Screening Level and Refined Flowing Water Pesticide Exposure Modeling for use in Endangered Species Assessments

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Motivation

National Endangered Species Assessments are requiring that pesticide expected environmental concentrations (EECs) in flowing water bodies be determined

Draft Biological Evaluations (BEs) for three OPs used existing EPA modeling tools to simulate pesticide EECs in flowing water systems

EPA noted unrealistically high modeled concentrations and trends for flowing water

Simulated flowing water EECs were much higher than the edge of field concentrations

A recent ESA Stakeholder Workshop was held to address these modeling challenges

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Objectives and Approach

Objectives:

- Develop and evaluate an efficient, screening level approach to more realistically model "worst case" exposure in flowing water habitats
- Implement a refined, spatially explicit flowing water modeling approach

Approach:

Screening Level:

- Identify the causes for unrealistically high EECs in current approach
- Reconsider the basic parameterization of the flowing water scenarios
- Evaluate alternative receiving water models

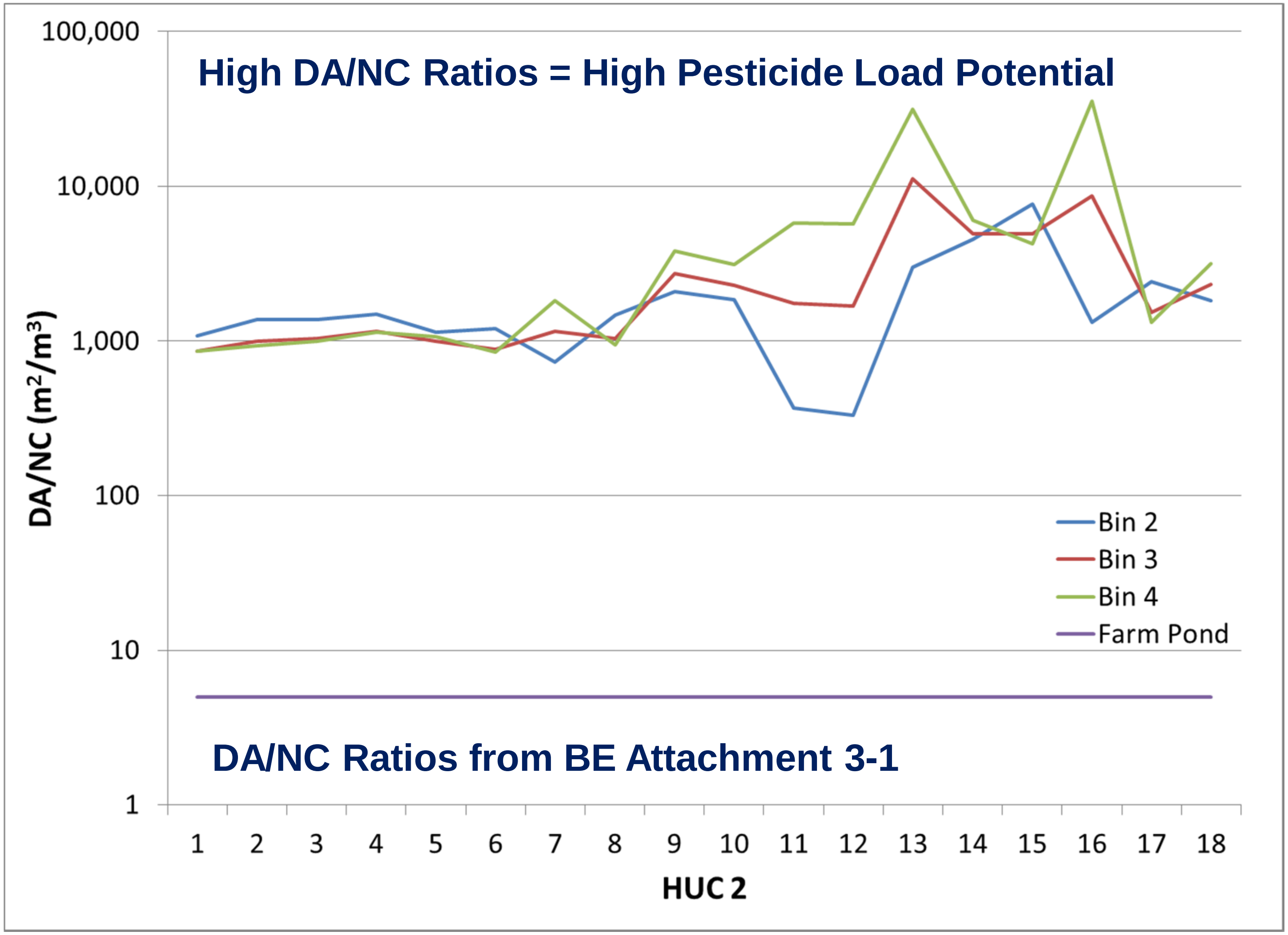
Refined:

- Implement a spatially distributed watershed model
- Integrate the PRZM5 regulatory model
- Generate species-specific exposure probability distributions

Causes for High Flowing Water EECs: Watershed Area

Watershed Area

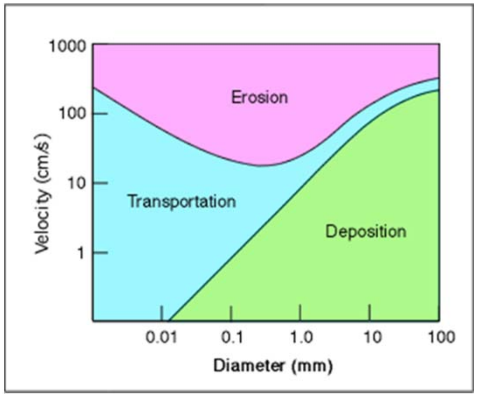
- Watershed area was derived from NHDPlus dataset regressions of mean annual flow versus drainage area at the HUC2 level
- Very large drainage areas often result
- Drainage Area / Normal Capacity (DA/NC) >>> farm pond



Causes of High Flowing Water EECs: Model Limitations

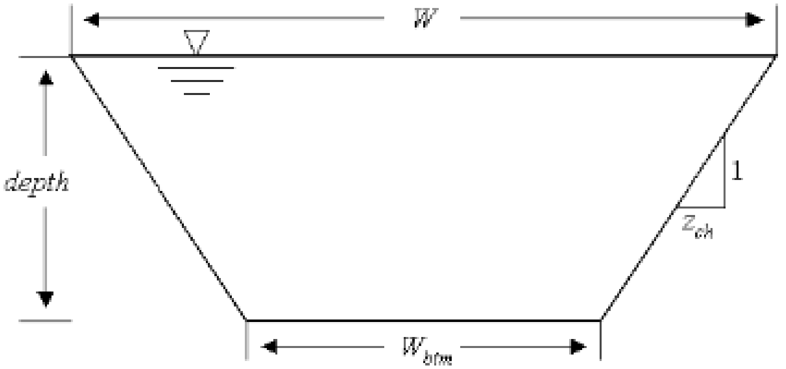
Sediment dynamics, important for some pesticides, are not accounted for in VVWM

- Downstream transport out of water body
- Deposition
- Resuspension



Channel vs. Pond Model

- VVWM is designed and parameterized as pond that can overflow
- Flowing water models consider channel geometry and factor that affect velocity



Unrealistic Assumptions

- Instantaneous loading of all chemical into the water body, without accounting for a change in volume
- Physically impossible leading to extreme peak EECs for flowing water bodies with larger watersheds

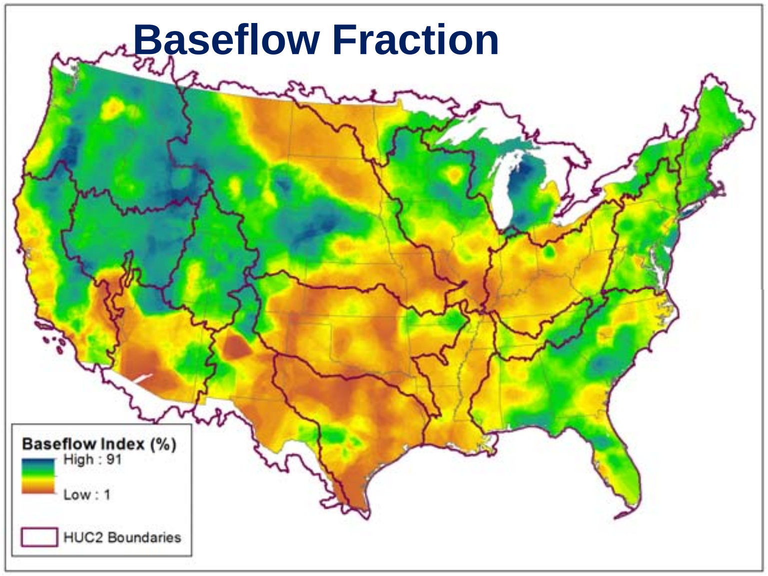
Causes of High Flowing Water EECs: Landscape Parameterization

Landscape Characteristic	Assumption
High Vulnerability PRZM Runoff/Erosion Scenario	HUC2/Crop Group scenario with highest curve number
Watershed Homogeneity	Pesticide apps all on the same date; rainfall spatially uniform; high runoff/erosion vulnerability for entire watershed
Percent Cropped Area	100%
Percent Treated Area	100%

Re-parameterization of the Flowing Water Scenarios

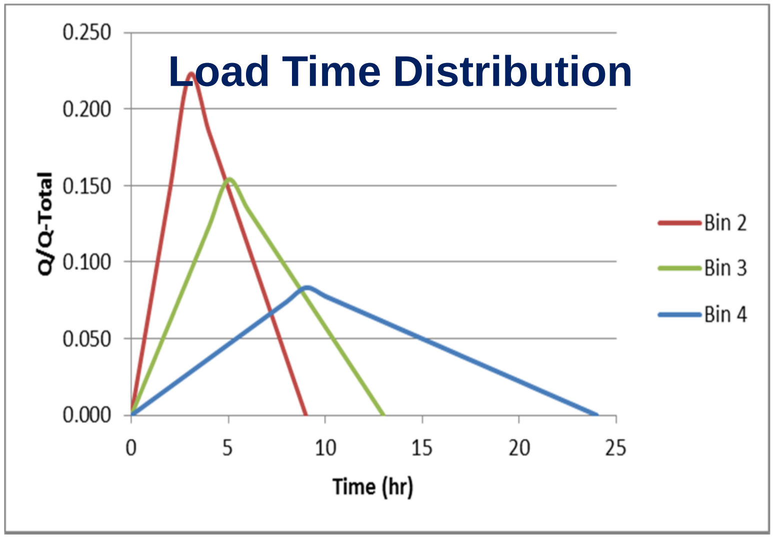
Watershed Size: Utilize hydrology time of concentration and unit hydrograph to determine the max watershed area contributing in 1-day

Baseflow: Calculate USGS baseflow index averaged over each HUC2



Water Body/Channel Characteristics: From habitat Bin width, depth, flow, and velocity, define: Channel length, slope, roughness

Landscape Loading: Time-distribute PRZM pesticide and flow



Landscape Characteristics: Account for PCA

Alternative Receiving Water Models

SWAT (Soil and Water Assessment Tool)

- Watershed scale water quality model developed by USDA/ARS
- Used internationally and well renowned for simulating water quality
- Channel flow-routing component simulates downstream movement of water, sediment, nutrients, and pesticides
- Is the basis for EPA Office of Water's Hydrologic and Water Quality System (HAWQS), a national water quality modeling tool

AGRO-2014

- Based on the Canadian Environmental Modeling Center (CEMC) Quantitative Water, Air, Sediment Interaction (QWASI) Fugacity model
- Simulation of sediment dynamics, including settling/resuspension of incoming sediment and burial
- Similar to VVWM in conceptualization of static water body with flow overflow

Evaluation of Alternative Receiving Water Models

Generate watershed runoff/erosion/pesticide from PRZM5 following the modified watershed parameterization approach

Parameterize receiving water models (VVWM/SWAT/AGRO-2014) as consistently as possible

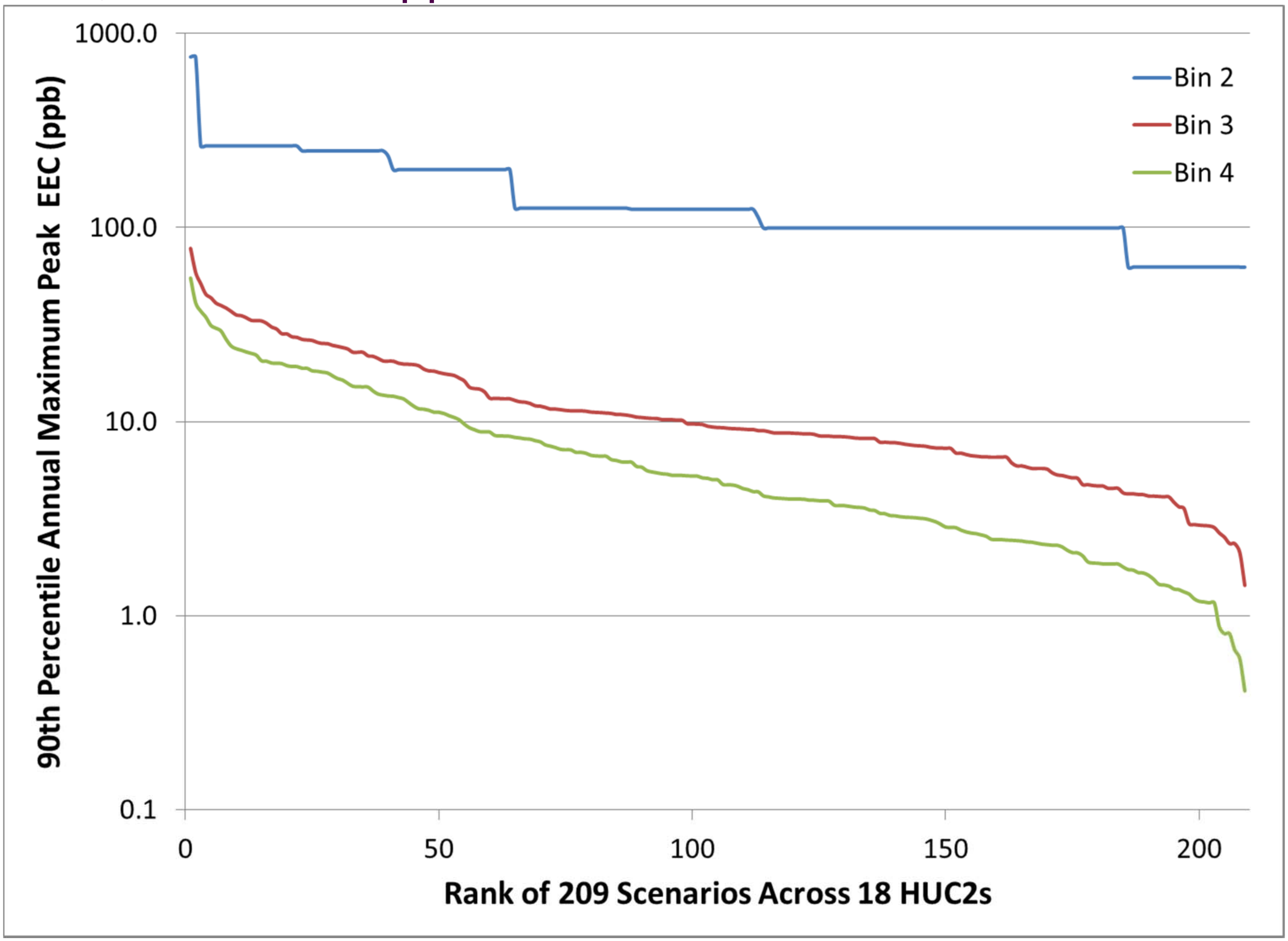
- VVWM and AGRO do not have water body length or channel attributes
- Baseflow rate and volume of the water bodies is equivalent across all 3 models

Run simulations for all 3 flowing bins for all HUC2s and crop groups bins, compare, and review:

- 90th percentile annual maximums for peak, 1-day, and 21-day EECs
- Time series of individual events from different bins

SWAT Results for Peak EECs, Malathion

The trend in EECs from low to medium to high flow habitats is as expected, and values appear more realistic for “worst case”

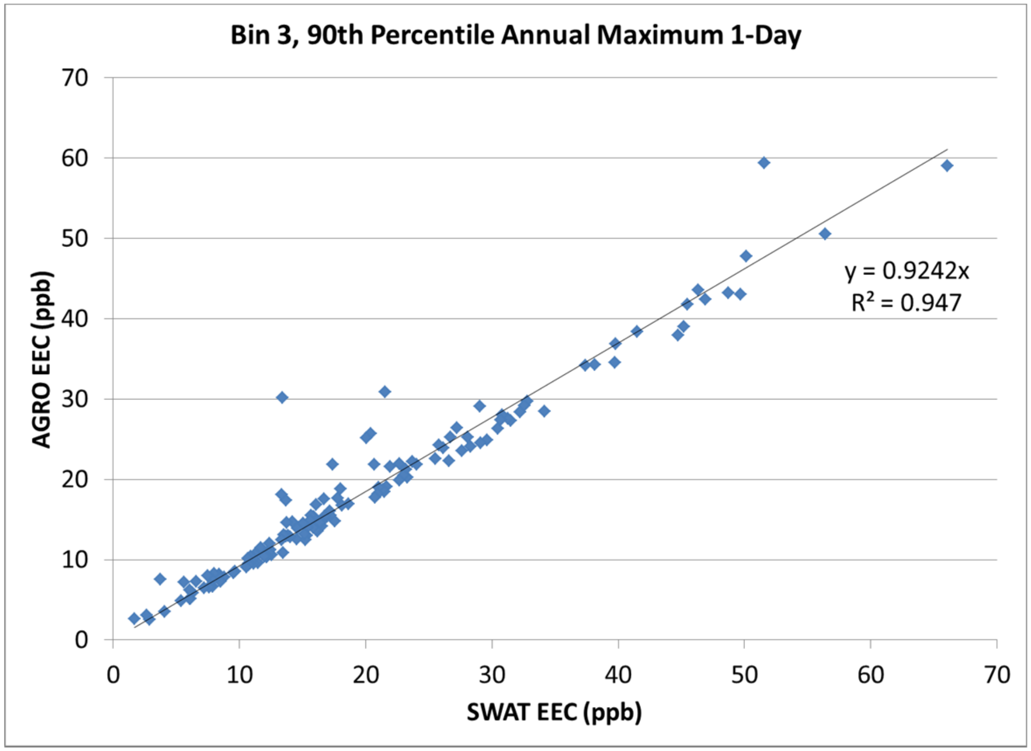


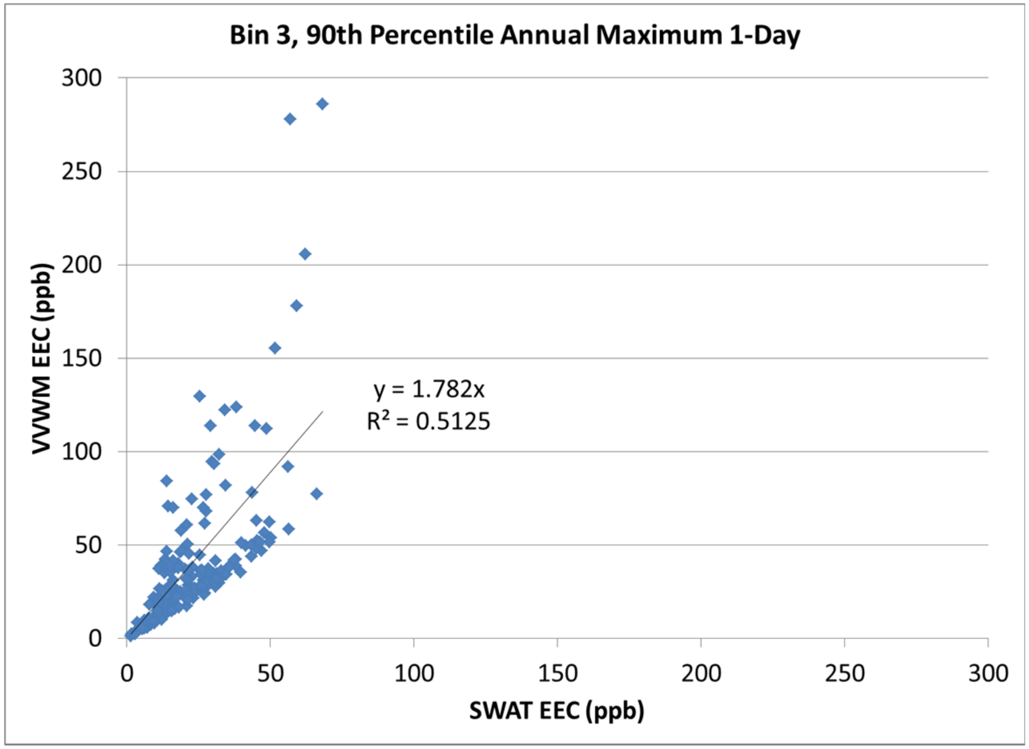
AGRO-2014 Model Compares Well with SWAT for Bin 3 1-Day EECs for Chlorpyrifos

AGRO and SWAT have much closer agreement for Bin 3 compared to VVWM and SWAT

- Likely a function of VVWM sensitivity to watershed area

AGRO has a slight low bias compared to SWAT





Screening Level Approach Summary and Conclusions

The unrealistically high EECs derived for flowing water in the draft BEs were due to:

- The conceptual model and parameterization of the scenarios
- Limitations of the VVWM receiving water model

Modifications to the conceptual model and parameterization, tested with both VVWM and 2 alternative models, were found to be effective at bringing EECs into a more realistic worst case range

- The peak EECs predicted by VVWM are still unrealistically high

The SWAT and AGRO-2014 models showed strong agreement for Bin 3 1-day and 21-day EECs, adding confidence to their predictions

The SWAT model is the currently preferred receiving water model for flowing water simulations because of its:

- Conceptual appropriateness
- Ability to represent channels with different characteristics and complexity

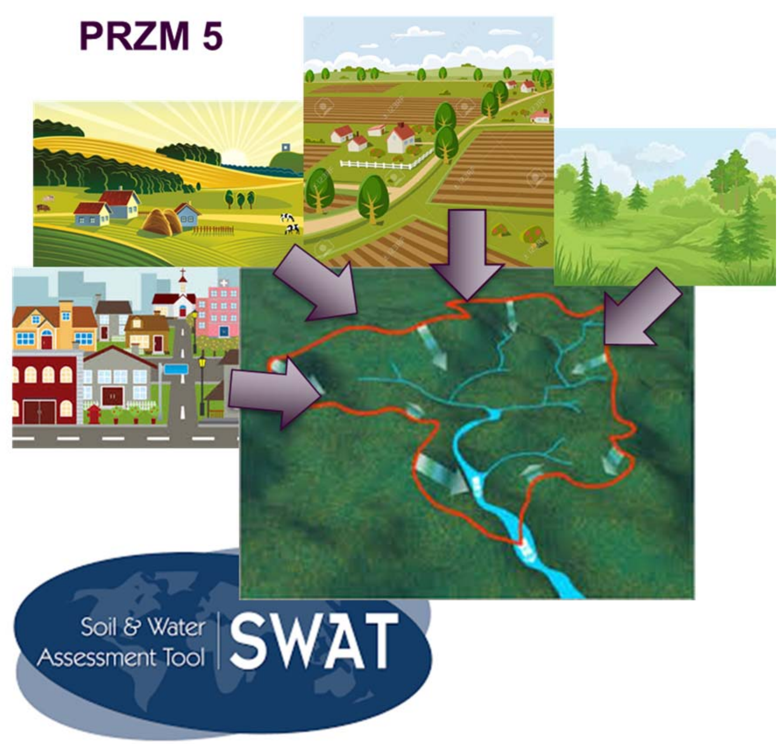
A Refined, Species-Specific Flowing Water Modeling Approach

Requirements:

- Spatially explicit, species specific
- Account for variability in environmental conditions and agronomic practices
- Allow flexibility in refinement options (e.g., pesticide use, probabilistic inputs)

Flowing water modeling methodology:

- Apply PRZM5 to generate daily time series runoff, sediment, soluble pesticide, and sorbed pesticide loadings for each catchment
- Integrate with the EPA Office of Water HAWQS SWAT model for:
  - Daily baseflow simulation
  - Flow connectivity and channel attributes to parameterize and simulate downstream routing



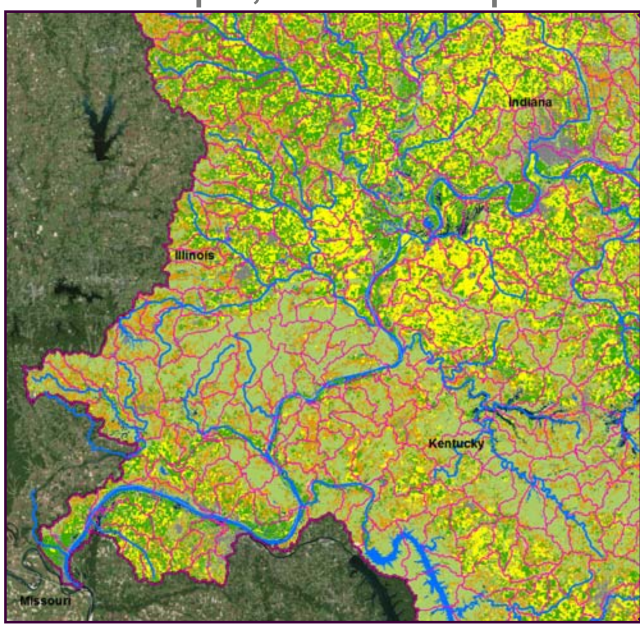
Refined Flowing Water Modeling Applied to HUC2-05

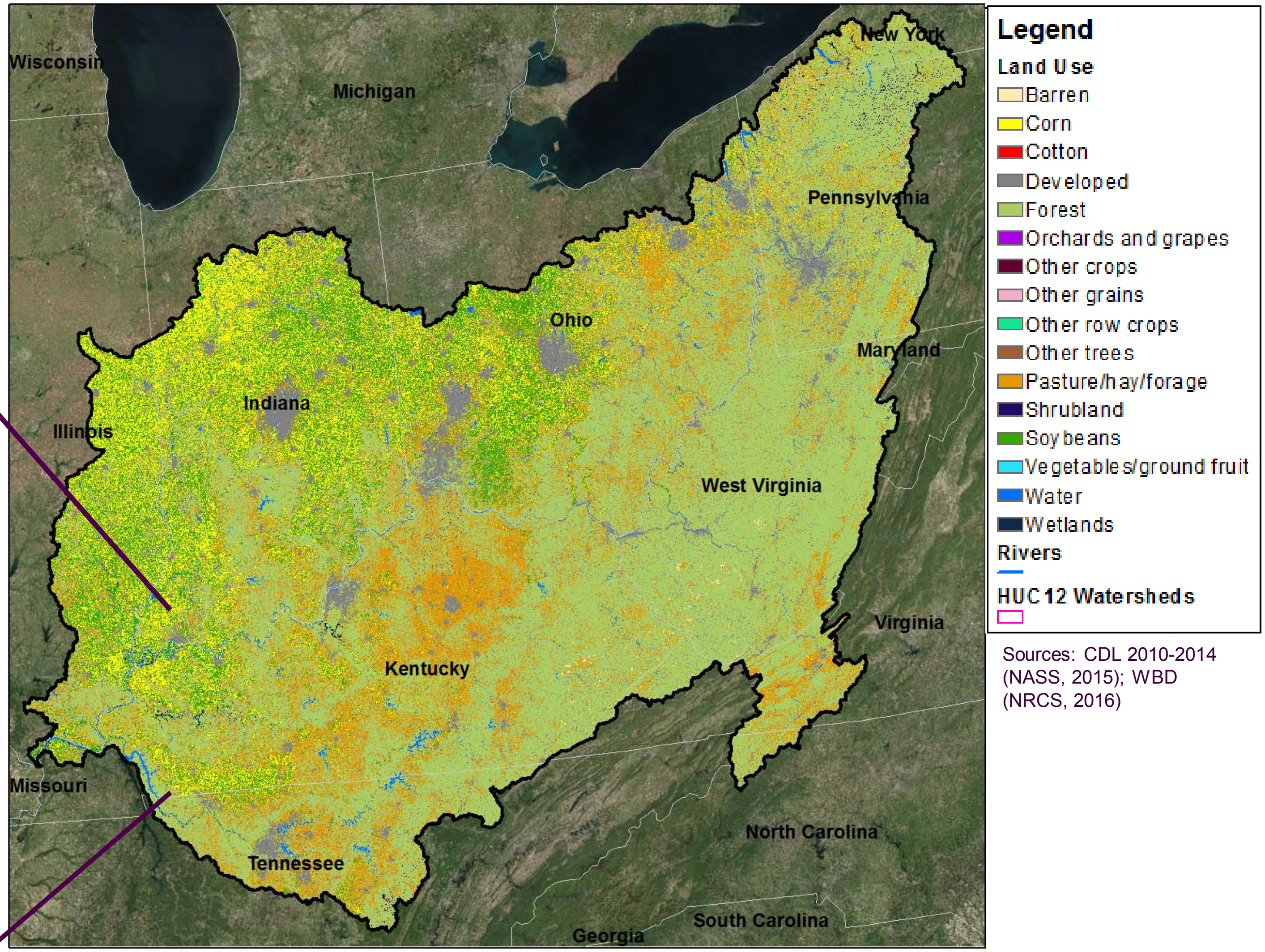
Model applied to HUC2-05(Ohio Basin) at HUC12 watershed scale:

- 5,277 HUC12 watersheds
- 163,000 mi^2 total drainage area

Applied for Chlorpyrifos

- Treated crops include: corn, soybean, cotton, pasture, orchards, vegetables, other grains, other row crops, other crops



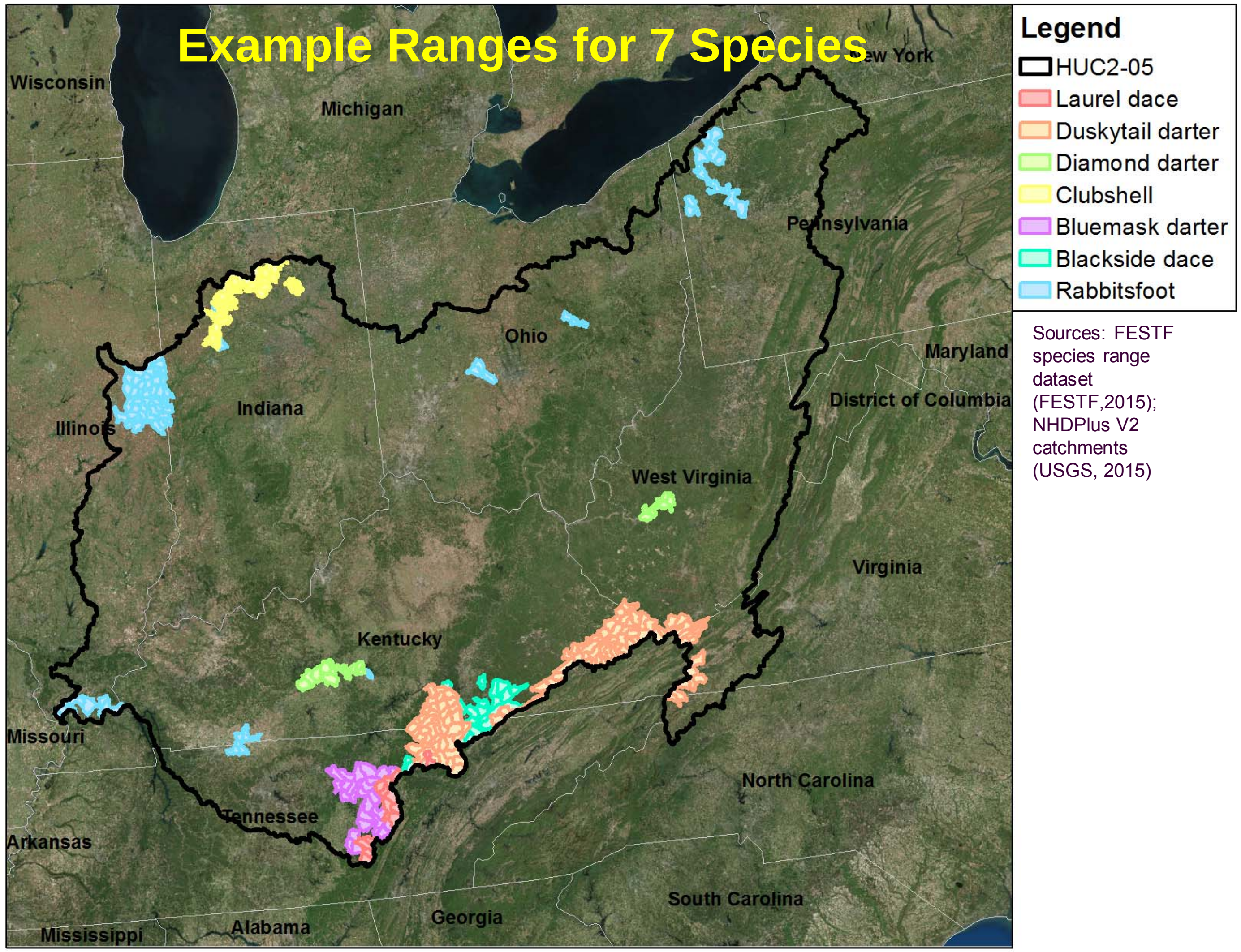


Sources: CDL 2010-2014 (NASS, 2015); WBD (NRCS, 2016)

Exposure Predictions Made for 23 Fish, Mollusks, and Crustacean Species Ranges

The EECs relevant to each species will be based on the spatial intersection of HUC12 catchments and species ranges

Taxon	Common Name
Crustaceans	Kentucky cave shrimp
Crustaceans	Nashville crayfish
Fish	Blackside dace
Fish	Bluemask (=jewel) darter
Fish	Boulder darter
Fish	Cumberland darter
Fish	Diamond darter
Fish	Duskytail darter
Fish	Laurel dace
Fish	Palezone shiner
Fish	Pallid sturgeon
Fish	Roanoke logperch
Fish	Scioto madtom
Fish	Slender chub
Fish	Spotfin chub
Mollusks	Clubshell
Mollusks	Fanshell
Mollusks	Northern riffleshell
Mollusks	Orangefoot pimpleback (pearlymussel)
Mollusks	Rabbitsfoot
Mollusks	Rayed bean
Mollusks	Sheepnose mussel
Mollusks	Snuffbox mussel



Sources: FESTF species range dataset (FESTF,2015); NHDPlus V2 catchments (USGS, 2015)

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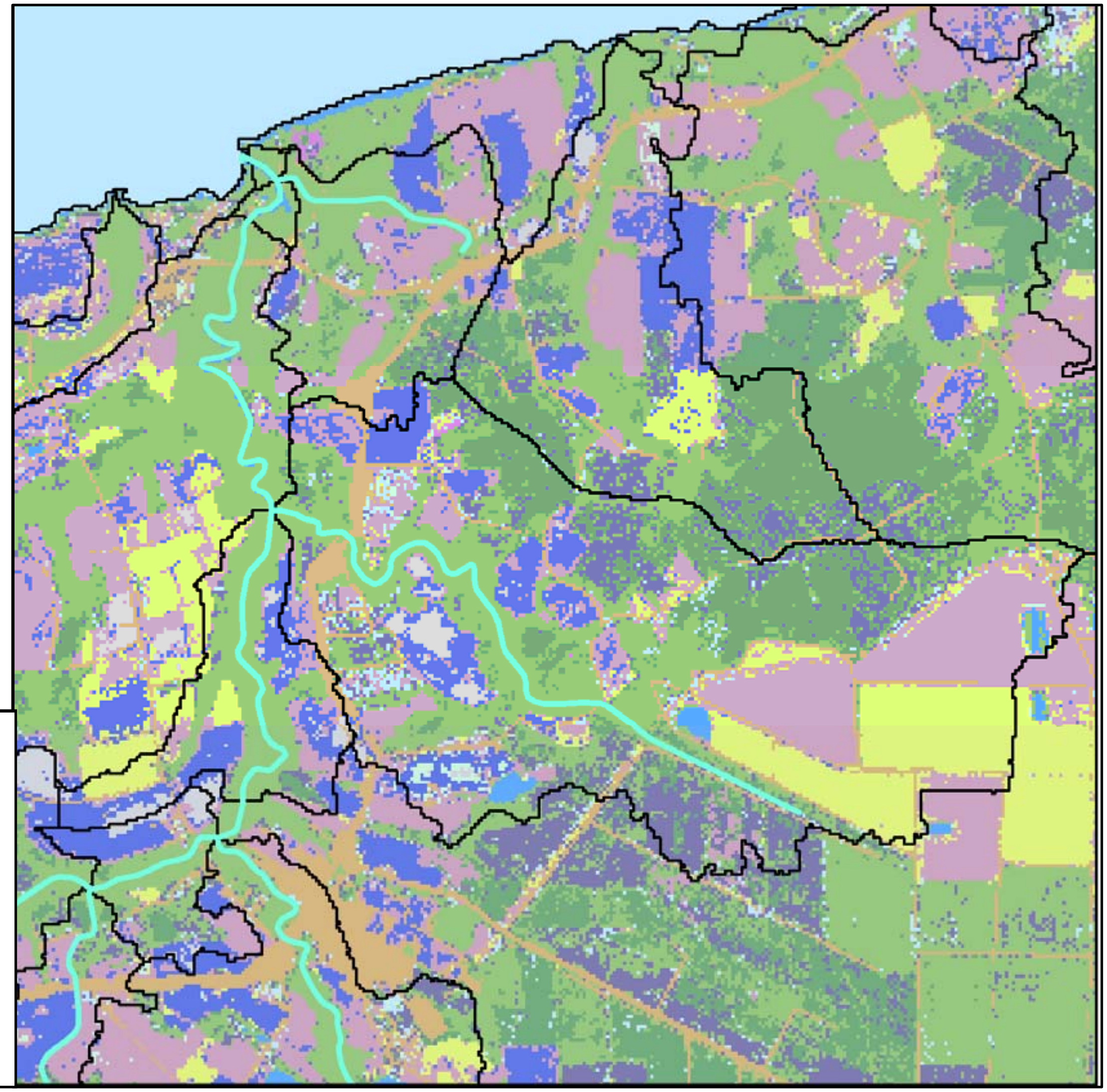
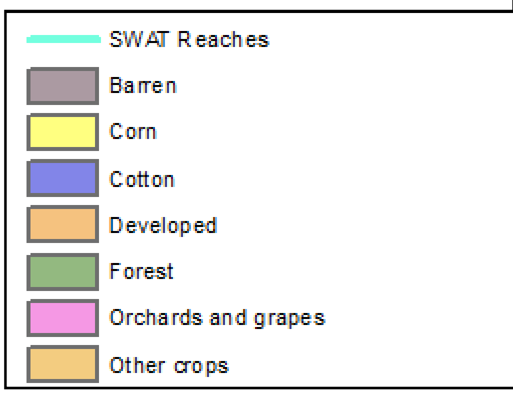
Coupling PRZM5 and SWAT for Spatially Explicit Flowing Water Modeling

Unique combinations (226,361) of land cover/soil/weather simulated using PRZM5 to represent each of 5,277 HUC12 watersheds

- 19 Land over/crop classes
- 343 soil bins
- 1,010 weather time series



Area-weighted sums of runoff, erosion, and pesticide fluxes from PRZM5 simulations for each HUC12 watershed provided as loading input time series to each SWAT reach



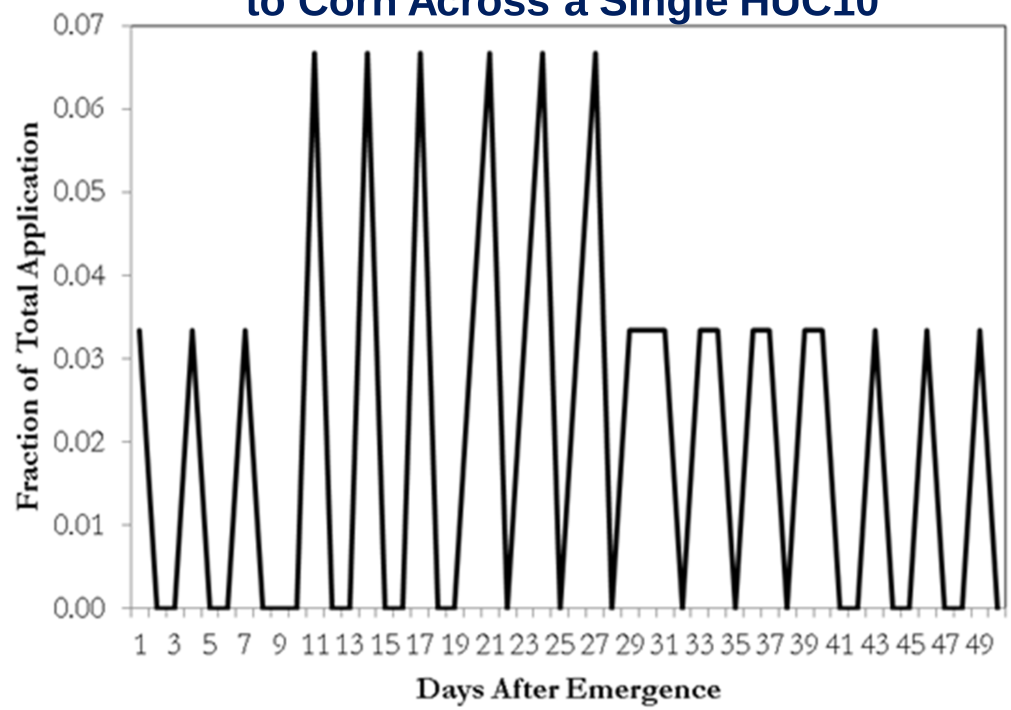
Watershed Scale Pesticide Application Refinement Approach

Typical chlorpyrifos application windows for each treated crop were derived from a literature review and calls to local ag extension agents

For each crop in a HUC10 watershed, the earliest initial application date was randomly chosen from the window

Within a HUC10, the initial application date within the HUC10 could vary by up to 30 days

Depending upon the use pattern, this resulted in 6 to 25 initial application dates within a HUC10



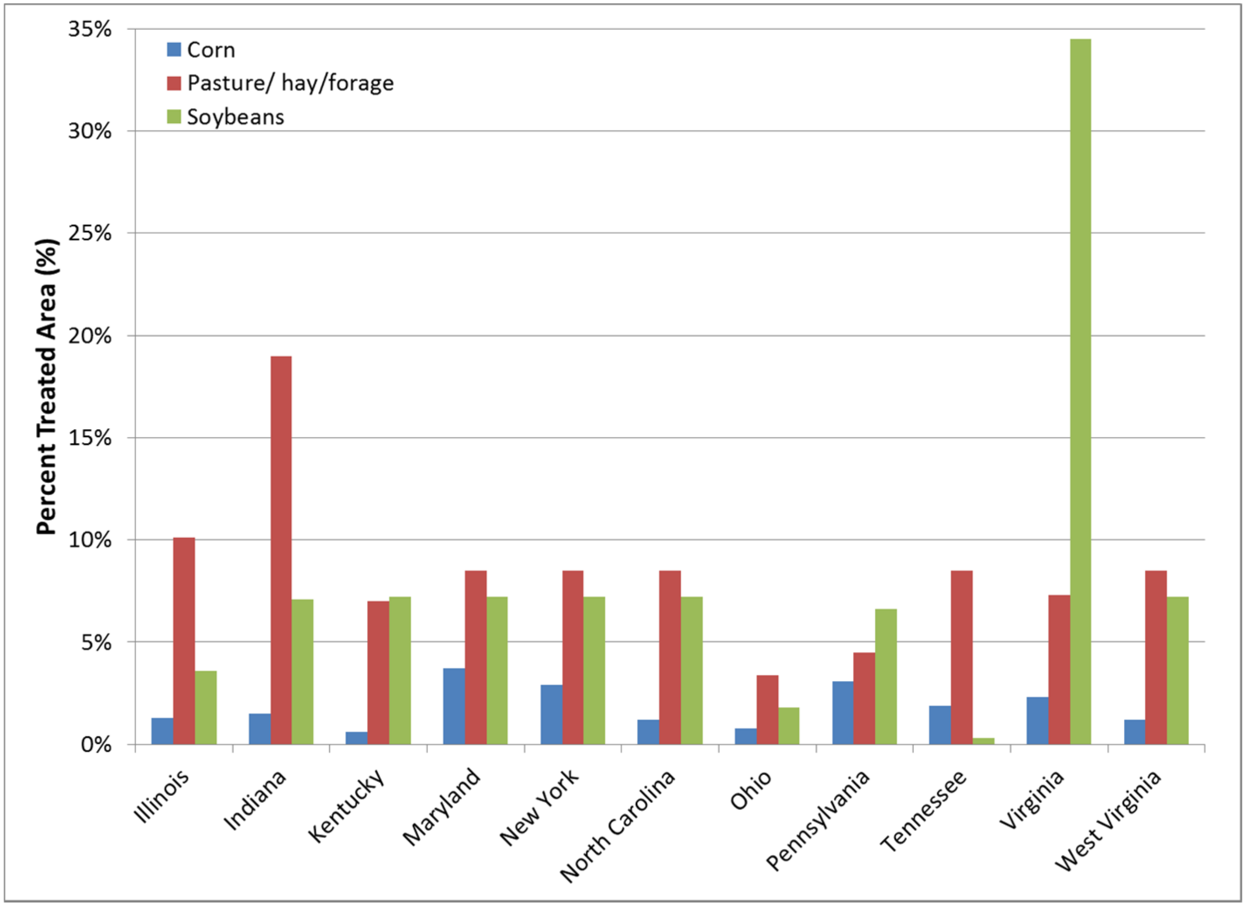
Percent Treated Area Refinement Approach

Chlorpyrifos is registered for use on a broad spectrum of crops

State-level use data from 2010 – 2015 was obtained from AgroTRAK and the Percent Treated Areas (PTA) was calculated by state/crop group

The 90th percentile PTA was calculated for each crop and state

- Corn: 0.3% - 3.7%
- Soybean: 0.3% - 34.5%
- Pasture/Hay: 3.4% -19%



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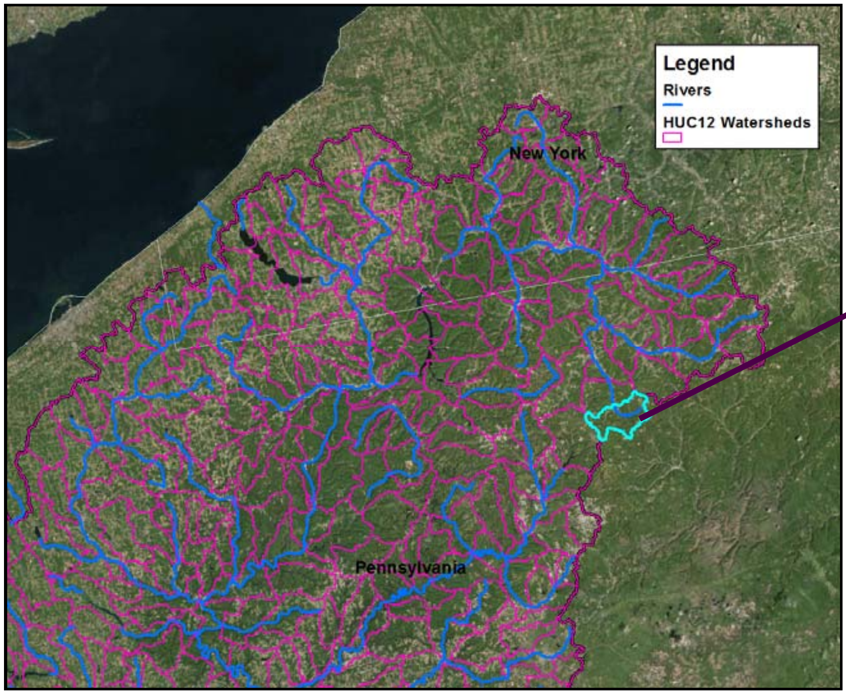
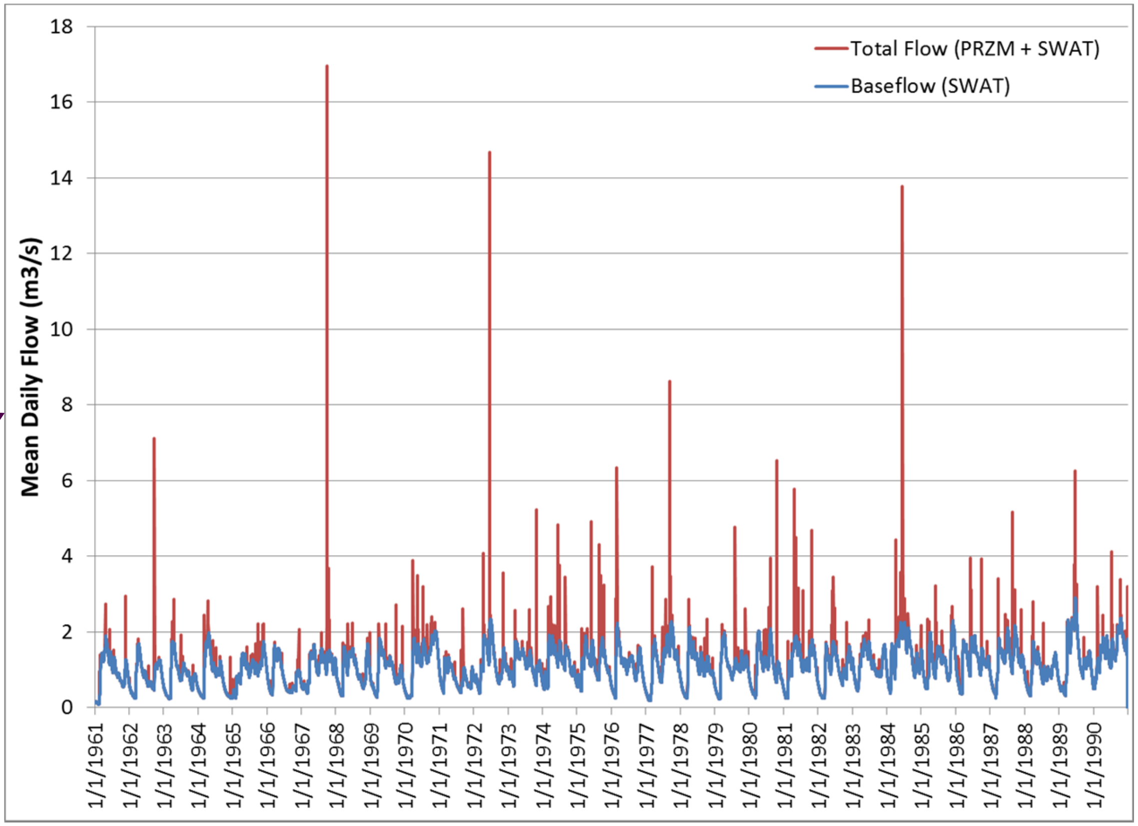
Incorporation of Daily Baseflow from HAWQS SWAT

Baseflow, or subsurface contributions to streamflow, varies daily

The SWAT model simulates the entire hydrologic cycle, including shallow subsurface and deeper groundwater baseflow components

The EPA HAWQS SWAT model generated daily baseflow, and PRZM5 provided surface runoff





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Model Simulation Approach and Uncertainty Analysis

Probability distributions of annual maximum EECs were generated for each of 5,277 HUC12 stream segments based on 8 scenarios to account for uncertainty in 3 model parameters:

- Soil Half Life: 28.3 to 96.3 days
- Baseflow: A high and low SWAT baseflow parameterization
- Channel Routing: A high and low channel velocity parameterization

Uncertainty Scenario	Environmental Fate	Baseflow[1]	Channel Routing[2]
1	High soil half-life	Baseflow Low	Channel Velocity Hi
2	High soil half-life	Baseflow Low	Channel Velocity Low
3	Low soil half-life	Baseflow Low	Channel Velocity Hi
4	Low soil half-life	Baseflow Low	Channel Velocity Low
5	High soil half-life	Baseflow Hi	Channel Velocity Hi
6	High soil half-life	Baseflow Hi	Channel Velocity Low
7	Low soil half-life	Baseflow Hi	Channel Velocity Hi
8	Low soil half-life	Baseflow Hi	Channel Velocity Low

1. Baseflow uncertainty using two CN adjustment methods; soil moisture and plant ET

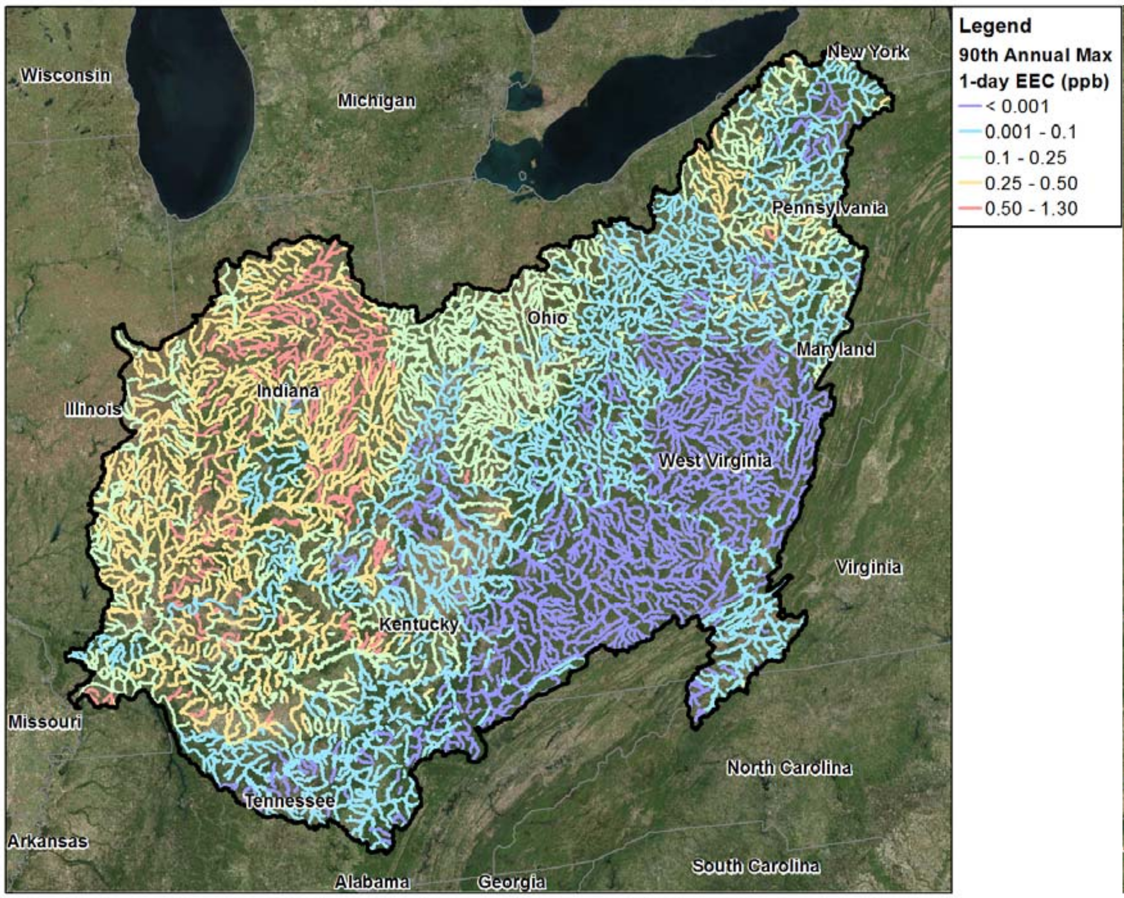
2. Channel routing uncertainty accounting for velocities based on two different Manning's n value; 0.014 and 0.05

Spatial Distribution of Chlorpyrifos EECs

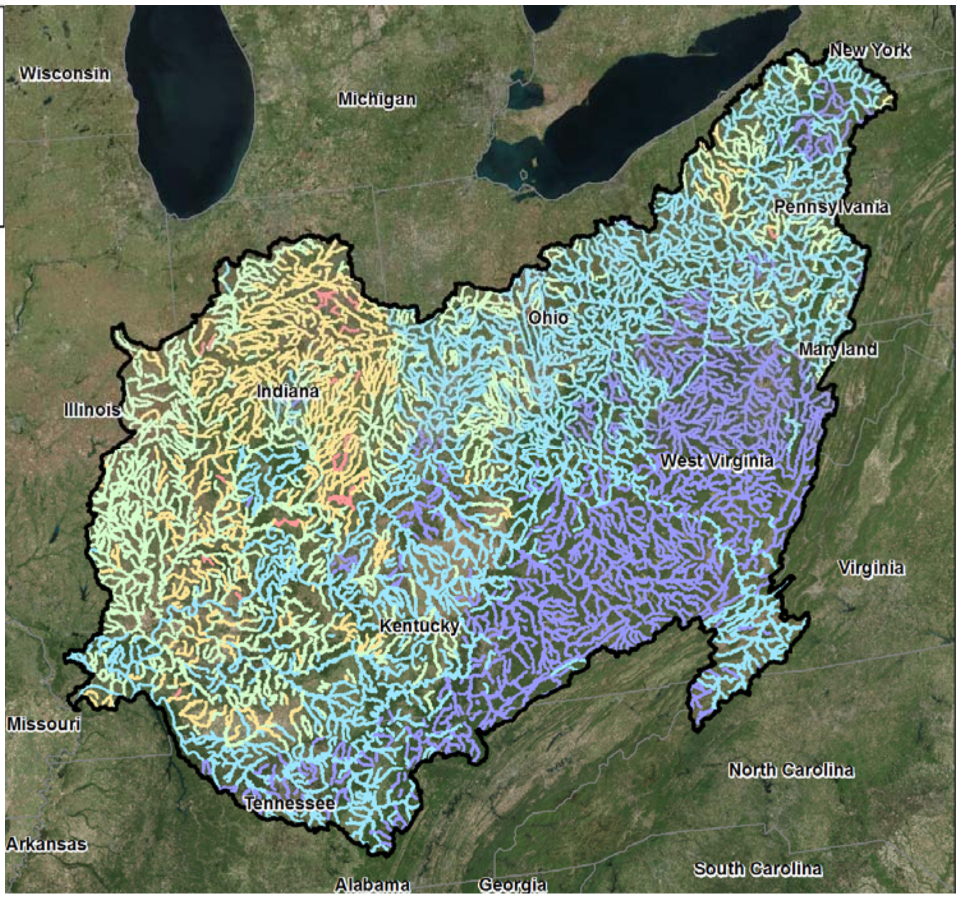
PRZM-SWAT simulations were run for each of the 8 scenarios

- Very high spatial variability observed across HUC2-05
- Of the 3 uncertainty parameters evaluated, the soil half life had the greatest impact on EECs

High Soil HL, Low Baseflow, High Channel Vel.



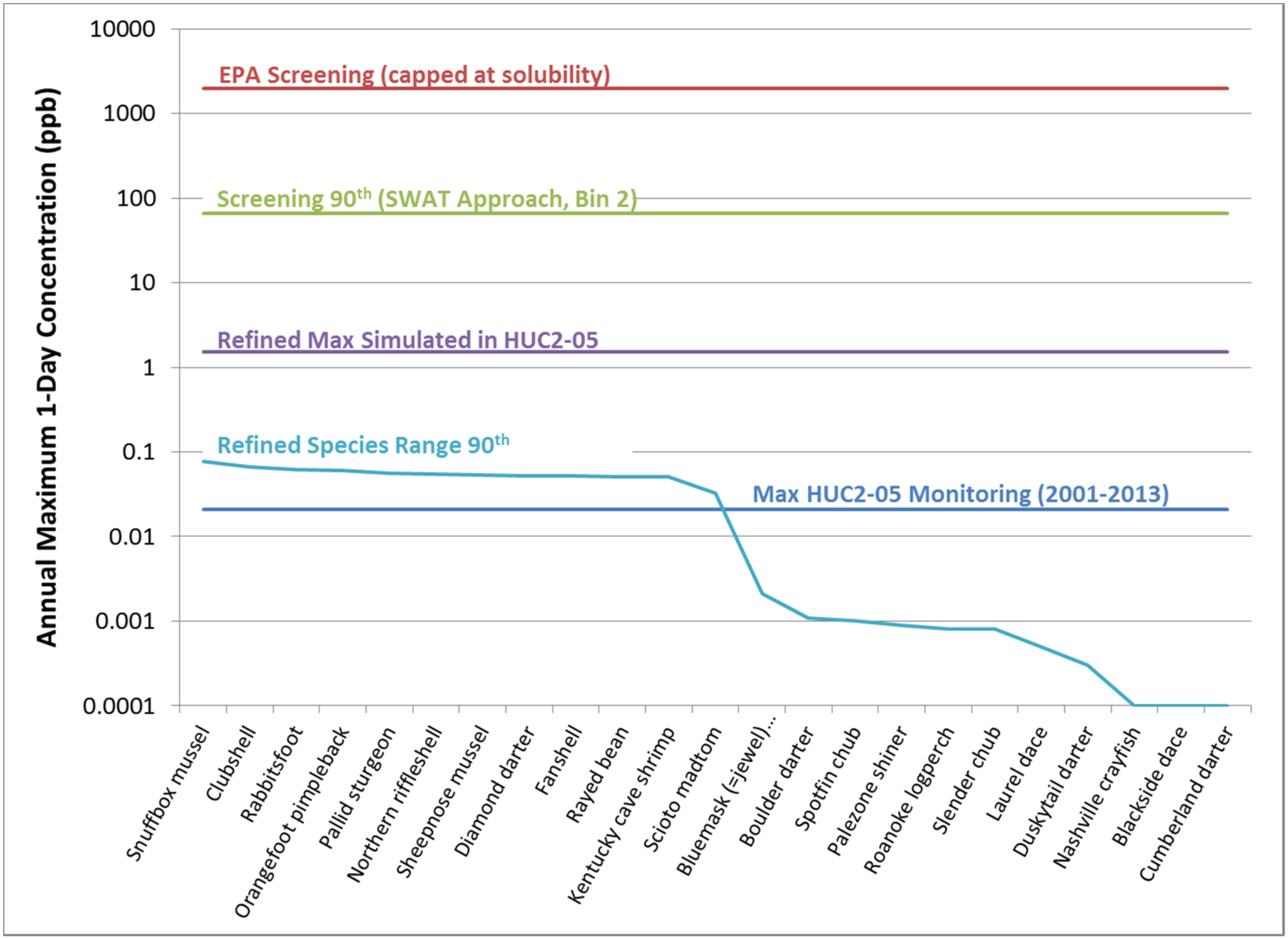
Low Soil HL, High Baseflow, Low Channel Vel.



EECs by Species Comparison with Screening and EPA

Refined EECs vary several orders of magnitude across species ranges

Refined EECs are still conservative relative to monitoring data



Refined Modeling Approach Summary and Conclusions

A refined modeling approach to assess exposure of aquatic endangered species to pesticides was developed

The refined approach integrates the regulatory PRZM5 model with components of the SWAT watershed scale model

- Allows for a range of possible input refinements
- Suitable for incorporating uncertainty analysis

The species-specific, probabilistic EECs generated from this approach provide high value informing endangered species effects determinations at multiple steps of the ESA process

The modeling approach demonstrated in this example addresses the flowing water modeling recommendations identified during the June 2016 ESA Stakeholder Workshop

Thank you.

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