

Coupling Monitoring with High Spatial and Temporal Resolution Data to Improve Predictions of Catchment Scale Drift and Runoff Exposure

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Regulatory Relevant Discussion Points

The need to estimate run-off and spray drift contributions to exposure in flowing water bodies at the watershed scale is necessary for human health and ecological risk assessments.

Higher spatial and temporal resolution data on pesticide application locations, environmental conditions, and receiving water monitoring leads to more realistic aquatic exposure model scenarios and predicted exposure concentrations (PECs).

Probabilistic model parametrization approaches can be used in place of high resolution, site specific data if needed.

Case Studies

Identification of Herbicide Source Areas in a High Agricultural Intensity Catchment

- Watershed scale source area analysis and BMP assessment (Belgium)

Simulations of In-Stream Pesticide Concentrations from Off-Target Spray Drift

- Watershed scale exposure assessment (Oregon, USA)

National Scale Refined Modeling of Pesticide Exposure in Flowing Water Bodies at the Watershed Scale

- Ecological exposure assessment (continental USA)

Case Study I: Motivation and Objectives

Identification of Herbicide Source Areas

Analysis of load for one herbicide

- Water quality standards occasionally exceeded (Water Framework Directive)

Application of a physically-based water quality model

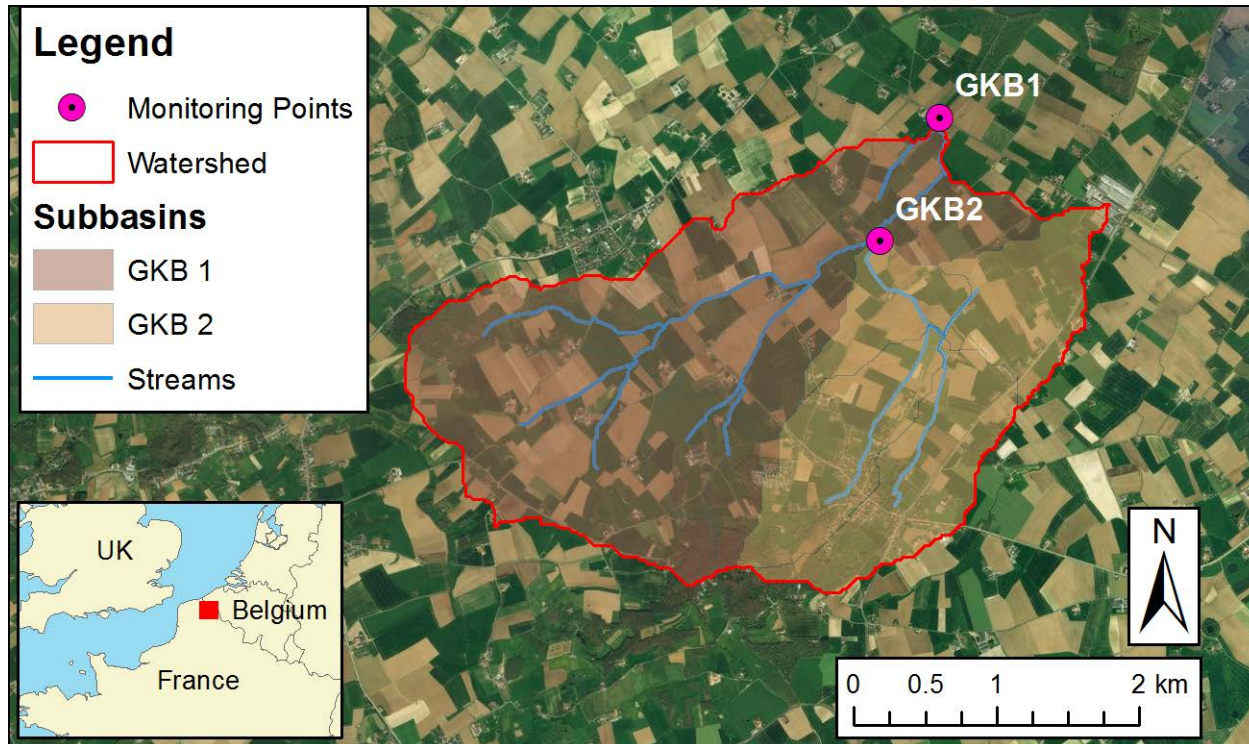
- Calibration of Soil and Water Assessment Tool (SWAT) model to observed flow and chemical data
- Ensemble simulations (Monte-Carlo)

Combining modeling, monitoring, and application data

- Evaluate transport processes and estimate source areas

Case Study I: Study Area

Study Area: Grote Kemmelbeek (GKb) catchment



Study area: 992 ha

Main landuse: Agriculture (> 90 %)

Elevation: 159 m to 24 m

Precipitation: 816 mm per year

Monitoring and Pesticide Application Data

Surface water monitoring

- Two sampling points (GKB1 and GKB2)
- May 17th, 2010 to December 31st, 2013

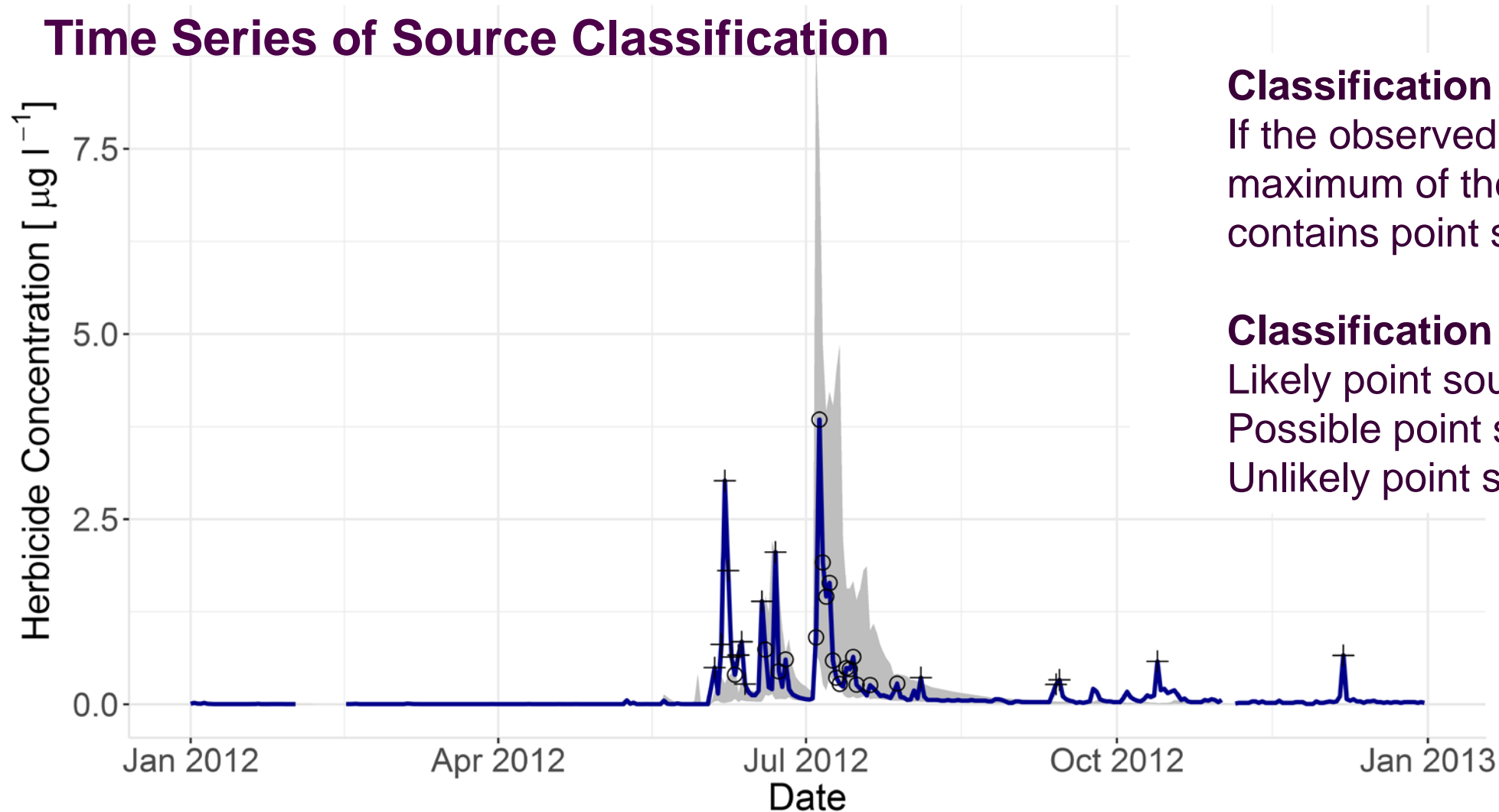
Farmer's survey

- Application data: Product used and application rate



Case Study I: Results, Event Classification

Time Series of Source Classification



Classification approach (simplified):
If the observed daily concentrations exceeds the maximum of the ensemble approach it likely contains point source contributions

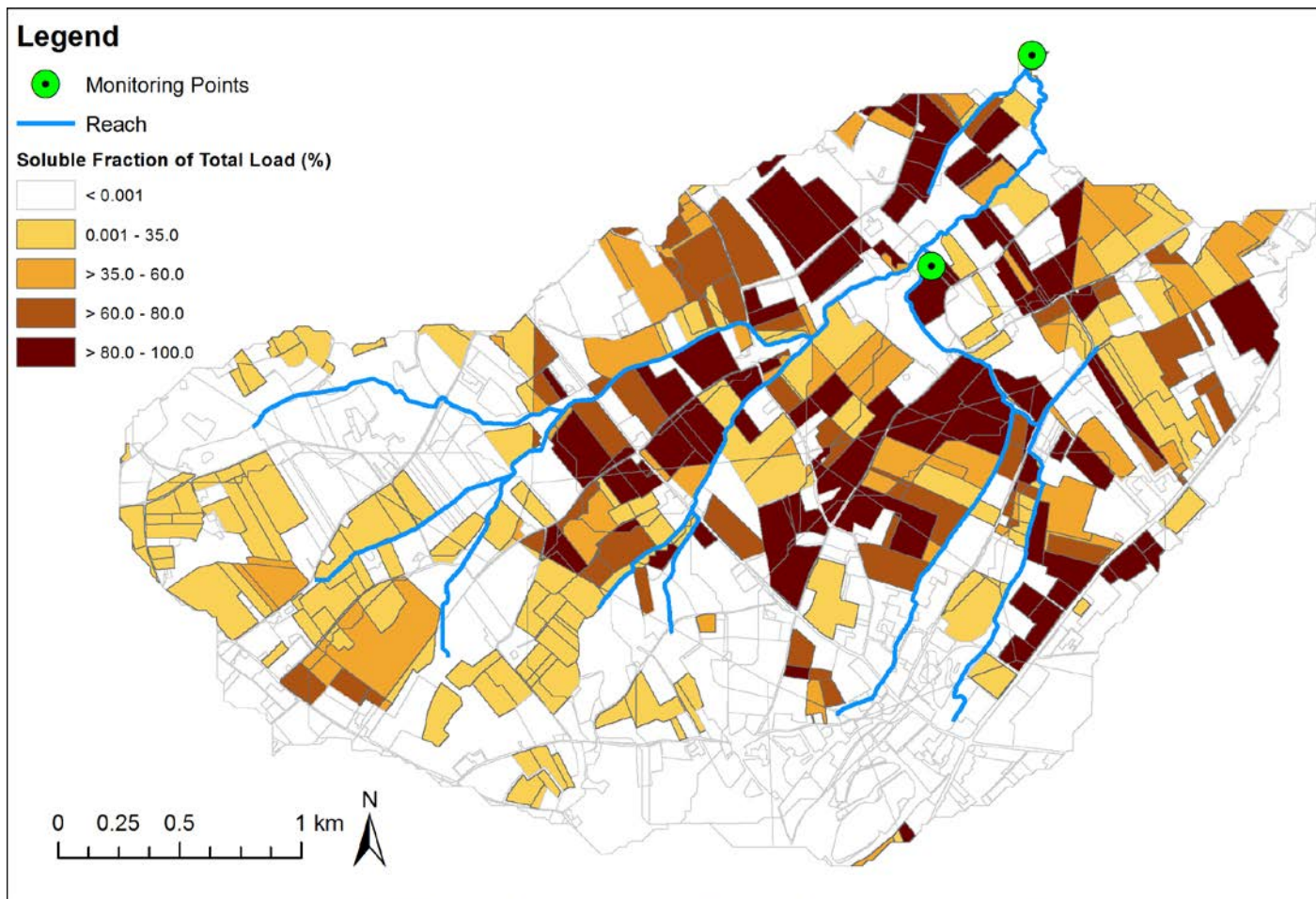
Classification results:
Likely point source contributions: 46% (34)
Possible point source contributions : 3 % (2)
Unlikely point source contributions : 51 % (38)

- + Likely point source contributions
- x Possible point source contributions
- o Unlikely point source contributions
- Observed
- Ensemble

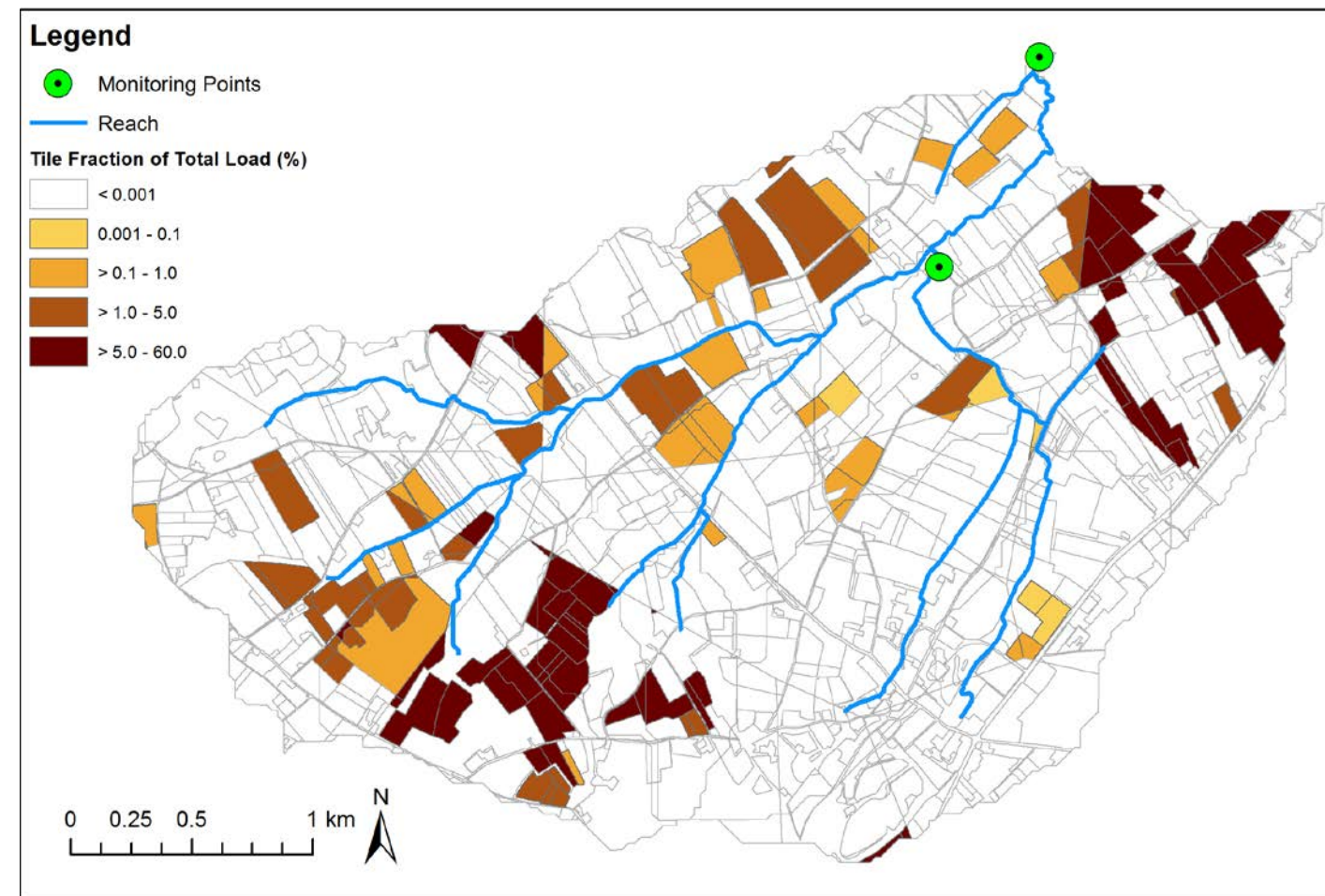
Peak event classification at the outlet

Case Study I: Results, Spatial Source Area Analysis

Soluble Pesticide Load in Surface Runoff



Pesticide Load in Tile Drain Flow



Case Study I: Conclusions

Probabilistic watershed scale modeling based on high resolution spatial data and high frequency monitoring allows for exposure pathway analysis and source area identification.

Pesticide source areas at the watershed scale can be a mix of diffuse sources (surface, subsurface, and aerial) combined with point sources, and depend on:

- Topographic and soil conditions
- Artificial drainage
- Proximity to surface water
- Human behavior

Case Study II: Motivation and Objectives

Watershed Scale Drift Exposure

Spray drift is a potentially significant aquatic exposure source for many pesticides and types of aquatic environments.

Screening level aquatic exposure modeling relies upon conservative assumptions of pesticide spray drift entry to surface water.

Can higher spatial and temporal resolution data lead to more realistic aquatic exposure concentrations?

- Evaluate model performance with increasing detail of model input data

Case Study II: Study Location

Two watersheds in the Dalles, Oregon

- Mill Creek
- Threemile Creek

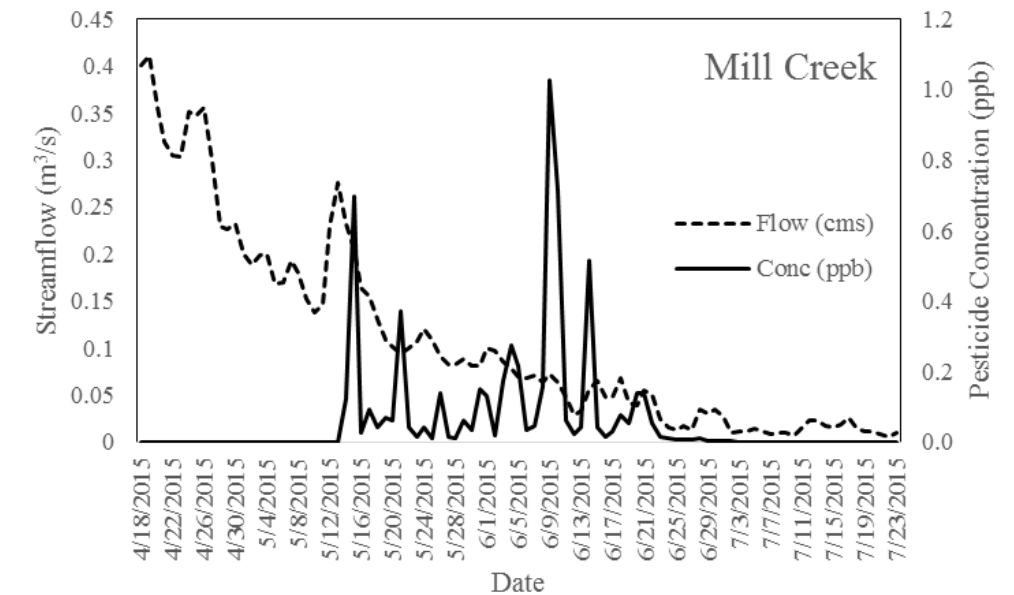


High use intensity of an insecticide on cherry orchards.

Sub-daily sampling throughout 6-week application period, hourly sampling for most intense week.

Maximum observed instantaneous concentrations:

- Mill Creek: 1.03 ppb
- Threemile Creek: 0.46 ppb



Case Study II: Modeling Experiments

1

- Screening level assumption (e.g., applications at max label rate, worst case wind)

2

- Incorporate actual application dates and rates applied to specific fields

3

- Incorporate actual wind direction

4

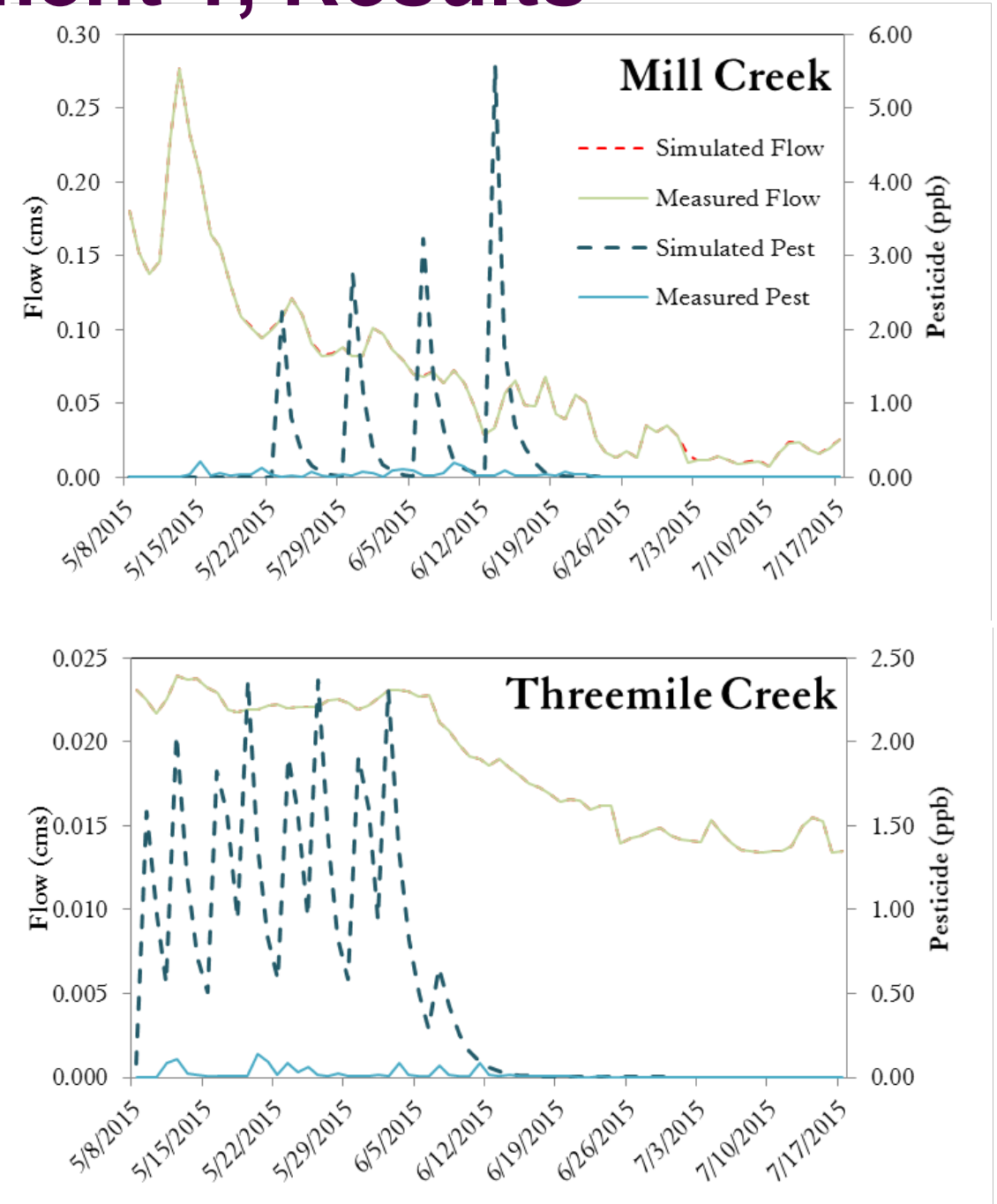
- Incorporate actual wind speed

Case Study II: Modeling Experiment 1, Results

Data from **baseline simulation** compared against the average daily measured insecticide concentrations.

Predicted concentrations are:

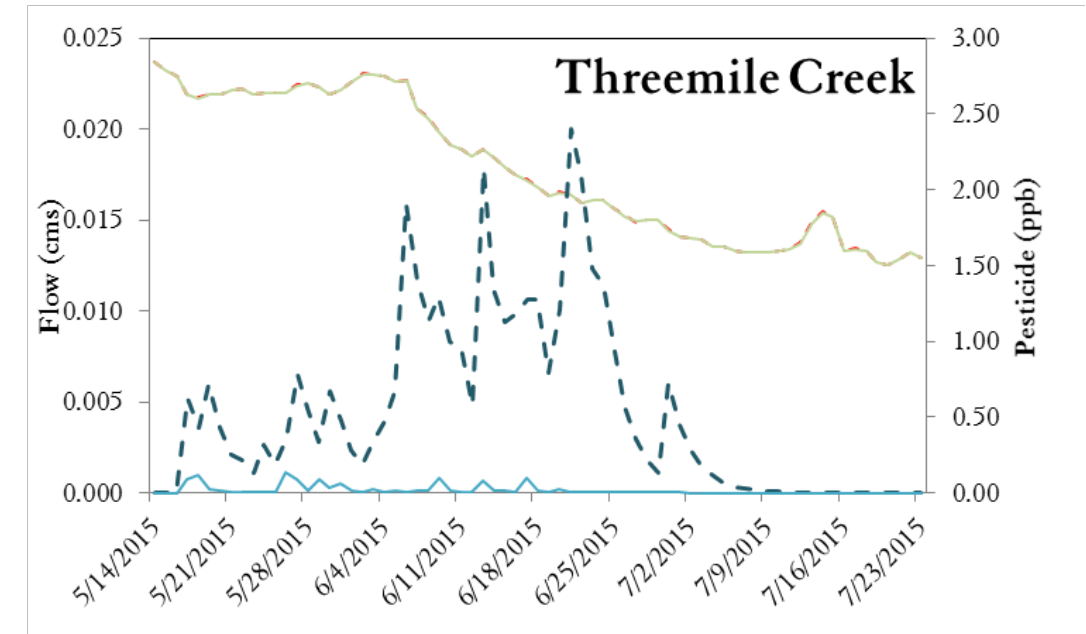
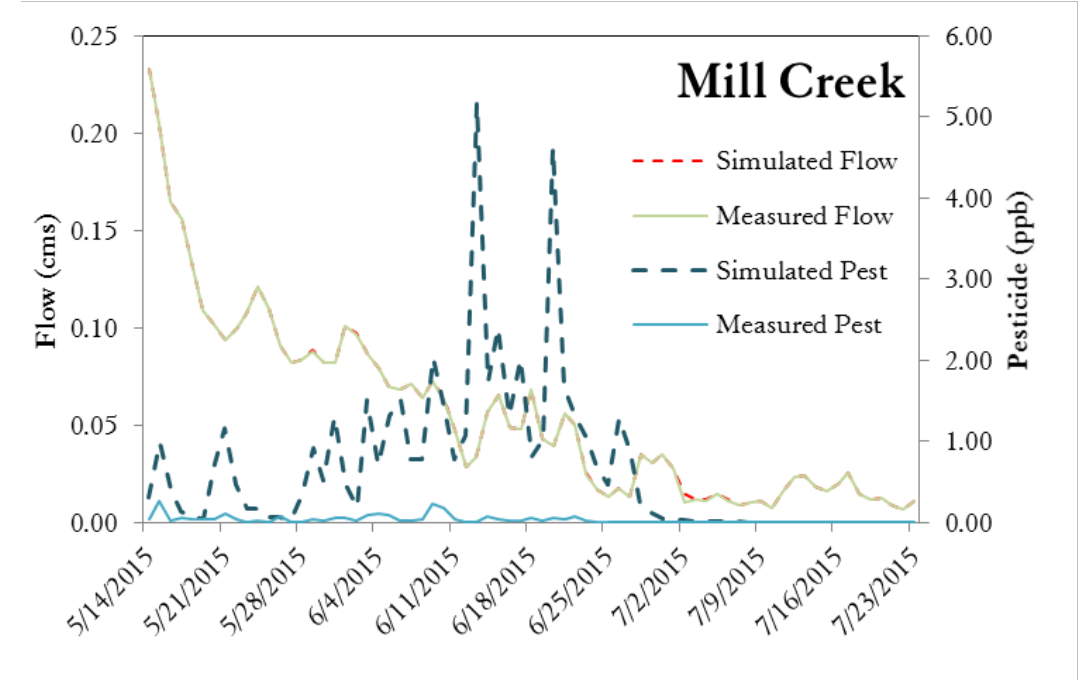
- Overly conservative (17x – 27x above observed max)
- Show a temporal mismatch



Case Study II: Modeling Experiment 2, Results

Accounting for realistic application data, the predicted concentrations still exceed the observed mean daily concentrations by nearly the same magnitude as the baseline simulations.

The temporal pattern of peak concentrations is slightly improved.

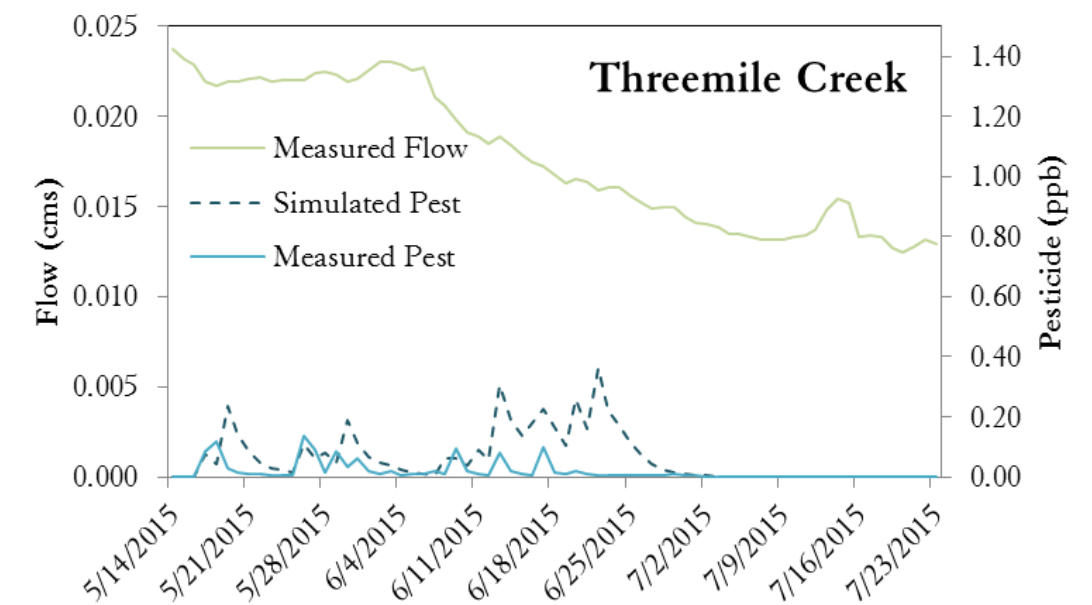
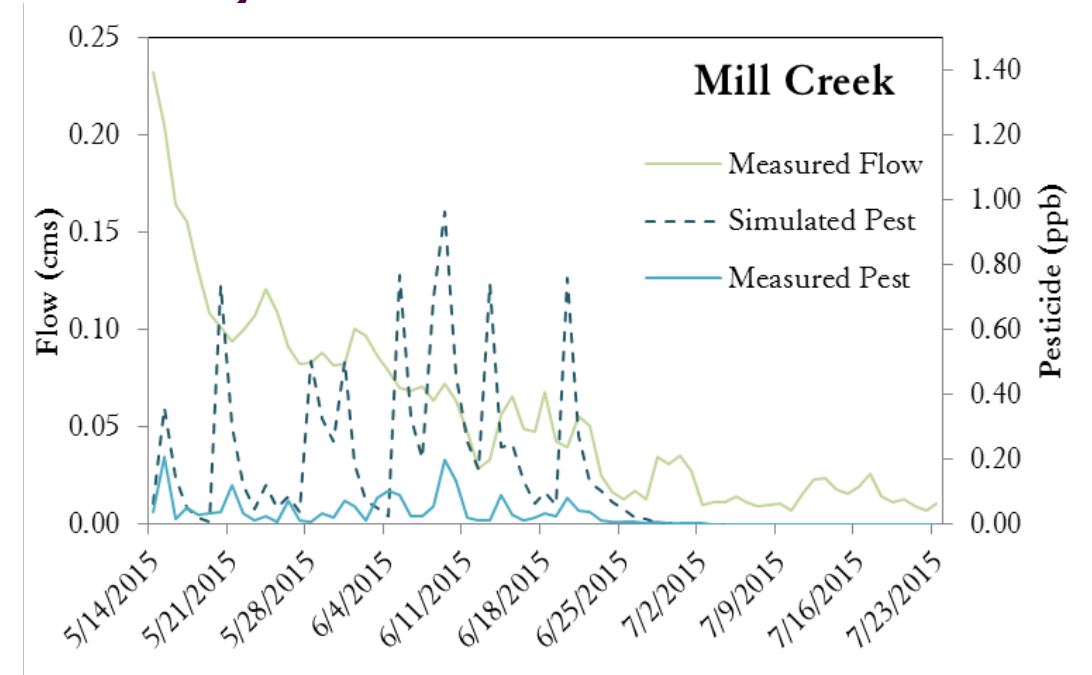


Case Study II: Modeling Experiment 3, Results

Accounting for wind direction, and the fact that wind does not always blow from a treatment site to a receiving water body, greatly improved the simulated insecticide concentrations.

Mill Creek: Max simulated concentration 4.6 times higher than observed

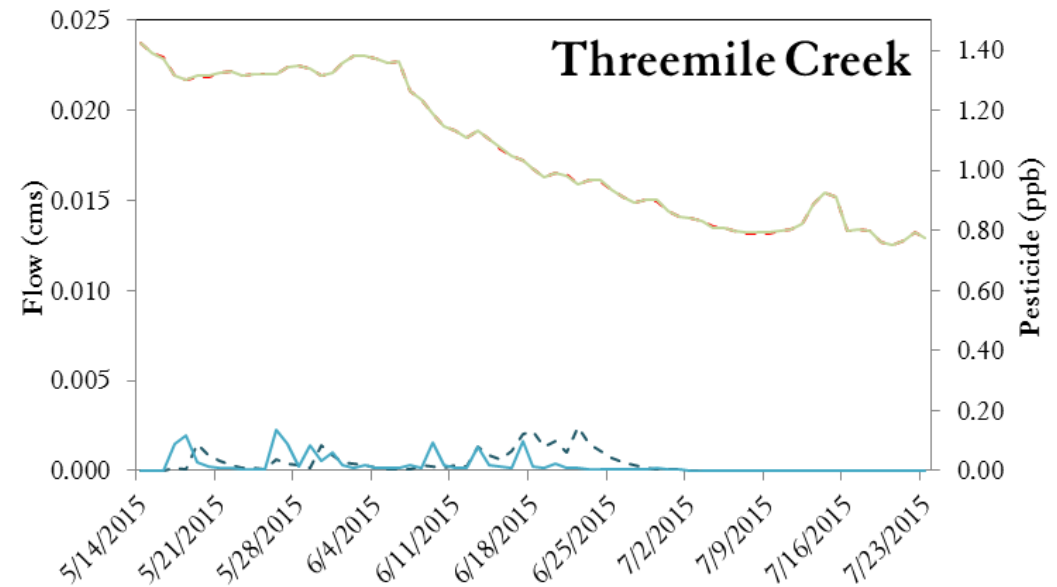
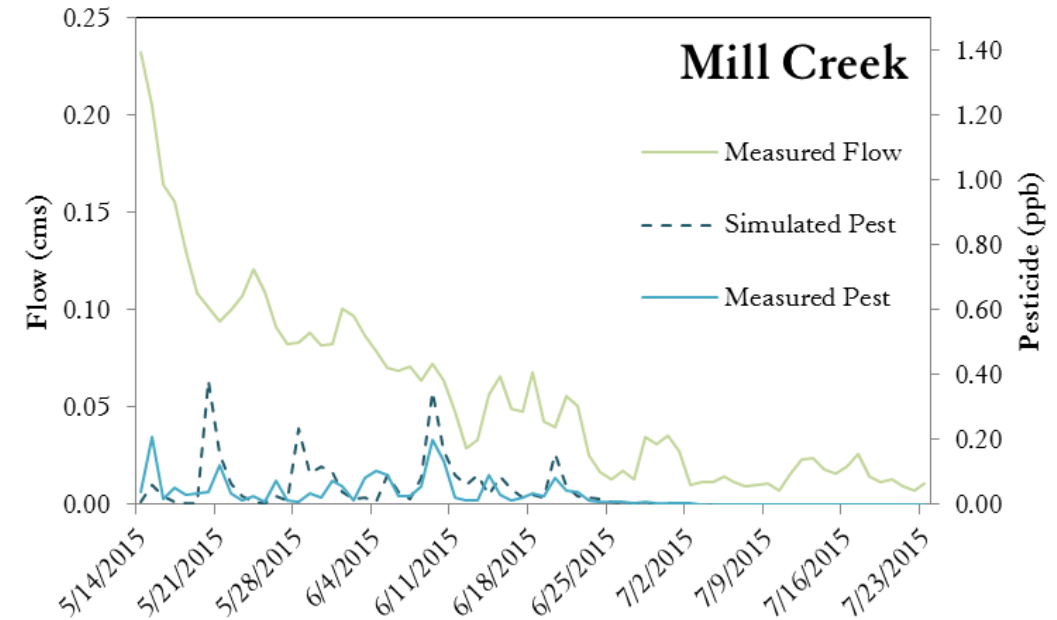
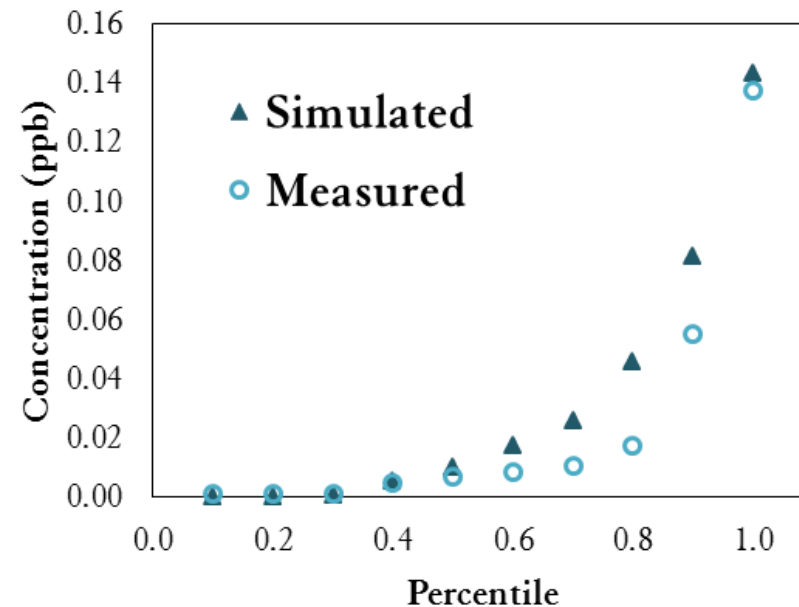
Threemile Creek: Max simulated concentration 2.6 times higher than observed



Case Study II: Modeling Experiment 4, Results

Accounting for actual wind speed leads to a very close agreement between the simulated and observed times series of pesticide concentrations.

The concentration exceedance probability distributions are a close match, slightly conservative.



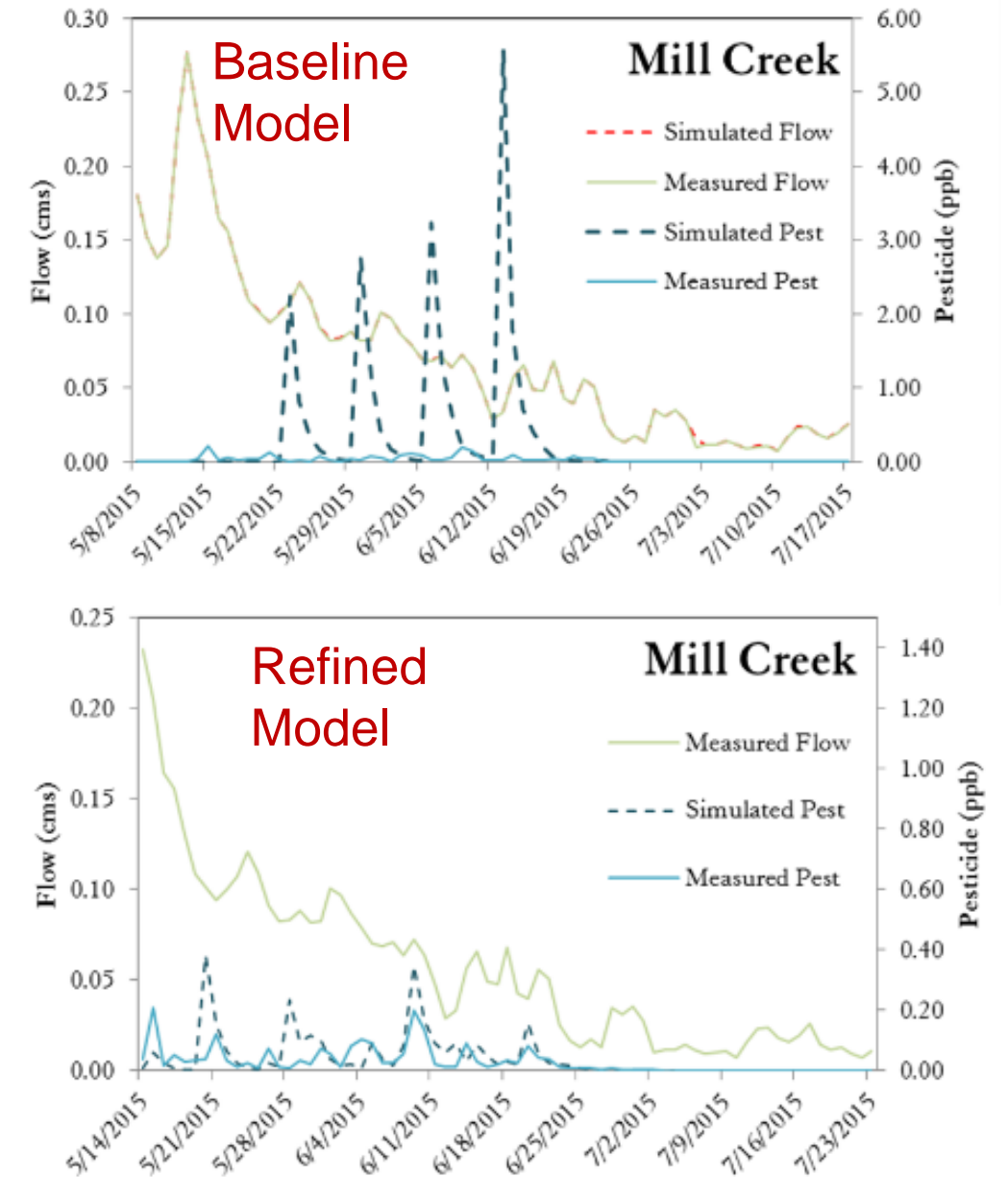
Case Study II: Conclusions

Conservative assumptions made in screening level modeling often do not reflect real world conditions.

High temporal and spatial resolution data can lead to significantly more accurate simulated pesticide concentrations in flowing water bodies resulting from off-site spray drift.

Reference:

Winchell, M., Pai, N., Brayden, B., Stone, C. Whatling, P., Hanzas, J., Stryker, J. 2018. **Evaluation of Watershed-Scale Simulations of In-Stream Pesticide Concentrations from Off-Target Spray Drift.** *Journal of Environment Quality.* 47(1): 79-87.
10.2134/jeq2017.06.0238.



Case Study III: Motivation and Objectives

National Scale Refined Modeling of Aquatic Exposure in Flowing Water Bodies at the Watershed Scale

Ecological exposure assessment of 72 representative species in the continental USA

Current methods in US regulatory aquatic exposure modeling

- Simplistic conceptual model with a single treated field adjacent to a static receiving water body

Reality

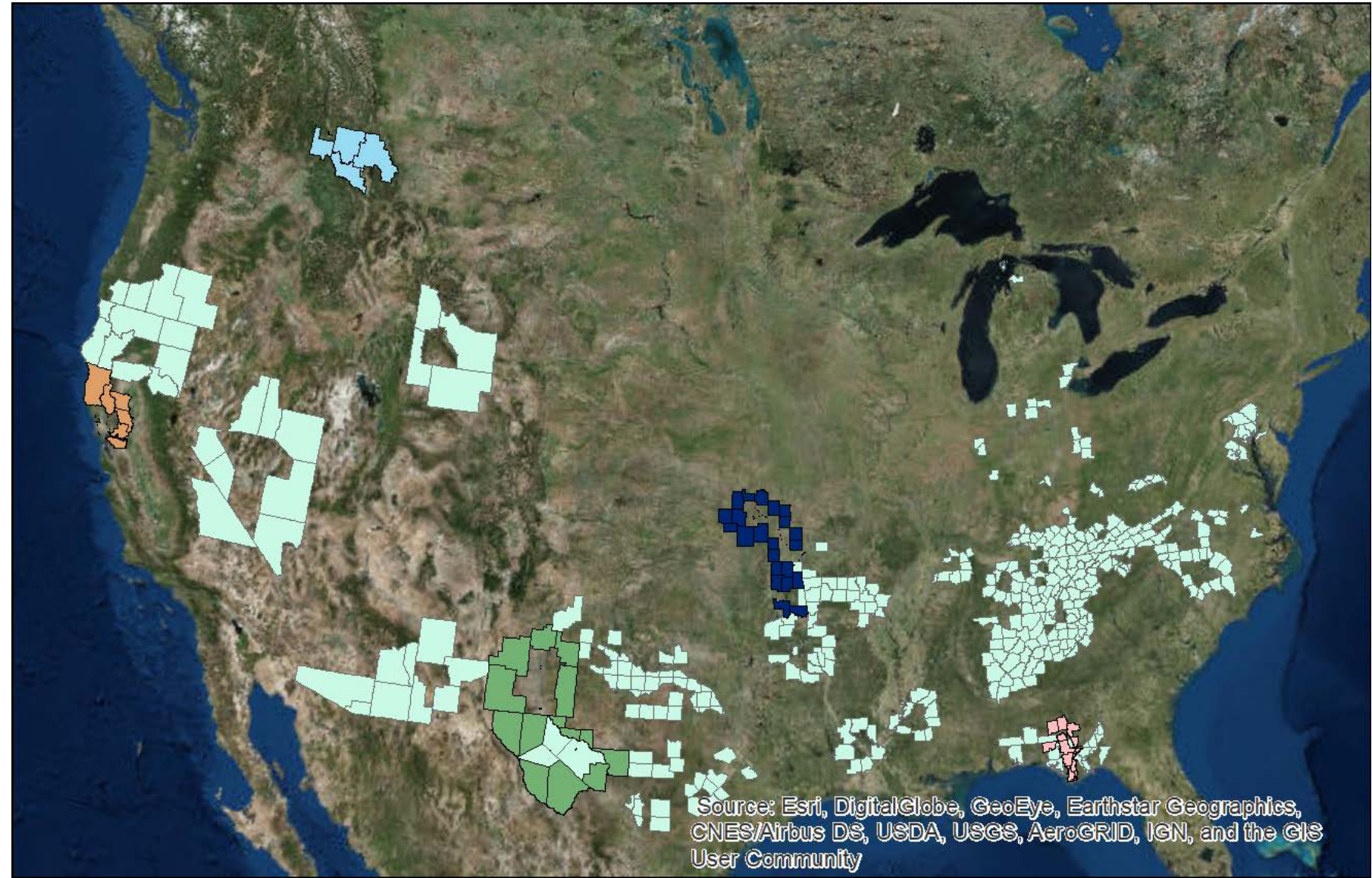
- Potential exposure is largely driven by connectivity and travel time of upstream treated areas to the flowing water segments of interest

Case Study III: Model Approach

Species ranges can be limited to a relatively small geographic region.

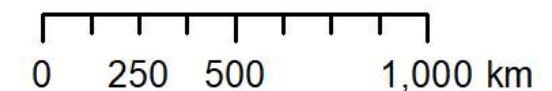
Exposure predictions specific to individual species.

Must account for upstream contributing areas that can extend beyond the species range.



Legend

 Spatial extent of selected species



Case Study III: Model Approach

NHDPlus Hydrography Dataset

- Catchment boundaries/flowlines
- Upstream/downstream connectivity
- 2.8 million within contiguous US

Intersection of NHD catchments with species range data

- Use stream connectivity to get upstream (i.e. contributing) area

Intersect upstream area with land use data and soil data

- 5 years of spatial crop data realizations (2012-2016)

Estimate runoff loadings

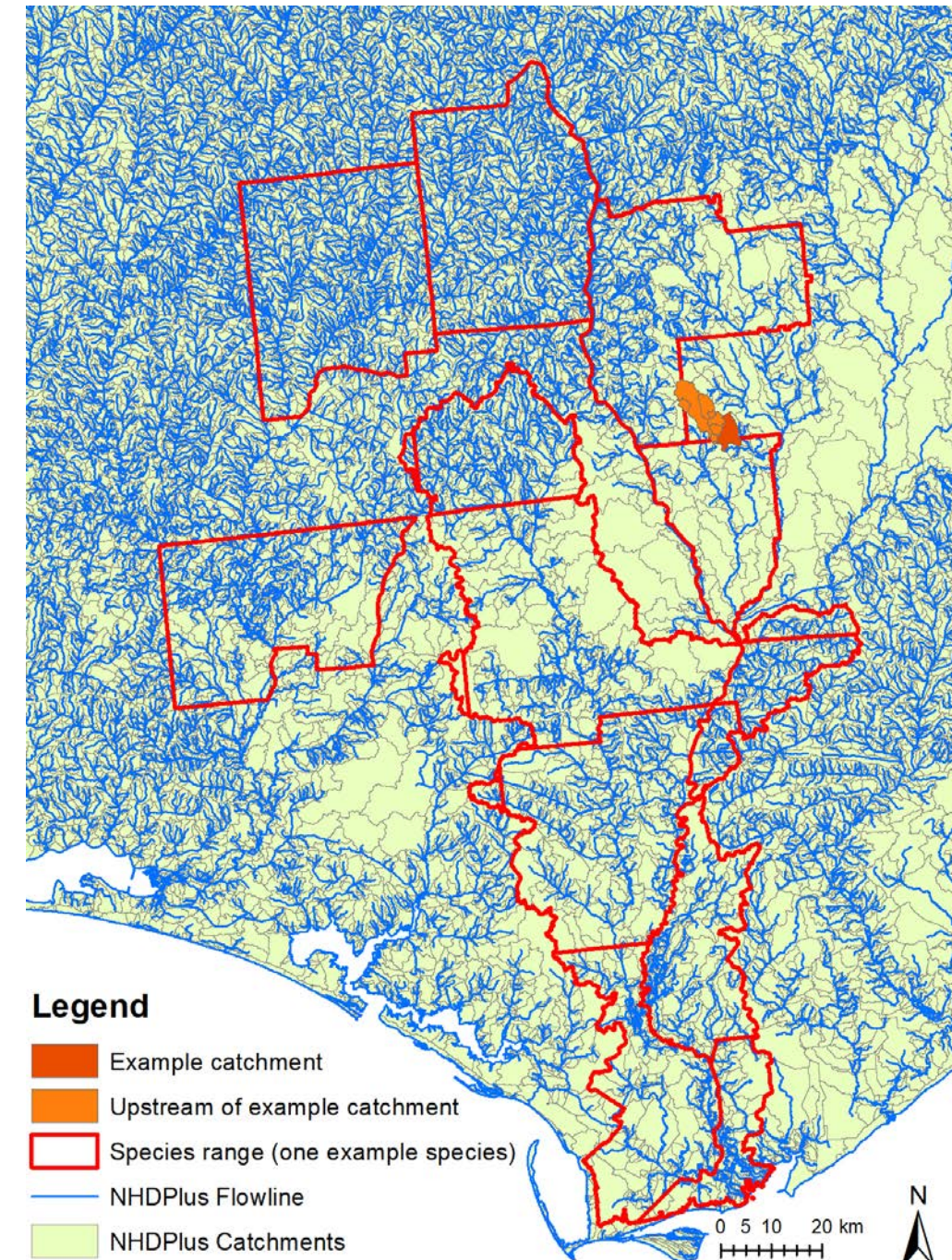
- One PRZM run for each crop-soil combination per catchment

Estimate drift loadings (using crop proximity to a flowing water body)

- AGDISP and AGDRIFT

Incorporate historical use data (percent of crop treated)

- Random selection until historical use acreage is reached



Case Study III: Model Approach

Model selection (US regulatory models)

- PRZM (land phase): designed for field scale simulations
- VVWM (water body): intended for static water bodies with flow through

Large number of model runs

- 264,608 intersections between catchments and species range data
- 1,798,504 total upstream catchments (i.e. number of catchments to model)
- 5 years of crop data realizations (264,608 x 5=1,323,040 VVWM runs)

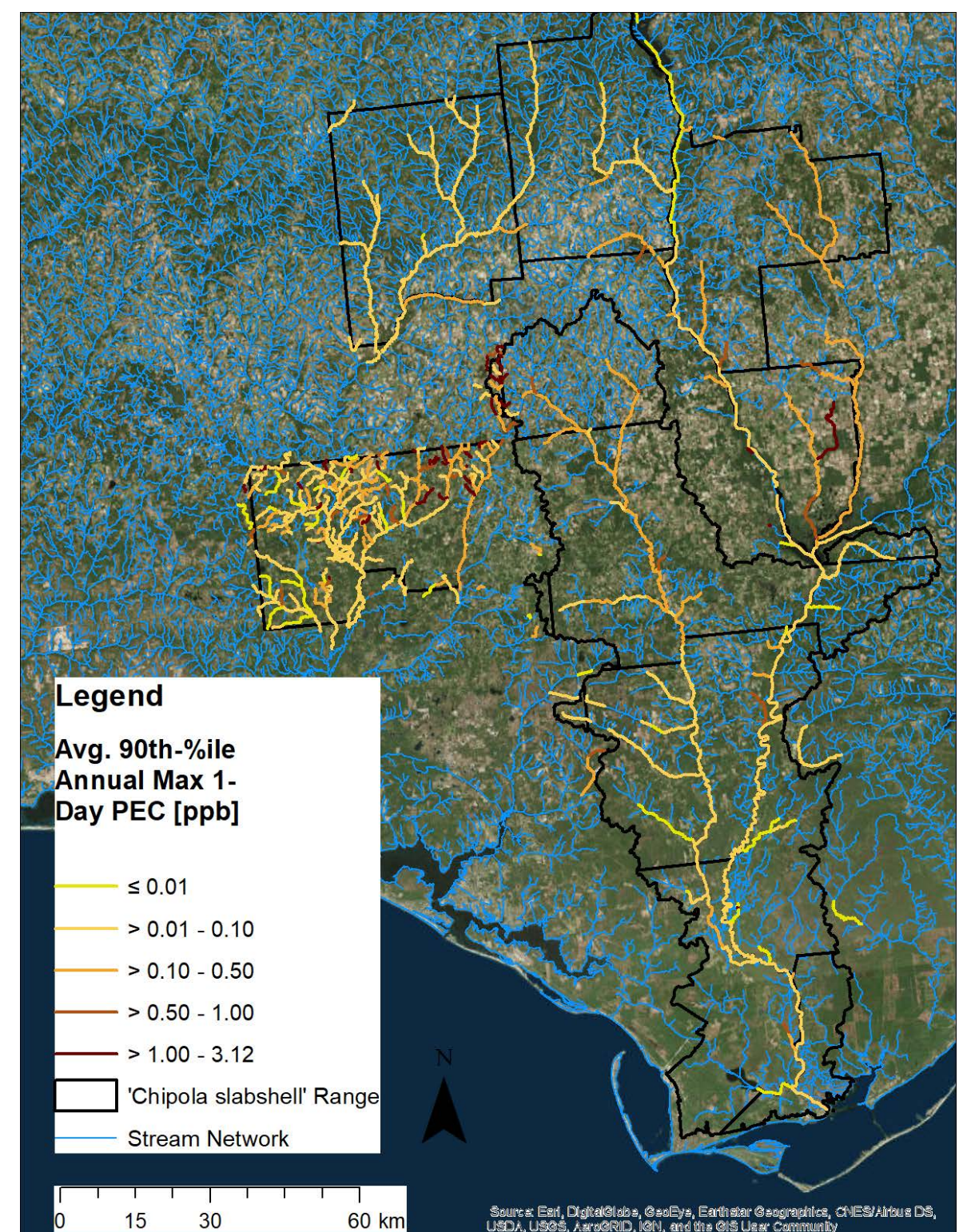
Results

- Spatially explicit, species specific, PECs
- Understanding exposure variability throughout flowing water network
- Probabilistic exposure distributions for use in ecological risk assessments

Case Study III: Results

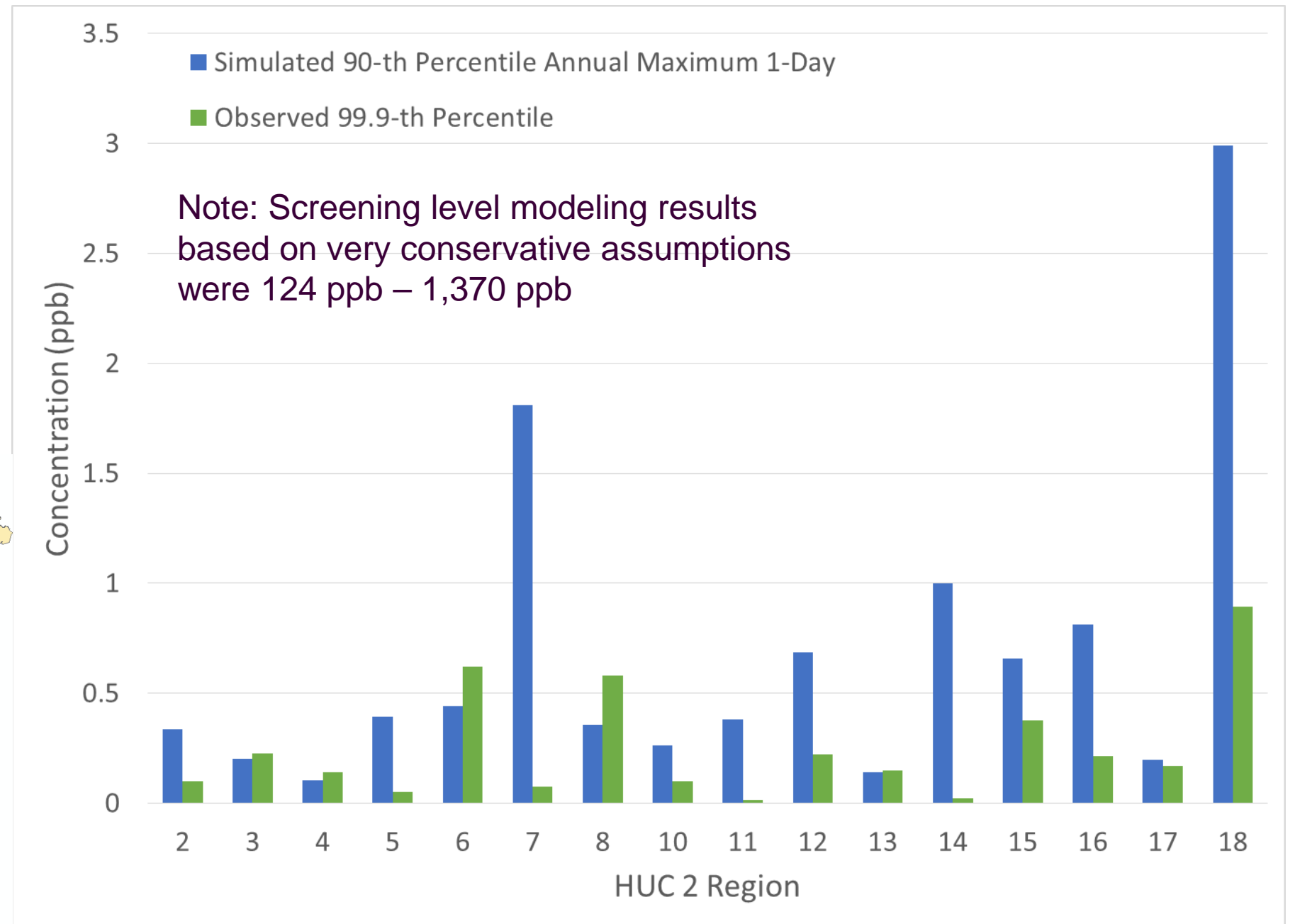
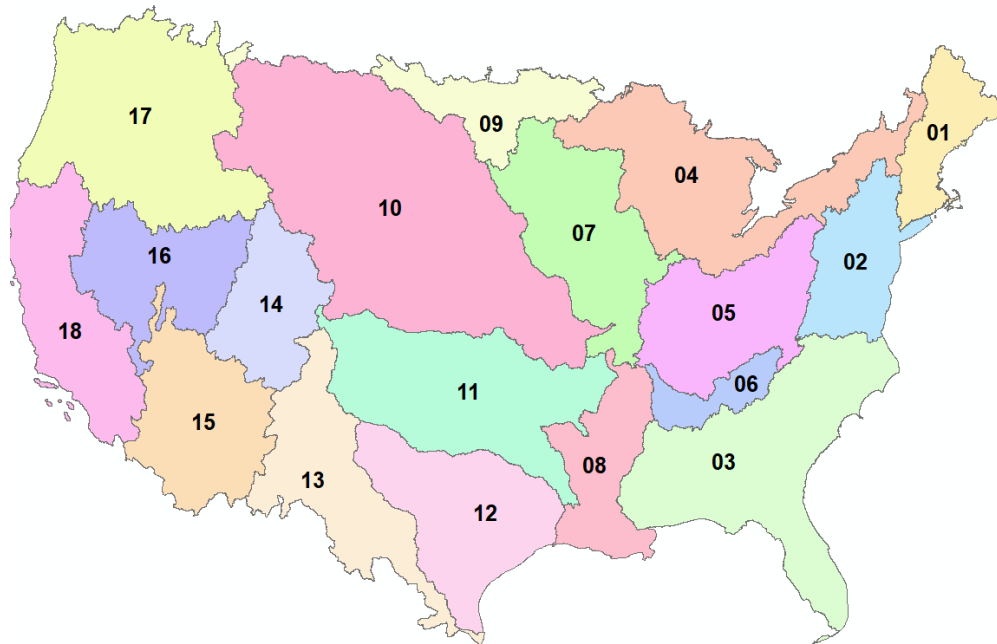
Chipola slabshell (a freshwater mussel) PECs (preliminary):

- Species lives in streams with flow greater than 1 m³/s
- Results for each channel segment (1,079)
 - 5 years of crop data realizations
- PECs range widely from < 0.01 ppb to 3.12 ppb



Case Study III: Results, Regional Watershed Level (HUC2)

Comparison of monitoring data (32,782 samples) and modeling results aggregated by large regional watersheds (HUC2 level)



Case Study III: Conclusions

A probabilistic modeling approach can provide realistic but still conservative exposure estimates throughout networks of flowing water systems.

- Species specific exposure
- Realistically parametrized models
- Probabilistic, spatially explicit results

Regulatory Relevant Discussion Points

Screening level exposure modeling provides limited insight about which factors and processes contribute most to elevated concentrations at the watershed scale.

Realistic input data leads to more accurate exposure predictions, which is critical at the watershed scale.

Probabilistic model parametrizations can provide realistic exposure estimates even if high-resolution input data are not available.

Higher tier exposure modeling approaches can lead to improvements in regulatory decision making and mitigation strategies.

Thank you.

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