the range of 1 to 2 feet below the surface, with irrigation events occurring about twice per week in the spring and up to 3 times per week in the summer (communication L. Parsons, South Florida Agricultural Extension Office). During the spring, soil moisture depletion should be no less than 1/3 of the available water capacity (AWC), while during the remainder of the year, up to 2/3 of the available water capacity can be depleted without severe effects (Boman et al., 2002). Irrigation at 50% of AWC was assumed for modeling.

c. Citrus Production and Crop profile

About one-half of citrus in Florida is grown on deep (Central Ridge), sandy soil using the unbedded tree row production technique. The remainder is grown on heavier and wetter soils in Florida Flatwoods. Citrus on the Central Ridge is planted along the natural contour. No leveling is required for the Entisols because of their natural drainage (Obreza and Collins, 2002). Although Ridge citrus roots can penetrate as deep as 15 feet, most of the roots are in the top 3 feet. Because rooting depth is coupled to the depth of irrigation in all of the transport models, rooting depth in the models should be set to the appropriate depth of irrigation (~2 feet in the case of Ridge citrus).

d. Water Table and Aquifer Characteristics

The water table in the region has an upper limit 3.5 to 6 feet below the surface (USDA Soils Data Mart). The upper limits are generally reached in the winter months (January to December). Typical depths may be considerably deeper. For example in the

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groundwater study conducted by Hornsby et al. (1990) in this area, water table depths were reported to be greater than 20 m. In the study of Jones et al (1987), depths of 4 m were reported.

Jones et al (1987) reported that a representative typical high lateral groundwater velocity in the Ridge area was 0.15 m/day. They also observed that the pH of the groundwater was typically 4.5, with a range of 3.5 to 6, and temperature of 20 to 25 C. The USGS Lake Wales Ground Water Monitoring Study (http://fisc.er.usgs.gov/Lake_Wales_Ridge/) reports surficial aquifer pHs in the range of 4 to 7 (median 4.9).

2. GA Peanuts

The southern part of Georgia is an area of prime farmland, suitable for field and row crops. Crops grown in this region include cotton, peanuts, beans, fruit, tobacco, potatoes, sweet potatoes, grain corn, and melons among others. Peanuts were chosen as the representative crop because Georgia has the highest peanut acreage in the U.S., and acreage within Georgia is primarily concentrated in the southwestern part of the state. This area, lying in the Southern Coastal Plain, has shallow groundwater that is susceptible to contamination (Donohue, 2001) and is used for drinking water in some cases (Crandall and Berndt, 1996). For these reasons, OPP chose the area in Figure II.D.7.6 for scenario development. In addition, a prospective groundwater study was conducted in this area (MRID 43099601) which allows some evaluations regarding the suitability of the scenario parameterization.

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II.D.7. 6- Location of the southern Georgia scenario. The circle indicates the approximate vicinity.

a. Soil

Based on soil data from Cook and Colquitt counties (Soil Data Mart, USDA, 2005; Ma et al., 2000), at the center of the relevant region (Figure II.D.7.6), Tifton loamy sand is the dominant soil (23.9% of coverage in the region) and is also a prime farmland soil. Tifton is a very deep, well drained soil on uplands. The subsoil is loamy and extends to a depth greater than 5 feet. Plinthite occurs below a depth of 30 to 50 inches. Ironstone nodules are present throughout the soil. Permeability is moderate throughout the subsoil. Available water capacity is moderate. Some properties of this soil that are relevant for pesticide transport modeling are listed in Table II.D.72. This soil falls into the Hydrologic Group B.

Table II.D.7.2. Soil Properties of the Southern Georgia Scenario

Horizon (cm)	Texture	Saturated Hydraulic Conductivity (µm/s)	Organic matter (%)	Moist Bulk Density	Available Water Capacity (in/in)	pH
0 -25	Loamy sand	42 - 141	0.5 - 1.0	1.3 - 1.55	0.03 – 0.08	4.5 - 6.0
25-46	Fine sandy loam	42 - 141	0.5 - 1.0	1.45 - 1.65	0.08-0.12	4.5 - 6.
46-83	Gravely sandy clay loam	4 - 14	0.0 - 0.5	1.5 - 1.7	0.12-0.16	4.5 - 6.0
83-162	sandy clay	1.4 - 4	0.0 - 0.5	1.55 - 1.80	0.1-.13	4.5 - 5.5
162-216	sandy clay	1.4 - 4	0.0 - 0.5	1.65 - 1.85	0.1-0.12	4.5 - 5.5

b. Irrigation

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Georgia peanuts are grown on dryland and on irrigated land. About 50% of Georgia peanut acreage is irrigated. Typical irrigation amounts may be around 1 to 2 inch per week using center pivots. Total seasonal use could be 10 inches.

c. Crop Production and Profile

Peanuts are typically rotated with cotton or a grass-type crop. Conventional tillage is used for almost all Georgia peanut crops. Planting dates are from April 23 and May 25, and harvest runs from early September to early November. Plantings are typically single rows 36 inches apart.

d. Water Table and Aquifer Characteristics

The water table is typically at a high of 4 to 6 feet below the ground surface, and some domestic wells draw from this shallow aquifer. The pH of the surficial aquifer in the Southern Coastal Plain ranges from 4.1 to 7.4 (median 5.2) according to a survey by Crandall and Berndt (1996).

3. NC Cotton

North Carolina is ranked sixth in the nation in cotton acreage and seventh in production, generating 5 percent of the United States cotton crop. Most of the cotton produced in North Carolina is grown in the eastern half of the state, or the coastal plain region. Three of the four highest cotton producing counties, Northampton (63045 acres), Halifax (61933 acres), and Edgecombe (46001 acres), in North Carolina are located in northeastern North Carolina (USDA, Ag Census, 2002, http://www.nass.usda.gov/census/census02/volume1 /us/us2appxa.pdf). Figure II.D.7.7 shows the region for which this scenario was developed. Crops grown in this region include corn, peanuts, tobacco, soybeans, small grains, cotton, and pasture.

The coastal plain is North Carolina’s largest physiographic province, covering 45 percent of the state. The province can be subdivided into two regions—outer and inner coastal plain. The outer coastal plain (sometimes called the 'tidewater' region) consists of the immediate coast, barrier islands, sounds, marshes, lower river systems and associated mainland, and is generally less than 20 ft in elevation. The inner coastal plain includes the region from the outer coastal plain to the Fall Line.

The climate of North Carolina's coastal plain province is temperate. Average high temperature during summer months is in the mid-upper 80s, while average lows are near 70 degrees. During winter, average highs are in the mid 50s, while average lows are in the mid 30s. Temperatures tend to be more moderate n the outer coastal plain. Average rainfall is about 51 inches. Snowfall is infrequent and generally averages less than 5 inches per year in the inner coastal plain and less than 2 inches per year in the outer coastal plain.

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II.D.7. 7- Location of the North Carolina scenario. The circle indicates the approximate vicinity.

a. Soils

Cotton is predominately grown on sandy loam soils of the coastal plain. These soils require subsoiling (treatment to fracture and/or shatter soil with narrow tools below the depth of normal tillage with a minimum mixing of the soil) to breakup naturally occurring hardpans. Dominant cotton soils in the three counties of interest (Edgecombe, Halifax, Northampton) are the Norfolk loamy sand (Fine-loamy, kaolinitic, thermic Typic Kandiudults) and Wagram loamy sand (Loamy, kaolinitic, thermic Arenic Kandiudults). The Norfolk loamy sand was selected as it is present in both Edgecombe and Northampton counties, is designated as prime farmland, and is an NRCS benchmark soil (National Soil Handbook, part 630). This soil is Hydrologic Group B.

Table II.D.7.3. Soil Properties Norfolk Series

Horizon (cm)	USDA Texture	Saturated Hydraulic Conductivity1 in/hr	Organic matter1 (%)	Field Capacity2 (33 kPa)	Wilting Point (1500 kPa)2	Moist Bulk Density1	Available Water Capacity (in/in)	pH
0 -9	Loamy sand	42-141	0.5-2.0	5.1	2.0	1.55-1.7	0.06-0.11	3.5-6.0
9-14	Loamy Sand	42-141	0.3-0.8	5.1	2.0	1.55-1.7	0.06-0.11	3.5-6.0
14-70	Clay Loam	4-14	0-0.5	12	8	1.3-1.65	0.1-0.18	3.5-5.5
70-100	Clay loam	4-14	0-0.5	13	10	1.2-1.65	0.12-0.18	3.5-5.5

[1]USDA Soils Data Mart
[2]Approximated from USDA Norfolk pedons NSSL query

c. Irrigation

Limited cotton acreage in North Carolina is irrigated. The USDA Ag Census 2002 estimates that about 3.4% of acreage is irrigated. Irrigation is not included in the NC cotton model scenario.

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d. Cotton Production and Profile

The majority of cotton is located on the sandy loam soils of the coastal plain; these require subsoiling to break naturally occurring hardpans. However, about 20 percent of the cotton produced in the coastal plain is grown on heavier soils that do not require subsoiling. No-till systems are gaining in popularity in these locales, as the soils have higher levels of organic matter and are often the most productive. Traditionally, these soils have been heavily tilled, utilizing two disking operations followed by subsoiling/bedding. Strip-till is increasing dramatically in this area as a method of controlling sand blasting. The heavier clay soils of the piedmont do not require subsoiling, and most of this cotton is produced in no-till systems.

Planting begins in mid-April and usually is finished by the end of May (most active is May 1 to May 29). Harvesting begins at the end of September and ends mid December (most active is October 15 to November 15).

4. WA Potato

A major crop for Washington is Irish Potatoes, grown primarily in the central portion of the state (Figure II.D.7.8). Washington is the second leading potato-growing state in the U.S. (WA Dept. of Ag, Statistics). The highest potato-producing areas within the state are located in Grant and Yakima counties. These are also the counties with the highest usage of carbamates in the northwest. Grant County was the top potato-producing county in the nation in 1998 (WA Dept. of Ag, Statistics), with almost 50,000 acres in potato production in 2002 (USDA, NASS 2002 Census of Agriculture). Groundwater is generally shallow in Grant County, with little or no overlying confining layer in most places. As is typical for areas where potato production is favorable, the soils tend to be coarse-grained and well drained (Sieczka and Thornton, 1993). Sandy, well-drained soils are also likely to be fairly low in organic carbon; carbon (and nutrient) loss is exacerbated by common potato production practices, such as heavy tillage (Lang et al., 1999). These factors make Grant County especially susceptible to groundwater pesticide contamination. Figure II.D.7.8, location of the hypothetical central Washington potato scenario.

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II.D.7. 8 - Washington State County Map. Grant County (circled) and Yakima County are the major potato-producing counties in the state.

a. Soil

Potatoes are primarily grown in Entisols (Torriorthents, Torripsamments) and Aridisols (Haplocambids, Haplodurids) in central Washington, which are generally characterized by low clay content, good drainage, and low organic content (USDA Keys to Soil Taxonomy, 2003). The most productive and widespread soil series cropped with potato in Grant County (and other areas within the central Washington region) are Kennewick, Sagehill, and Wiehl (USDA-NRCS, Soil Data Mart). These soils tend to be coarse-grained (sand fractions typically range from 60-80%) with low organic matter content (<1%). Most of these soils are in hydrologic group B. Several relevant soil properties are listed in Table II.D.7.4.

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Table II.D.7.4. Washington Soil Properties for potato.

Soil Series	Depth (in)	Texture	Sand (%)	Silt (%)	Clay (%)	Saturated Hydraulic Conductivity (µm/s)	Organic Matter (%)	Moist Bulk Density (g/cc)	Available Water Capacity	pH
Kennewick	0-9	Loamy fine sand	61.5-79.9	16.6-35.0	3.5	4.0-14.0	0.5-1.0	1.15-1.45	0.11-0.17	7.4-8.4
	9-60	Fine sandy loam	---	---	3.0-18.0	1.4-4.0	0-0.5	1.3-1.5	0.18-0.21	7.9-9.0
Sagehill	0-8	Very fine sandy loam	59.7	35.3	5.0	14.0-42.0	0-0.5	1.2-1.4	0.18-0.2	6.6-8.4
	8-19	Silt loam	---	---	2.0-8.0	14.0-42.0	0-0.5	1.3-1.55	0.18-0.2	6.6-8.4
	19-60	Fine sandy loam	---	---	2.0-8.0	4.0-14.0	0-0.5	1.3-1.6	0.18-0.2	7.9-9.0
Wiehl	0-8	Fine sandy loam	66.0	27.5	6.5	14.0-42.0	0.5-1.0	1.2-1.4	0.13-0.17	7.4-7.8
	8-18	Silt loam	---	---	5.0-8.0	4.0-14.0	0-0.5	1.3-1.5	0.15-0.19	6.6-7.8
	18-25	Gravelly silt loam	---	---	5.0-8.0	4.0-14.0	0-0.5	1.3-1.5	0.13-0.17	7.4-8.4
	25-35	Weathered bedrock	---	---	---	---	---	1.6-1.9	---	---

b. Irrigation

Almost all potato crops grown in the Pacific Northwest (and throughout the U.S.) are irrigated (Thomson et al., 1999), largely because potatoes are grown in sandy, well-drained soils and because of crop water demand. Information included herein regarding crop yields, production techniques, etc. assume at least some irrigation is conducted. Therefore irrigation water must be included in total water inputs to the system (e.g., precipitation plus irrigation water). Irrigation at 50% of AWC is used for this scenario.

c. Potato Production and Crop Profile

Potatoes are among the most expensive major crops to grow. They require greater amounts of fertilizers (especially N) and pesticides than grain and feed crops, and need more intensive management (tillage, equipment, monitoring). Potato confers very little organic material to the soil. Although potatoes will grow on a wide variety of soils, optimal soils are usually deep, coarse-grained, and well-drained. Sandy soils are particularly good for potato production. Generally, soils with little or no slope are preferable, so that runoff is minimized (and less water and organic matter is lost).

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Potato requires consistent amounts of water throughout its growing cycle. Seasonal requirements range from ~20-40 inches. It is advantageous to keep the soil near field capacity; soil should not be allowed to get below 65% of field capacity. However, soil should not be allowed to exceed field capacity, or quality and yield will become dramatically lowered. The effective rooting depth of potato is 2 feet (Sieczka and Thornton, 1993).

d. Water Table and Aquifer Characteristics

The water table associated with this type of soil in this region has an upper limit of 1 to 5 feet and a lower limit greater than 6 feet (USDA Soil Data Mart). Groundwater pH for this region ranges from 6.7-7.8; typical pH for shallow ground water is generally around 7.2 (personal communication, Washington State Dept. of Ecology).

D. Chemical Property Inputs

Only two of the N-methyl carbamates—aldicarb and oxamyl—were included in the groundwater assessment because the use data (appendix IID.2) and the relative toxicity suggest that these would be the major contributors to ground water exposure in the cumulative assessment. The chemical properties that drive these assessments are given in Table II.D.7.5. These properties came from an evaluation of registrant-submitted studies and represent reasonably conservative estimates of these properties. Other chemical properties are required as inputs in order for the models to operate, but they have negligible effect on model output; these properties can be found in the model input files. Properties for aldicarb represent total residue (parent aldicarb, plus the degradates aldicarb sulfoxide and aldicarb sulfone) properties (i.e. half-lives represent the most stable toxic-relevant constituent).

Table II.D.7.5. Relevant Chemical Inputs for Carbamates.

	Koc	**Soil Metabolism halflife**	**Hydrolysis (acid) halflife**	**Hydrolysis (neutral) halflife**
Aldicarb (total residue)	10 ml/g	55 days	500	63 days
oxamyl	6 ml/g	20 days	stable	8 days

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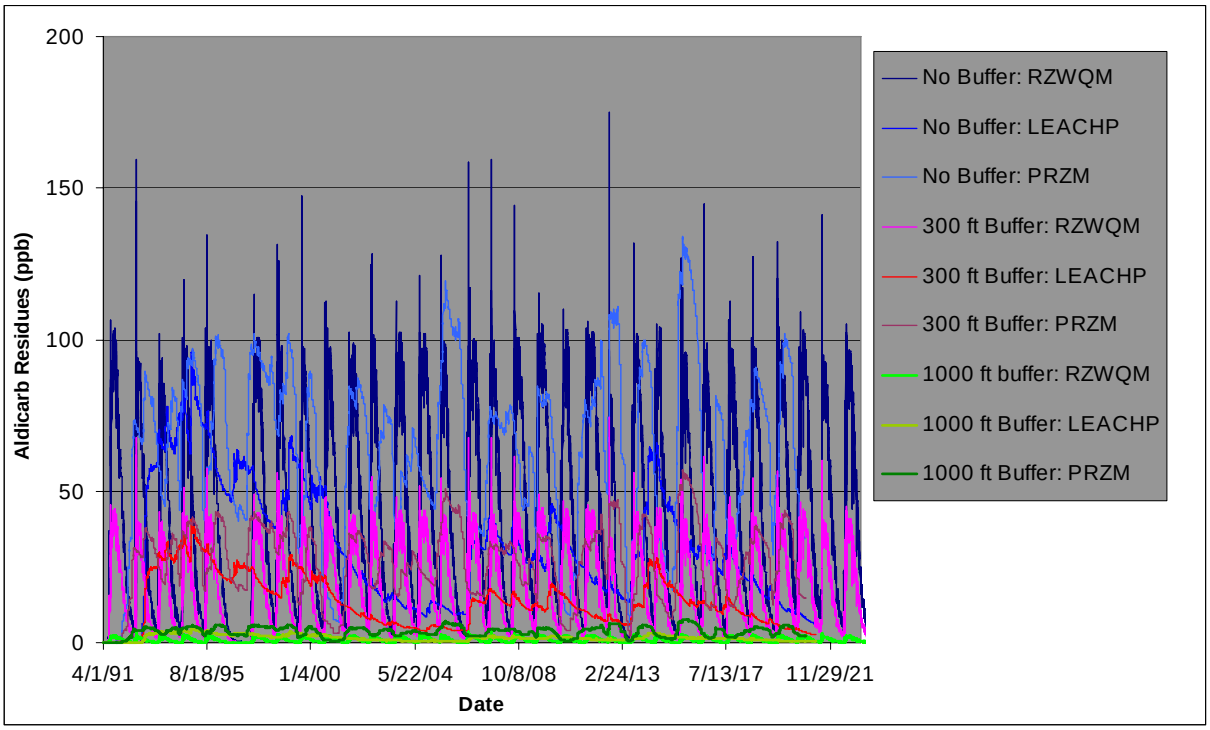
E. Results and Discussion

1. Florida Citrus

a. Florida Citrus / Aldicarb

Modeling results for the Florida citrus scenario are shown in Figure II.D.7.9. The concentrations estimated by RZWQM are spikier than those of PRZM and LEACHP, but on average the concentrations are quite similar. Although peak concentrations are estimated to be higher in RZWQM than for PRZM, the overall average RZWQM concentration is 30% lower than PRZM. For the 1 lb/acre application rate, the average concentration from PRZM is 27 ppb versus 19 ppb estimated by RZWQM. At the labeled rate of 5 lb/acre and without any setback considerations, these values would be 135 and 95 ppb, respectively. Setbacks considerably reduce the concentrations. The 1000-ft set back reduces concentrations to about 4% of the application site concentrations, whereas the 300-ft setback reduces concentrations to about half of the site concentration. With a 1000-ft buffer concentrations are well below 10 ppb.

II.D.7. 9 - Florida Citrus Results for RZWQM, PRZM, and LEACHP. Application of aldicarb at 1 lb/acre. For other application rates, the output concentrations are proportional. Distances in legend refer to setback distances as specified by state and federal regulations.



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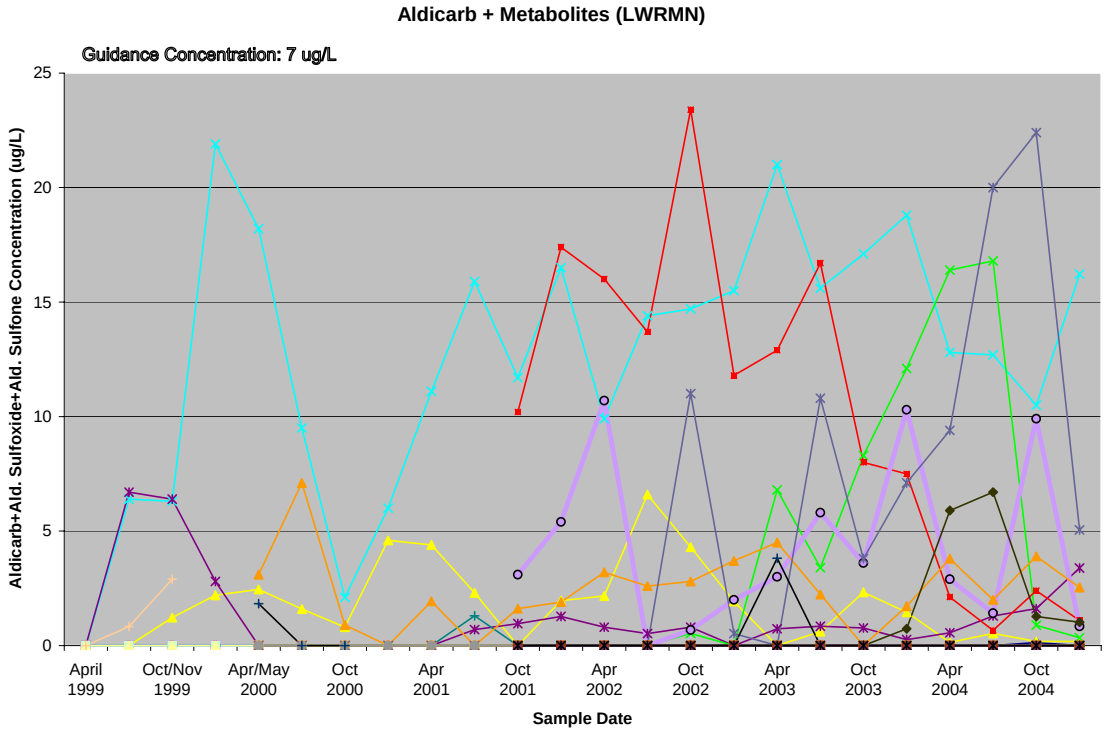
b. Monitoring in Florida / Aldicarb

These results are conservative with respect to a recent and on-going groundwater monitoring study on the Florida Central Ridge (http://fisc.er.usgs.gov/Lake_Wales_Ridge/). The USGS and the Florida Department of Agriculture is monitoring 31 wells within and around citrus groves on the Ridge (the area of the OPP scenario). Well depths range from 4 feet to 110 feet deep (two thirds in the 20 to 60 foot range), and pH ranged from 3.9 to 6.9 (median about 5). Concentrations as high as 23 ppb have been recorded in one 26-ft well, while a 4-ft well had reported concentrations as high as 21 ppb. Summarized results are shown in FigureII.D.7.10. This study is not targeted for any specific pesticide, but rather is designed as a survey mechanism—that is, it is not known how much aldicarb was used nor is it known how far aldicarb was used from the wells.

II.D.7. 10 - Monitoring results from the Lake Wales Central Ridge. Draft data subject to revision. Connected lines represent individual wells



In another monitoring study, Jones et al. (1987) applied 10 lb/acre (twice the current allowed label rate) to a grove plot on the Central Ridge and observed aldicarb residues in the saturated zone below the plot as high as 100 to 500 ppb. Concentrations of over 100 ppb were observed at distances of up to 300 feet from the point of application (Fig 6 of Jones et al, 1987). With consideration that the Jones et al. (1987) application rate was twice as high as current labeled rates, our modeling scenarios would appear to be reasonably conservative for the types of soil / ground water profiles modeled.

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The Florida Department of Environmental Protection (FDEP) monitors private drinking water wells in rural areas. The monitoring is not comprehensive, but instead is instituted when there has been an indication of a problem (personal communication, FDEP). Total aldicarb residues (parent, sulfoxide and sulfone degradates) as high as 47 ppb were reported in private drinking water wells in the early 1990s in the FDEP study. The concentrations dropped off in subsequent years. The reduction in concentrations of aldicarb may have resulted from label changes which reduced application rates and applied well setback requirements. Specific reductions at home sites also were also likely the result of a Florida State program to install carbon filters or to pipe water in from treatment facilities when contamination was found. Other reasons for the decline include the possibility of discontinued use in the vicinity of the contaminated areas (personal communication FDEP).

Jones and Estes (1995) reviewed monitoring studies for aldicarb, including studies conducted on Florida Central Ridge citrus. They reported that 119 potable wells out of 4009 sampled wells in Florida had aldicarb residue detections and that 33 of those had concentrations higher than 10 ppb. A breakdown of the percent detections on the vulnerable Central Ridge was not made available, thus these values represent the entire state (not specifically Ridge data).

c. Florida Citrus / Oxamyl

Model results from oxamyl use on the Florida citrus scenario are given in Figure II.D.7.11. Again, RZWQM predicts greater daily variations in concentrations and higher peak concentrations than does PRZM. Average concentrations are close, with PRZM giving 32 ppb and RZWQM giving 41 ppb, which is well within any reasonable expectation of certainty from these models. Oxamyl concentrations for this scenario are higher than for aldicarb, even though oxamyl has a shorter half-life. This is because there are no setback requirements for oxamyl as there are for aldicarb.

Monitoring results are much more limited for oxamyl than for aldicarb. The USGS has just started to monitor for oxamyl on the Florida Ridge (Choquette 2005, personal communication), and when these results become available, they will be evaluated with respect to model performance. Oxamyl was monitored for but not detected in the Florida Department of Health investigations (study described above for aldicarb).

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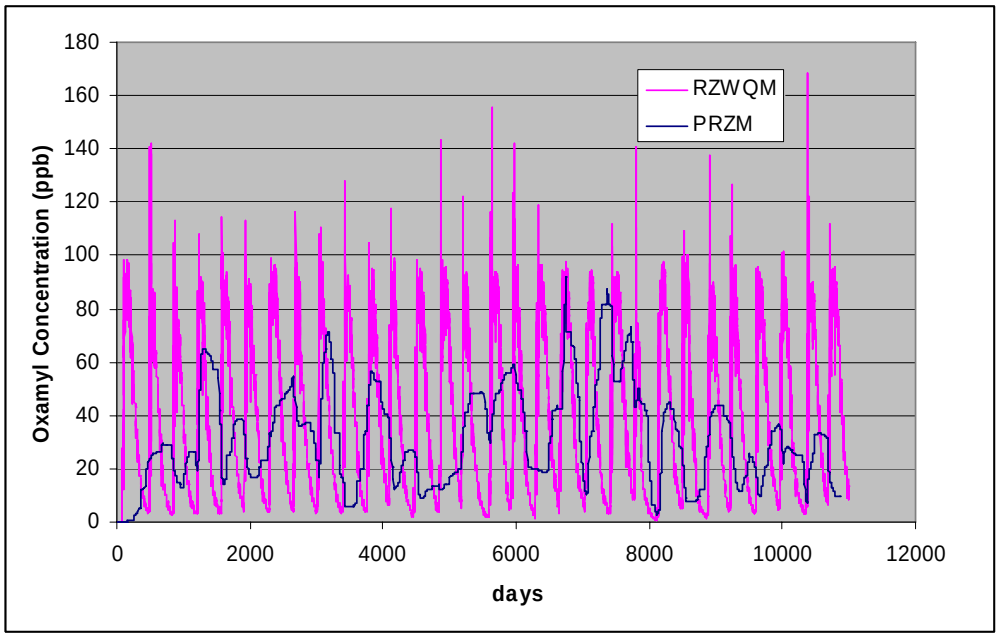
II.D.7. 11 - Model Results for Oxamyl concentrations with Florida citrus scenario



2. North Carolina

Results for North Carolina are shown in Figure II.D.7.12. Aldicarb is the only carbamate of interest in this area. The RZWQM simulation could not be performed with this scenario due to difficulties in establishing a water table. This problem is being worked out with assistance from USDA-ARS. PRZM and LEACHP results were fairly close. OPP is searching for monitoring data for comparison with model results.

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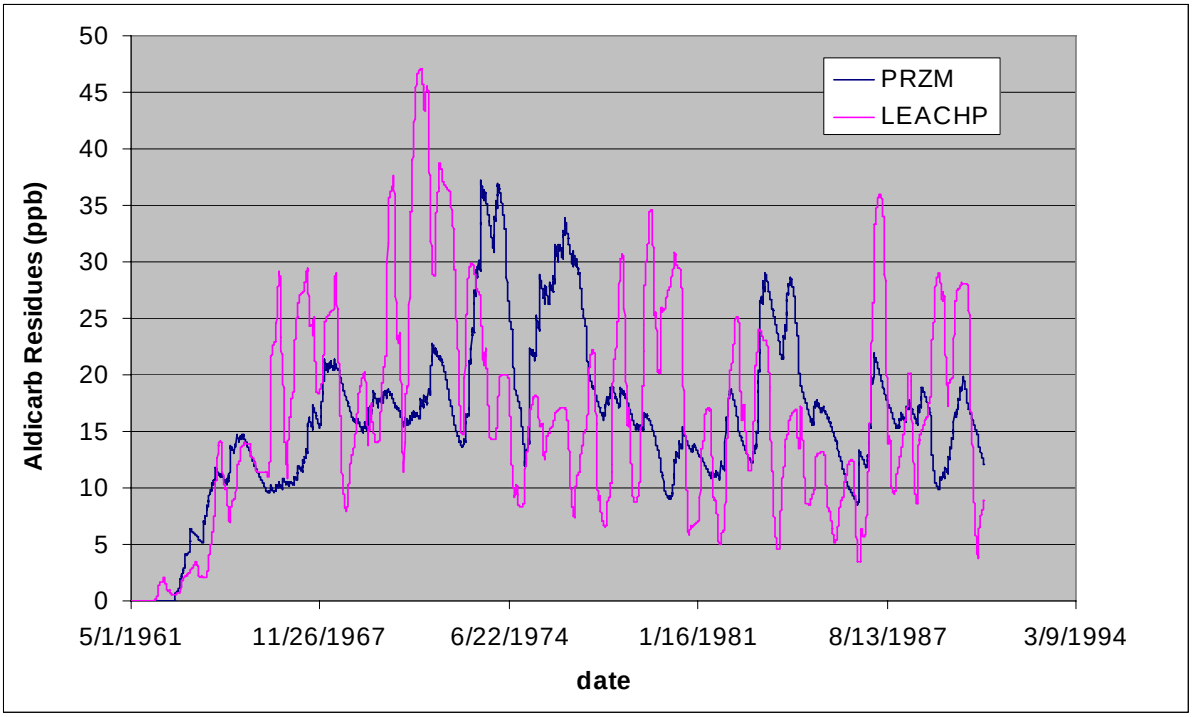
II.D.7. 12 - PRZM and LEACHP output for Aldicarb Total Residue for NC cotton. Application rate is 1 lb/acre.



3. Georgia Peanut

Results for Georgia Peanuts are presented in Figure II.D.7.13. Note that, as with all simulations here, concentrations are normalized to 1 lb/acre; actual rates may be higher or lower, but output will be proportional to application rate. Because labels do not require buffers for Georgia Peanuts, no adjustments for buffers were included. Model simulations of groundwater concentrations in Georgia are typically lower than those in Florida (without buffers). This is likely due to the lower rainfall and less irrigation used on peanuts, which causes pesticide to dwell longer in the upper 1-meter degradation zone. LEACHP concentrations are somewhat higher than PRZM or RZWQM calculations in this scenario. We are currently examining possible causes for this. OPP is searching for monitoring data for comparison with model results.

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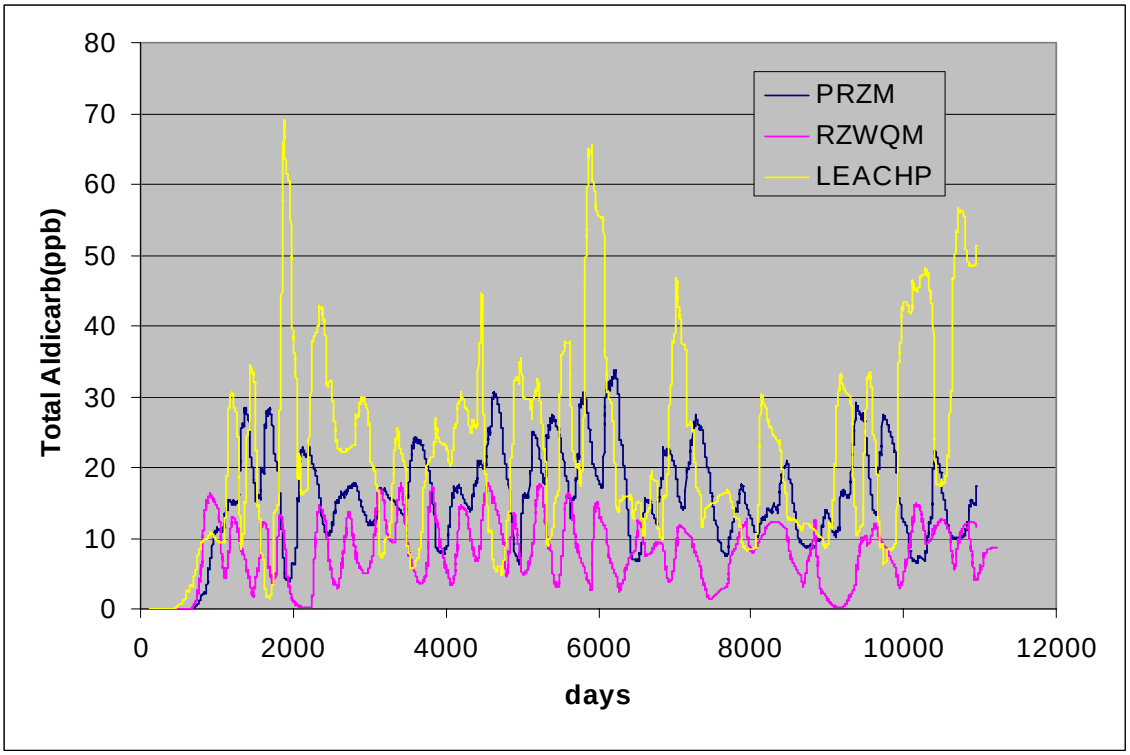
II.D.7. 13 – PRZM, RZWQM, and LEACHP results for aldicarb for the Georgia peanut scenario. All concentrations are normalized to 1 lb/acre.



4. Washington Potato

Both PRZM and RZWQM simulated negligible concentrations in the aquifer, consistent with an absence of detections from wells in this area (Kirk Cook, *Washington State Dept. of Agriculture, Pesticide Management Division*, personal communication). This was primarily due to the alkaline pH of the system which enhanced hydrolysis. Further analysis was discontinued for his scenario.

F. European Approach to Ground Water: FOCUS

Because EPA's proposed approach to addressing groundwater issues is new, a review of the approach that the European community uses is useful for placing the EPA's assessment into world perspective. The European community addresses standardization of evaluation of pesticide fate and transport through FOCUS (FOrum for Co-ordination of pesticide fate models and their Use; information available at http://viso.ei.jrc.it/focus/index.html). A review of FOCUS and a comparison of EPA's results with those that would be derived from FOCUS methods are presented here.

1. Background on European Regulatory Modeling

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The FOCUS groundwater scenarios are a set of nine standard combinations of weather, soil and cropping data which collectively represent agriculture in the European Union member countries for the purposes of a Tier 1 European Union-Level assessment of leaching potential. The scenarios and their derivation are described in detail in a published report (FOCUS,1995). The scenarios have been implemented as sets of input files for four simulation models - MACRO, PEARL, PELMO & PRZM (the reader should note that PRZM maintenance and improvement through FOCUS is done separately from PRZM as used by U.S. EPA regulators; at the present time there is not an exact match between versions of FOCUS PRZM and PRZM used by U.S. EPA).

The endpoints of concern evaluated in FOCUS modeling are driven by different legislative directives than in the United States. The use of pesticides that potentially contaminate the groundwater is banned by registration procedures at both the European level (Council Directive 91/414/EEC), and the level of individual member states (countries). The Directive places great importance on the use of models to calculate Predicted Environmental Concentrations (PECs) as a basis for assessing the environmental risks. Under the directive pesticide active ingredients and relevant metabolites thereof must not exceed a concentration of 0.1 ug/l in groundwater.

In the first tier of the current procedure, point scale leaching models are combined with a limited number of worst-case scenarios to assess PEC groundwater in Europe.

FOCUS model shells were used for running the models. The FOCUS shells guide the user to select input parameter values according to standardized procedures. The use of the standardized procedures means that some key input values may be different than was selected for the Carbamate Cumulative groundwater modeling of US scenarios. For example, the variance of pesticide half-life with depth (for this carbamate assessment) used the following standardized protocol for FOCUS modeling:

A “depth dependent correction factor” was applied to the pesticide degradation rates as follows:

0 – 30 cm depth	1
30 – 60 cm depth	0.5
60 – 100 cm depth	0.3
> 100 cm depth	0

Therefore, in the simulations run for total aldicarb residues, aldicarb degradation rate was reduced by half as aldicarb residues were passing through the 30 to 60 cm depth, by 70 % traveling between 60 and 100 cm deep, and no degradation took place for any residues that leached below 100 cm.

FOCUS models may use non-linear adsorption of the pesticide. FOCUS-PRZM differs from the PRZM version currently in use by EFED in this respect. Carbamate modeling used the FOCUS default assumptions and calculations as follows:

- normalized Freundlich equation used;
- layer specific Kd calculated from the PRZM shell and inputted into PRZM;

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- Freundlich exponent 1/n is entered in using the default value of 0.9 for n as specified in the FOCUS guidance document.

2. Interpretation of FOCUS Model Output based on Legislative Directives in the European Union

The model shells rank the twenty mean annual concentrations (in soil pore water moving past a depth of 1 meter) from lowest to highest. The seventeenth value (fourth highest) is used to represent the 80th percentile value associated with weather for the specific simulation conditions. Under the FOCUS modeling system this value is taken as the overall 90th percentile concentration for a combination of soil and weather conditions since the standard scenario site soil characteristics have also been chosen to represent an overall 80th percentile vulnerability. In the European Union, evaluation of model output is made independent of the specific toxicological properties of the pesticide.[1]

3. Comparison of FOCUS and Carbamate Cumulative Modeling Scenarios

Four of the nine FOCUS scenarios were applicable to citrus production agriculture: Piancenza, Porto, Sevilla, and Thiva. With the possible exception of the Porto site, these sites represent drier climates (Table II.D.7.6) and less permeable soils (Tables II.D.7.7, 8, 9, and 10) than the scenarios used in the Carbamate Cumulative assessment other than the low natural rainfall but heavily irrigated Washington state potato scenario.

Table II.D.7.6. European Union climate zones and predominance of agriculture represented by the FOCUS standard scenarios applicable to citrus uses.

Precipitation (mm)	Mean Annual Temperature (°C)	Arable land * (%)	Total Area * (%)	Representative Locations
601 to 800	>12.5	13	11	Sevilla/Thiva**
801 to 1000	>12.5	9	8	Piacenza
< 600	>12.5	4	4	Sevilla/Thiva

[1] Regulators in Europe compare the resultant chosen values for pesticide concentration in leachate against the 0.1 ug/l standard for groundwater; with the three possible categories of outcomes being exceedences at none of the sites, at some of the sites, or at all of the sites. If residues do not exceed 01 ug/l at any of the sites then the pesticide passes Tier 1 and may be registered because of its low probability of leaching to groundwater at concentrations in excess of 0.1 ug/l. The FOCUS guidance document does offer the following caveat, however: "This does not exclude the possibility of leaching in highly vulnerable local situations within specific Member States, but such situations should not be widespread and can be assessed at the Member State level." When exceedences occur at some of the sites, then registration may only be approved in the regions represented by the scenarios where the pesticide concentrations were below 0.1 ug/l. Registration may not be approved if the Tier 1 concentrations are above 0.1 ug/l. The FOCUS guidance does provide, however, for the possibility that Tier 1 failures can be overruled by substantial contrary evidence (that residues in groundwater will not in fact exceed 0.1 ug/l under normal use patterns) obtained through "lysimeter or field leaching studies, monitoring and more refined modeling."

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1001 to 1400	>12.5	3	3	Porto

*Relative to the area of the European Union plus Norway and Switzerland.
**Although these locations have less than 600 mm of precipitation, irrigation typically used at these two locations brings the total amount of water to greater than 600 mm.

Table II.D.7.7. Soil parameters for FOCUS Porto scenario.

depth	classification	pH-H2O	Texture µm			om	oc	bulk density	depth factor@
cm			<2	2-50	>50	%	%	g cm-3	-
0 - 35	loam	4.9	10	48	42	6.6	3.8	0.89	1.0
35 - 60	sandy loam	4.8	8	31	61	3.7	2.1	1.25	0.5
60 - 100	sandy loam	4.8	8	31	61	3.7	2.1	1.25	0.3
100 - 120	sandy loam	4.8	8	31	61	3.7	2.1	1.25	0.0
@ Factor applied to topsoil degradation rate.									

Table II.D.7.8. Soil parameters for FOCUS Piacenza scenario.

depth	classification	pH	texture µm			om	oc	bulk density	depth factor@
cm			<2	2-50	>50	%	%	g cm-3	
0-30	loam	7	15	45	40	1.72	1.00	1.3	1.0
30-40	loam	7	15	45	40	1.72	1.00	1.3	0.5
40-60	silt loam	6.3	7	53	40	0.64	0.37	1.35	0.5
60-80	silt loam	6.3	7	53	40	0.64	0.37	1.35	0.3
80-100	sand	6.4	0	0	100	0	0	1.45	0.3
100-170	sand	6.4	0	0	100	0	0	1.45	0.0
@ Factor applied to topsoil degradation rate.									

Table II.D.7.9. Soil parameters for FOCUS Sevilla scenario.

depth	classification	pH	texture µm			om	oc	bulk density	depth factor@
cm			<2	2-50	>50	%	%	g cm-3	-
0-10	silt loam	7.3	14	51	35	1.6	0.93	1.21	1.0
10-30	silt loam	7.3	13	52	35	1.6	0.93	1.23	1.0
30-60	silt loam	7.8	15	51	34	1.2	0.70	1.25	0.5
60-100	clay loam	8.1	16	54	30	1.0	0.58	1.27	0.3
100-120	clay loam	8.1	16	54	30	1.0	0.58	1.27	0.0
120-180	clay loam	8.2	22	57	21	0.85	0.49	1.27	0.0
@ Factor applied to topsoil degradation rate.									

Table II.D.7.10. Soil parameters for FOCUS Thiva scenario.

depth	classification	pH-KCl	texture			%om	%oc	bulk density	depth factor
			<2	2-50	>50	%	%	g cm-3	-
0-30	loam	7.0	25.3	42.8	31.9	1.28	0.74	1.42	1.0
30-45	loam	7.0	25.3	42.8	31.9	1.28	0.74	1.42	0.5

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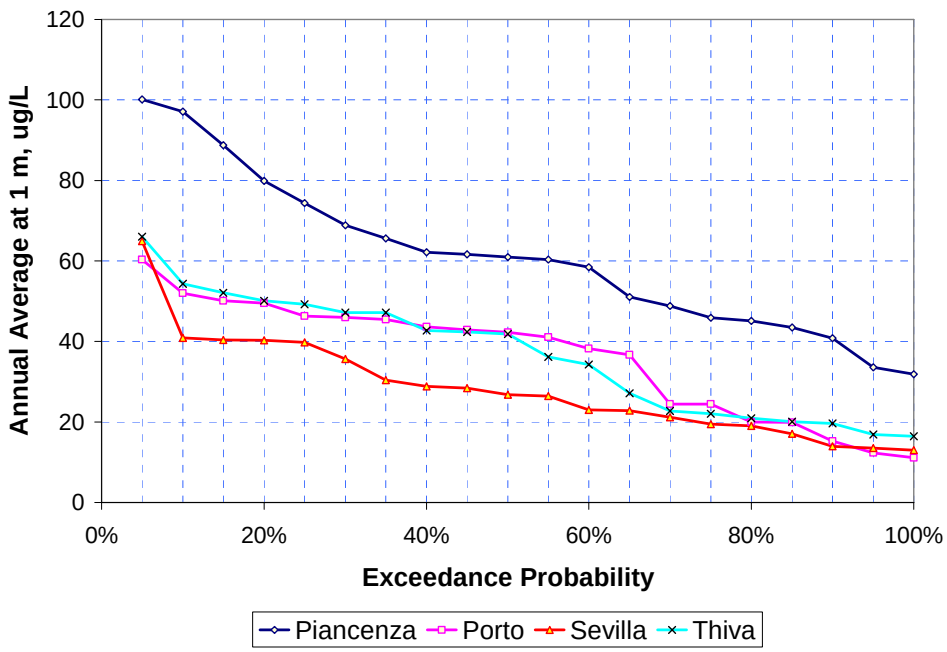
45-60	clay loam	7.1	29.6	38.7	31.7	0.98	0.57	1.43	0.5
60-85	clay loam	7.1	31.9	35.7	32.3	0.53	0.31	1.48	0.3
85-100	clay loam	7.1	32.9	35.6	31.5	0.31	0.18	1.56	0.3
100-???	clay loam	7.1	32.9	35.6	31.5	0.31	0.18	1.56	0.0
@ Factor applied to topsoil degradation rate.									

4. Results of FOCUS Modeling for Aldicarb Total Residues

The distribution of average annual concentrations of total aldicarb residues in leachate is provided in Figure II.D.7.14. Tier 1 screening concentrations were 50 to 80 ug/l for the four citrus production scenarios (Table II.D.7.11).

II.D.7. 14 - Distribution of annual average concentrations of total aldicarb concentrations at 1 meter depth after application of 1 lb ai/A to citrus (FOCUS European regulatory scenarios - PRZM simulations).



There are major factors which tend to make the FOCUS screening concentrations either more or less "worst case" than the Carbamate Cumulative output:

- FOCUS concentrations represent shallower water (1 m versus 3.5 m in the Carbamate Cumulative) and concentrations in leachate below the specified depth rather than concentrations in groundwater.
- FOCUS concentrations represent annual mean rather than daily water concentrations

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- The FOCUS scenarios were very likely less vulnerable than the Carbamate Cumulative scenarios in terms of soils and climate (soils much less sandy; precipitation generally lighter).

In spite of the significant differences in the setup and evaluation of modeling, the FOCUS modeling yielded results within the range of Carbamate Cumulative modeling for aldicarb residues. This is important to know since the FOCUS models have already been through extensive use by regulators in Europe for several years now. Future work may be done with other FOCUS models such as PEARL and PELMO to confirm if similar results are obtained with the other FOCUS models.

Table II.D.7.11. Selected Tier 1 concentrations for total aldicarb based on a 1 lb ai/A application rate; EU citrus scenarios. Tier 1 values are calculated per the FOCUS guidance document.

European (FOCUS) Site Name	Tier 1 ground water concentration, ug/l
Piancenza	79.87
Porto	49.52
Sevilla	40.28
Thiva	50.06

G. Prospective Groundwater Monitoring (PGW) Studies

As part of the pesticide registration process, registrants are sometimes required to perform prospective ground water studies (PGW) in order to better evaluate the fate and transport of a pesticide as it moves from a field site into the underlying ground water. A small number of studies have been performed on pesticides that are included in the list of n-methyl carbamate cumulative chemicals. These include Oxamyl in North Carolina, Oxamyl in Maryland, and Methomyl in Georgia. The EPA is evaluating model performance with regard to these studies. The work is ongoing and preliminary results are presented in this section. As of this writing, only the analysis of the North Carolina oxamyl study has been completed to enough of an extent to present results.

1. North Carolina

A small-scale prospective groundwater monitoring study was conducted for oxamyl and its oxime metabolite in Tarboro, North Carolina. The study is located in the same coastal plain region modeled in the North Carolina cotton scenario. The study site was chosen for its highly vulnerable soil and hydrogeologic characteristics. The soil at the site is relatively homogeneous sand to loamy sand with a layer of sandy loam to sandy clay loam at approximately two to four feet. It correlates with the NRCS Tarboro loamy sand series, characterized by excessive drainage and negligible runoff. The top one foot of soil has an average organic matter content of 0.85% and a pH of 5.8. Below this, the organic matter content ranges from 0.10 to 0.23% while the pH ranges from 4.3 to 7.9, generally lower at the top and increasing with depth. Based on undisturbed soil samples, the average field capacity is 9.6% in the top two feet and 15.1% from two to four feet and the bulk density at those depths averages 1.42 g/cm^3.

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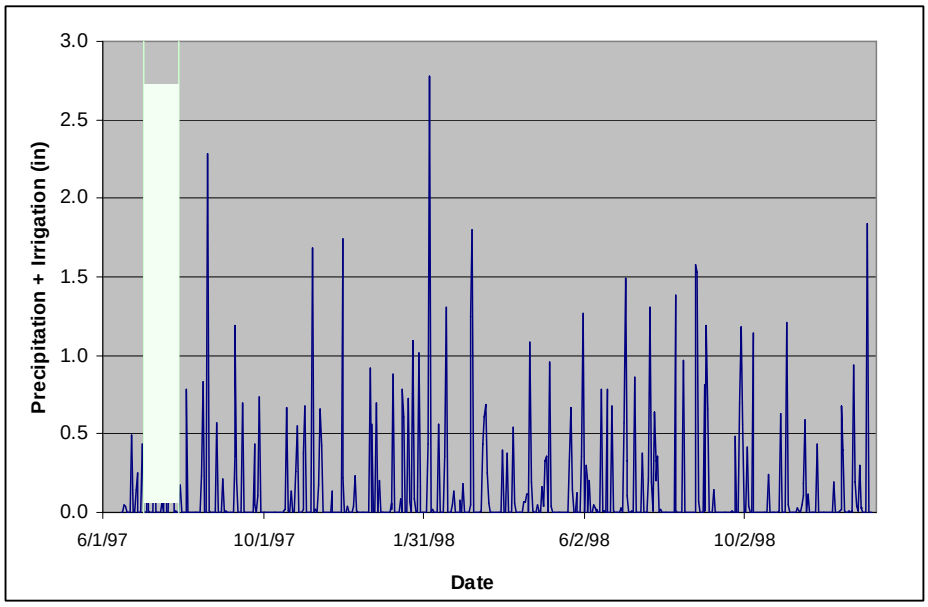
The study site has a history of cotton, soybeans, peanuts, tobacco, and corn production. For this investigation, cotton was planted on May 22, 1997 and multiple applications of oxamyl as well as a single application of a conservative bromide tracer were subsequently applied. The cotton was harvested in November and peanuts planted the following summer. Precipitation was supplemented with overhead center pivot irrigation to bring the combined precipitation and irrigation to 56.41 in., 120% of the historical mean precipitation (Figure II.D.7.15).

II.D.7. 15 - Precipitation and irrigation throughout the study period. The oxamyl application period is highlighted in light green..



Eight well clusters, including one shallow (12-17 feet screened interval) and one deep well (17-21 feet screened interval) each, were used to monitor groundwater and eight clusters of lysimeters at four depths were used to monitor soil pore water. During the study, the depth of the water table ranged from 10.27 to 17.15 feet, with a mean depth of 14.09 feet below the ground surface. Potassium bromide was applied as a conservative tracer on July 1, 1997, and indicated rapid vertical leaching and recharge to groundwater. It was detected in soil at all locations at the 18 to 24 inch depth by the first measurement at 27 days after treatment, and it reached groundwater in all shallow wells by 160 days after treatment.

In July, a series of 5 ground broadcast applications of oxamyl were made on a 2 acre plot at 6 to 8 day intervals. The first two applications were at a rate of 0.5 lb/A and the rest at 1.0 lb/A. This represents the maximum labeled seasonal rate using the minimum application intervals. Oxamyl reached all shallow wells, initially detected between days 124 and 194 after treatment. In one well, oxamyl persisted throughout the entire study period while in the others there were no detections beyond 376 days. The maximum detection was 3.91 ppb (Figure

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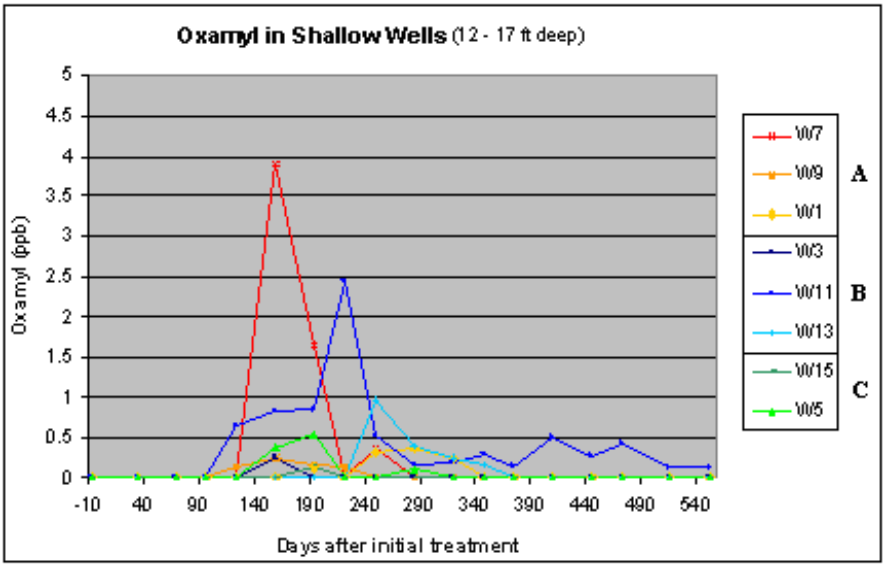
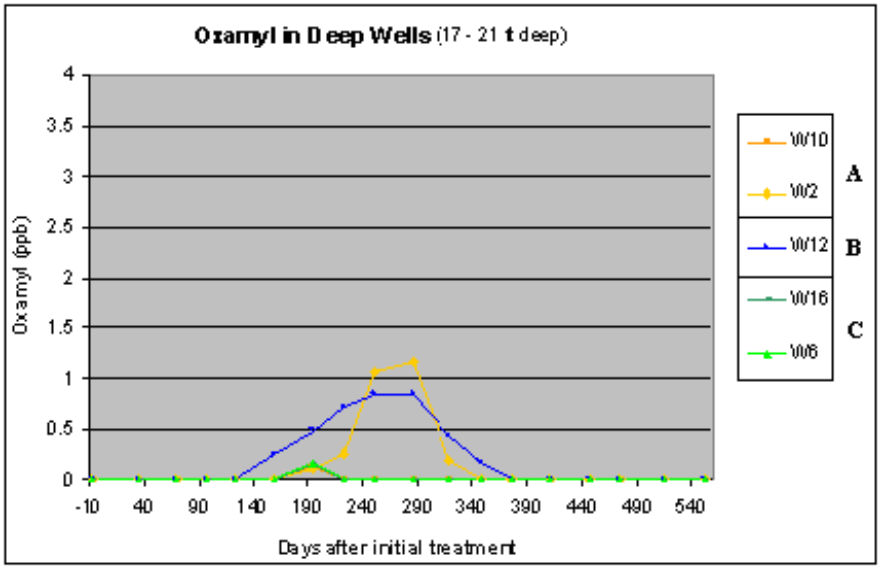
II.D.7.16). Oxamyl was only detected in 5 of the deeper wells, appearing by day 194 after treatment and undetected by day 378. The range of concentrations detected at this depth was 0.12 to 1.17 ppb (Figure II.D.7.16).

II.D.7. 16 – Oxamyl concentrations in shallow wells (top) and deep wells (bottom). Wells are grouped into subplots A, B, and C, where A is the most northern. Within each subplot, wells are listed upgradient to downgradient. Odd numbered shallow wells share a cluster.





Modeling work on this data has begun with an analysis of the bromide tracer in the shallow wells. The result PRZM and LEACHP are given in Figure II.D.7.17 along with the bromide data (RZWQM simulations have not been completed at the time of this writing). Both PRZM and LEACHP give similar responses, although LEACHP simulates a later arrival time than PRZM. Both predict higher concentrations than the data show. However note that lateral

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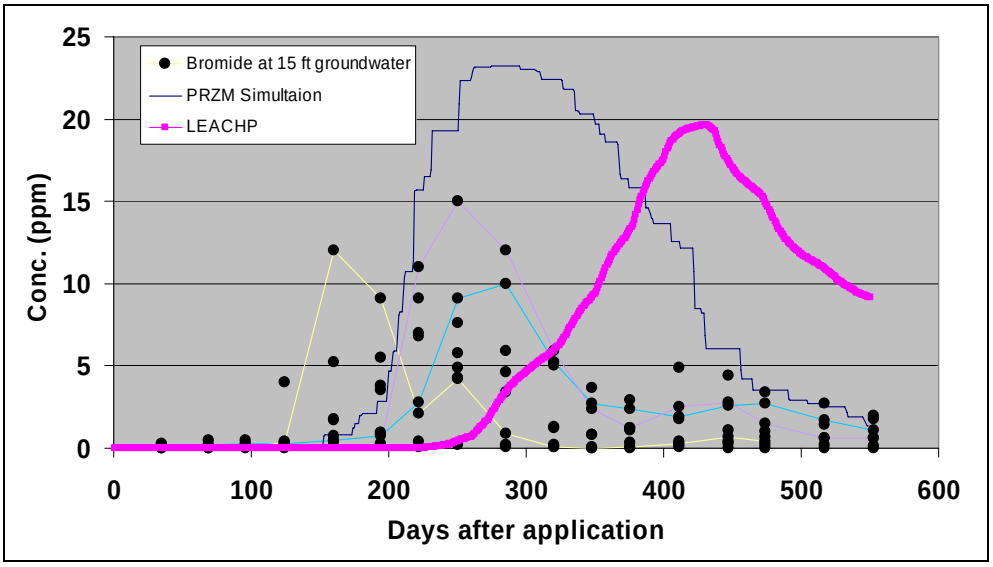
groundwater velocities at this location are quite high (51 feet per year) and that the groundwater flow transverses across the narrow side of the field. Thus advection and dispersion could have caused lower concentrations than those modeled In Figure II.D.7.17, the highlighted data represent the wells that were farthest downgradient at the site, and as can be seen, these are the wells with the highest concentrations.

Preliminary work with the parent oxamyl has shown that the models predict substantially higher oxamyl concentrations than those shown in Figure II.D.7.16. OPP is examining possible causes and will report results when available. Possibilities include an underestimation of the rate of degradation in the models. For example, under anaerobic conditions oxamyl half lives are on the order of 5 days, but this process was not included in the simulations. Investigations will continue and refinements may be necessary, but at the time of this writing modeling results have not compared well with the monitoring data.

II.D.7. 17 - Bromide concentration and model results of PRZM and RZWQM for the North Carolina study.



2. Georgia

A small-scale prospective groundwater (PGW) monitoring study was conducted in Cook County, Georgia from 1992-1993 to detect the presence of methomyl in ground water, soil-pore water and soil. The study was located in the coastal plain region—the same region chosen for the Georgia peanut scenario (see above). The site was selected for its hydrologic vulnerability: high annual rainfall; sandy, low-organic matter, permeable soil profile; low slope; shallow groundwater; and extensive groundwater recharge. The soil profile was relatively homogenous with no restrictive layers and was characterized as Kershaw fine

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sandy loam, with texture characterized as sand. The mean concentrations of sand, silt and clay were 95%, 4%, and 2%, respectively. The mean organic matter content in the upper 0.5 feet of the profile was 0.9% and the mean soil pH at the plow layer was 6.4.

The study site had been under agronomic production for five years prior to the study and was planted with both sweet potatoes and peanuts. For this investigation, corn was planted on August 3, 1992 followed by multiple applications of methomyl and a single application of a conservative bromide tracer. Precipitation was supplemented via a traveling-gun system to bring the combined precipitation and irrigation to 124% of the historical mean precipitation, based on the average of 30 years of meteorological data from two nearby weather stations.

Four two-well clusters, one shallow and one deep, were installed to monitor groundwater and fourteen lysimeters were installed to monitor soil-pore water at depths of 3 feet, 6 feet, 9 feet and 12 feet. During the study, the depth of the water table ranged from 7.71 to 22.42 feet, with a mean depth of approximately 15 feet below the ground surface. Potassium bromide was used as a tracer. Transport of bromide to a depth of 42-48 inches took between 22 and 34 days and was detected at elevated levels 62 DAT in one of the shallow wells (MW07). Soil, soil-pore water and groundwater samples were taken from three days prior to application of methomyl through 399 days after treatment.

Methomyl was first applied to postemergent corn on August 13, 1992. There were five whorl treatments spaced approximately 10 days apart and 20 daily ear treatments, conducted at 0.45 lbs ai/acre each for a total of 11.25 lbs ai/acre. The only detections of methomyl occurred at 62 and 117 days after treatment (DAT). The maximum detection was 0.42 ppb in a shallow well at 62 DAT. Methomyl was detected in two of the deep wells at 62 DAT and in three of the shallow wells (two at 62 DAT and two at 117 DAT). Only one shallow monitoring well, MW07 had detections above the detection limit at both 62 and 117 DAT.

The conductors of the study concluded that no detectable concentrations of methomyl were present in the groundwater and attributed the higher concentrations found at 62 and 117 DAT to be the result of either cross-contamination (field or lab) or the presence of methomyl in the soil and/or groundwater prior to the conduction of this study. These detections could also represent preferential flow delivery to the ground water. The presence of methomyl prior to the study was sampled for, and at the detection levels of 0.1 ppb for water and 2.0 ppb for soil, no methomyl was detected. In addition, there was no reported prior methomyl use at the study site.

Preliminary LEACHP modeling results, shown in Figure II.D.7.18, indicate a plausible Br simulation. We are further investigating how well

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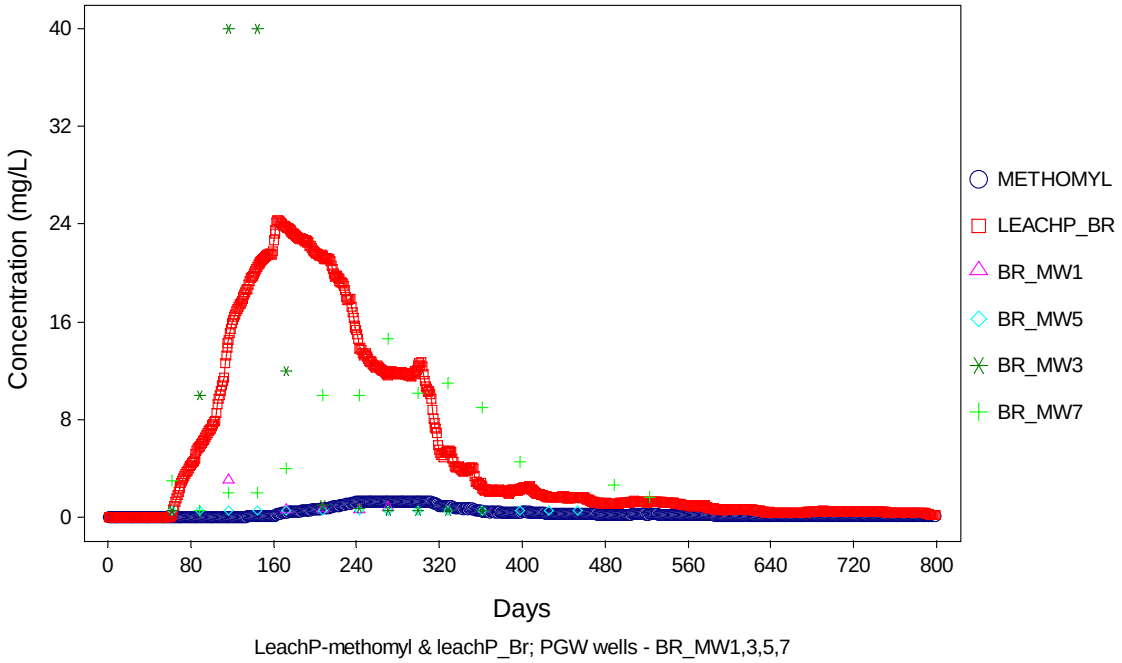
methomyl is simulated; no methomyl was detected in the PGW study, but model simulations revealed small but detectable concentrations. OPP will also evaluate similar simulations with PRZM and RZWQM using the same data set.

II.D.7. 18 - Bromide concentration and model results of LEACHP for the Georgia study.



H. Outlook

There is no clear "best" model to use to assess pesticide concentrations in groundwater. All three models give similar concentrations that are well within the uncertainty of any environmental prediction. Further evaluations will be required before OPP makes an ultimate decision on the groundwater model(s) to be used for general assessments. In this regard, OPP will continue its effort to evaluate the models on the performance and usability will continue as additional groundwater data is analyzed. OPP intends to analyze additional prospective groundwater studies, and is beginning to systematically enter relevant data into a database. Such an effort should allow model evaluation on a broader scale than just the available carbamate studies that were examined here.

OPP is continuing to work with USDA-ARS, EPA-ORD, and Health Canada in an effort to improve scenarios and models for pesticide groundwater assessments. Some of the issues currently being worked on include USDA-ARS investigation into ways to implement a fixed water table in RZWQM, EPA effort to fix PRZM's temperature routines in PRZM, and Health Canada's efforts to develop consistent groundwater

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scenarios. These collaborative efforts should result in a consistent and reasonable process for estimating pesticide concentrations in groundwater.

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