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Use of High Spatial and Temporal Resolution Monitoring Data to Improve Parameterization of Watershed Scale Drift Exposure Predictions

May 23rd, 2018

Michael Winchell[1], Ben Brayden[1], Paul Whatling[2]

1. Stone Environmental, Inc.
2. FMC Corporation

Motivation

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.

- High-end wind speed
- Wind always blows from treated field to water body
- Treated field immediately adjacent to water body

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

Can higher spatial and temporal resolution data on pesticide application locations, environmental conditions, and receiving water monitoring lead to more realistic aquatic exposure model scenarios?

Approach

Identify a watershed with high intensity malathion use where the mechanism for exposure is dominated by spray drift.

Collect high resolution temporal and spatial data on the watershed

- Streamflow and stream geometry
- Pesticide concentration in water
- Pesticide application locations, dates, and rates
- Wind speed and direction

Parameterize a watershed model (SWAT) with baseline, conservative assumptions and compare predicted concentrations to monitoring data.

Incorporate increasingly more refined data into the watershed model parameterization and asses the benefits of the more precise data.

Study Location

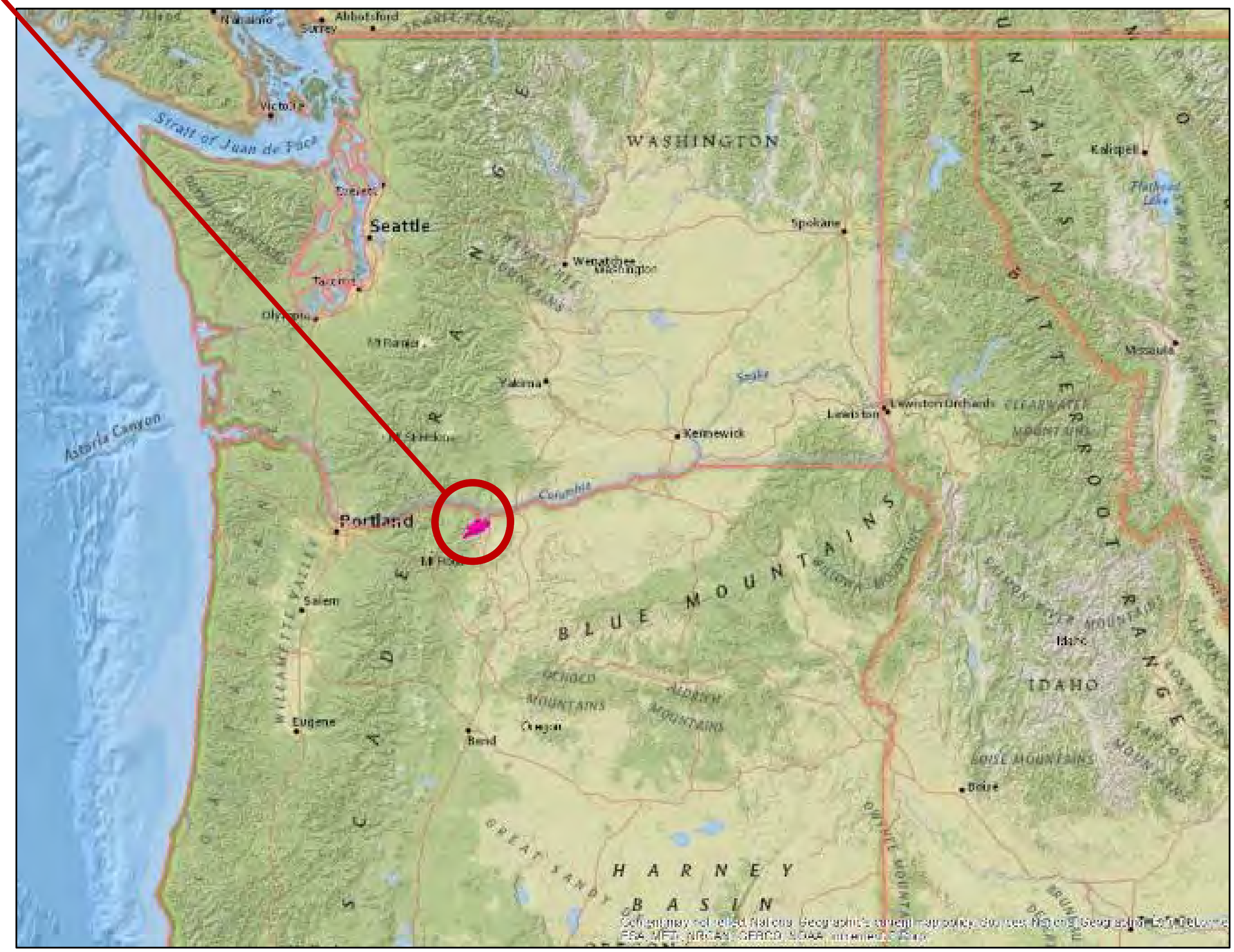
Two watersheds in the Dalles, Oregon

- Mill Creek
- Threemile Creek

High use intensity of malathion on cherry orchards.

All applications are aerial, within a few weeks of harvest.

- 6 week window (mid May – June)
- Dry season … no exposure due to runoff/erosion



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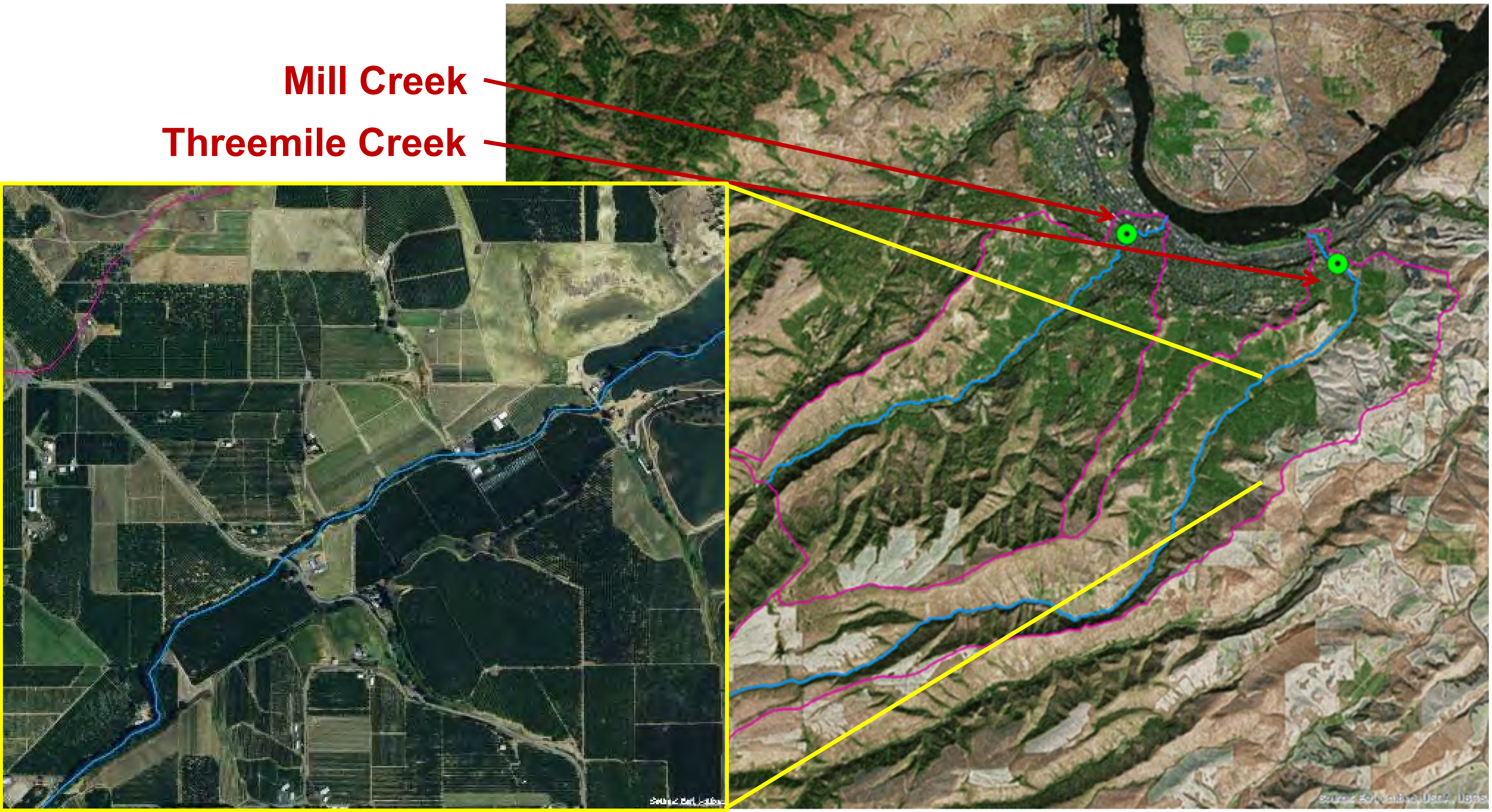
Study Location, Continued

Mill Creek: 164.5 km^2, 8% cherry orchards

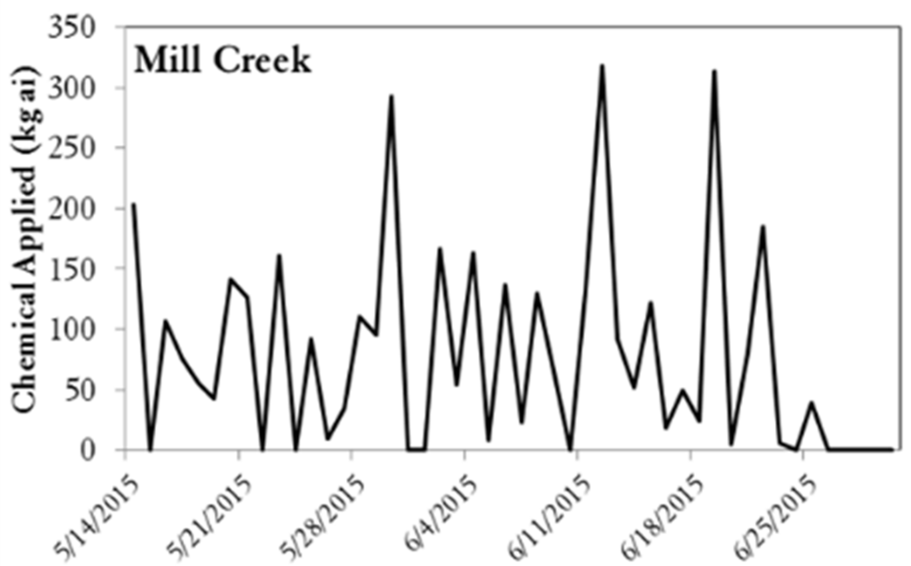
Threemile Creek: 53.7 km^2, 24% cherry orchards

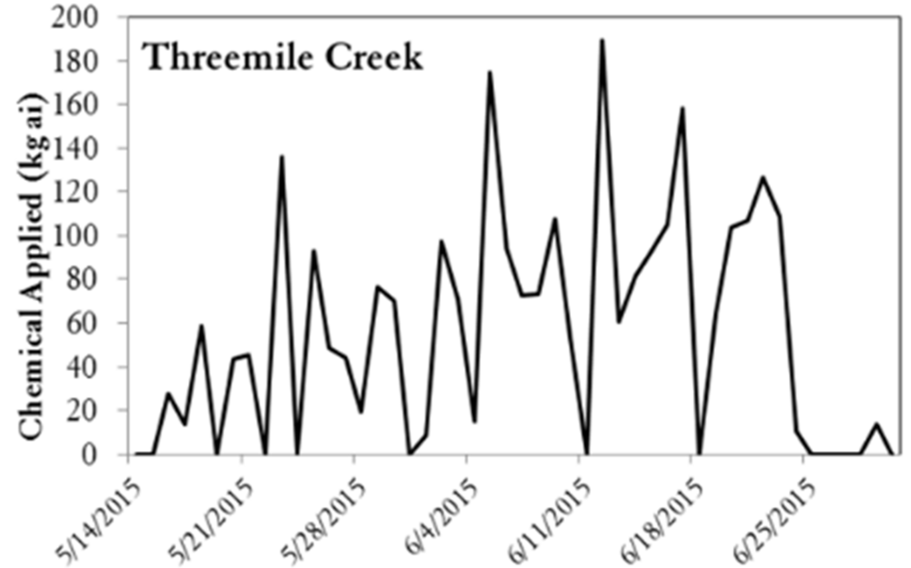


Field Study, Malathion Applications

All malathion applications were made by a single applicator.

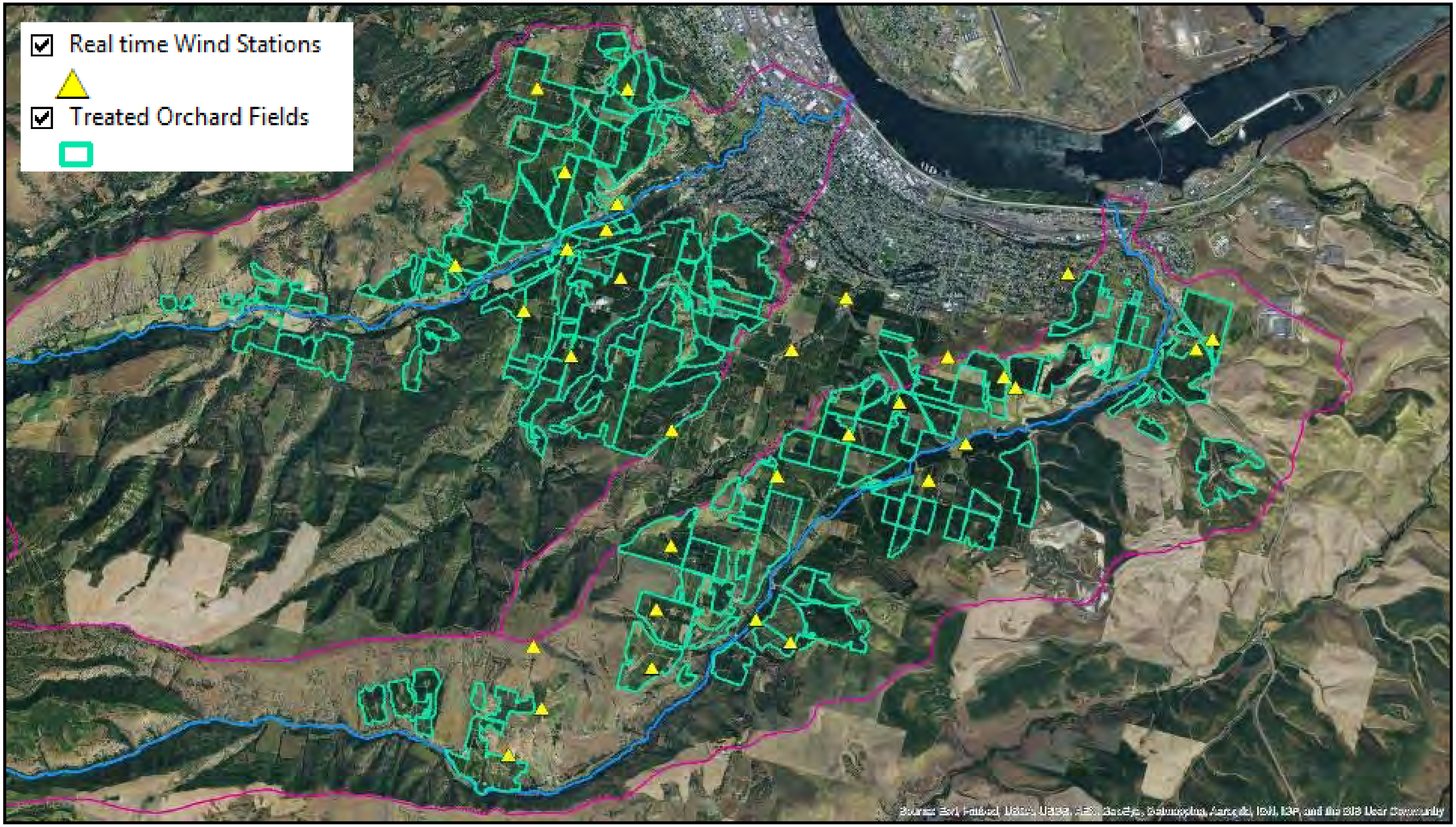
Information on the location, timing, rates, and acreage treated for each application were provided by the applicator.





Field Study, Wind Dataset

Real time wind speed and direction data from 33 stations was associated with every application on each field.



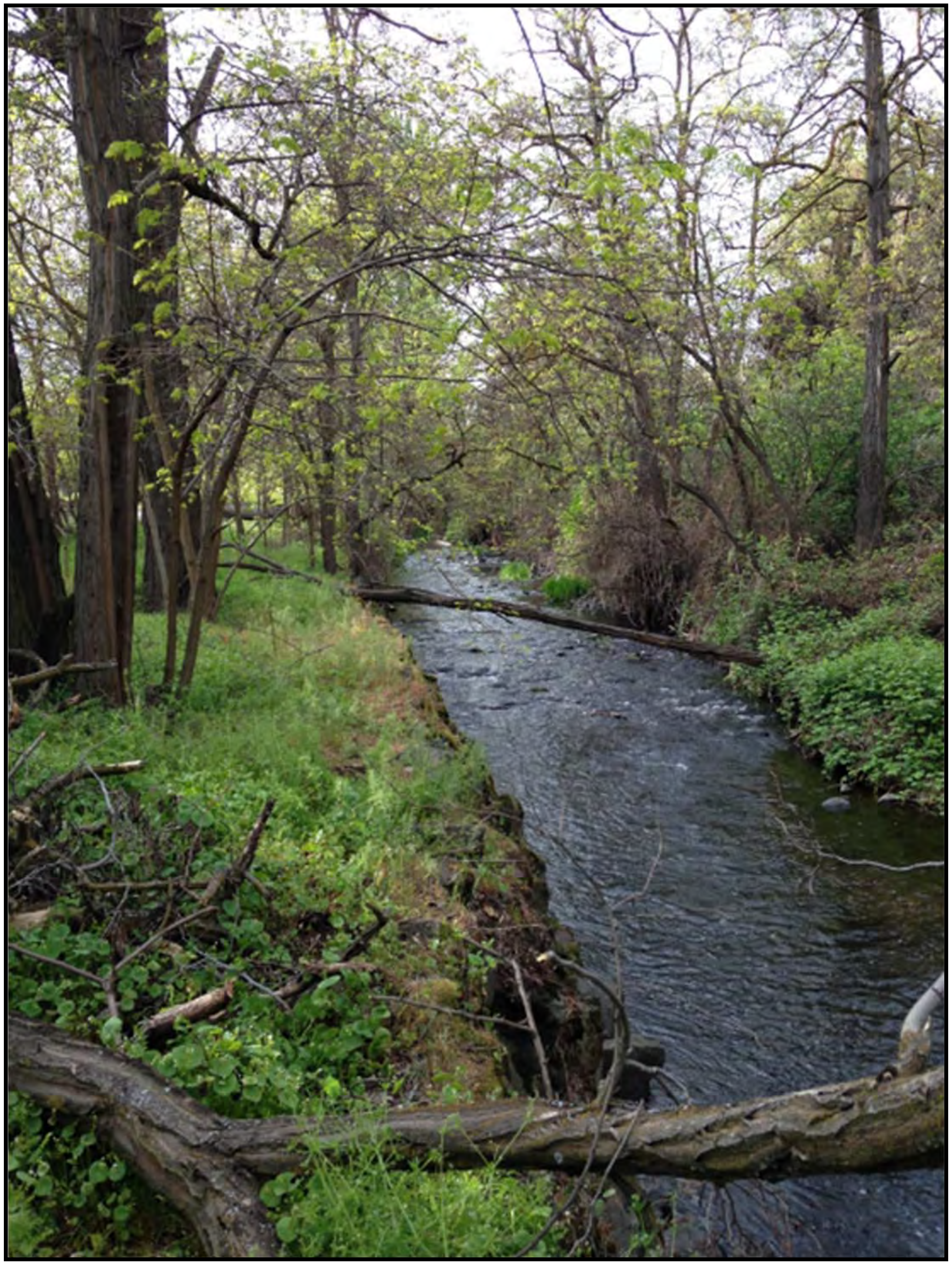
Field Study, Stream Monitoring

One downstream monitoring station was established on each stream during the 2015 growing season.

ISCO autosamplers:

- Flow: 5-minute increments
- Malathion:
  - Application Season: 6-hr composites, 1-hr subsamples
  - Most Intense Week: 1-hr composites, 10-min subsamples

Stream width surveys were conducted several times throughout the study.



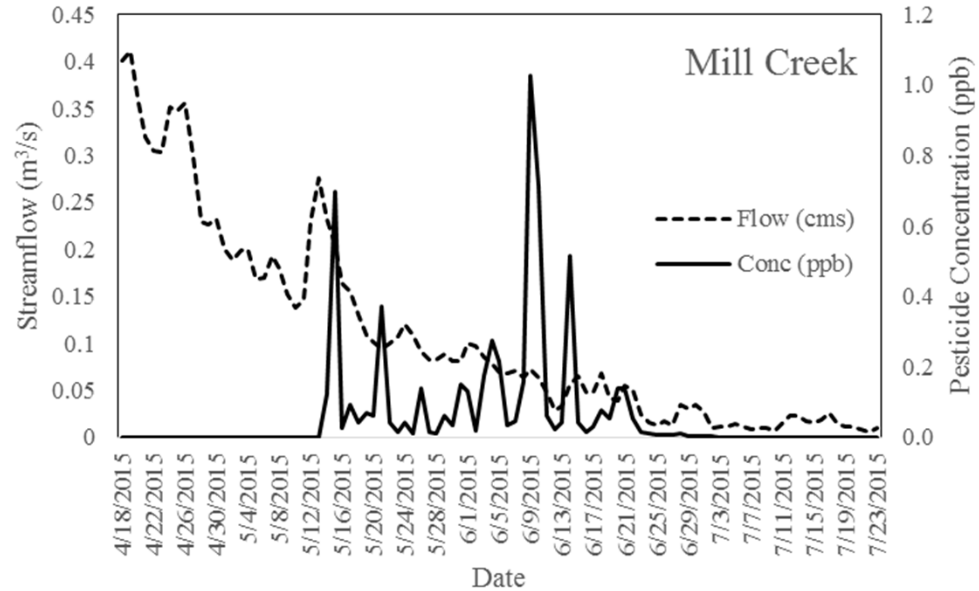
Field Study, Monitoring Results

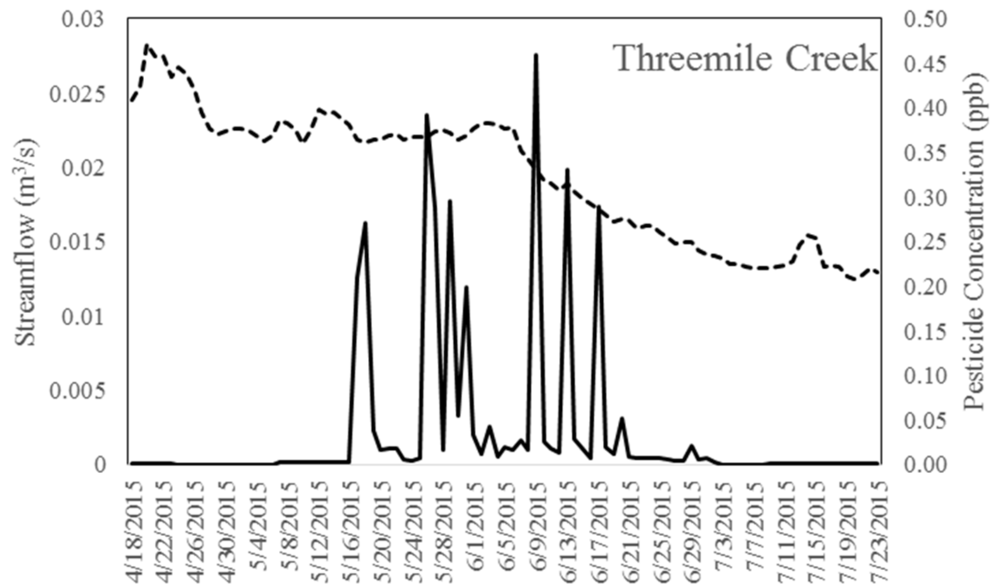
A total of 692 samples were collected during the 47-day application period (346 on each creek).

Malathion residues above the LOQ were observed in 166 samples (49%) from Mill Creek and 99 samples (29%) from Threemile Creek.

Maximum observed instantaneous malathion concentrations:

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





Modeling Experiments

1

- Applications at max label rate
- No temporal or spatial application information
- Seasonal use and application window set based on applicator data
- Conservative drift assumptions (10 mph wind always towards stream)

2

- Incorporate refined application data
- Actual dates and rates applied to specific fields

3

- Incorporate wind direction
- For each field and application, determine if a drift exposure event occurred

4

- Incorporate wind speed
- For each field and application, use a refined drift fraction estimation

Modeling Experiment 1, Baseline Assumptions

Streamflow set to measured flow as upstream input.

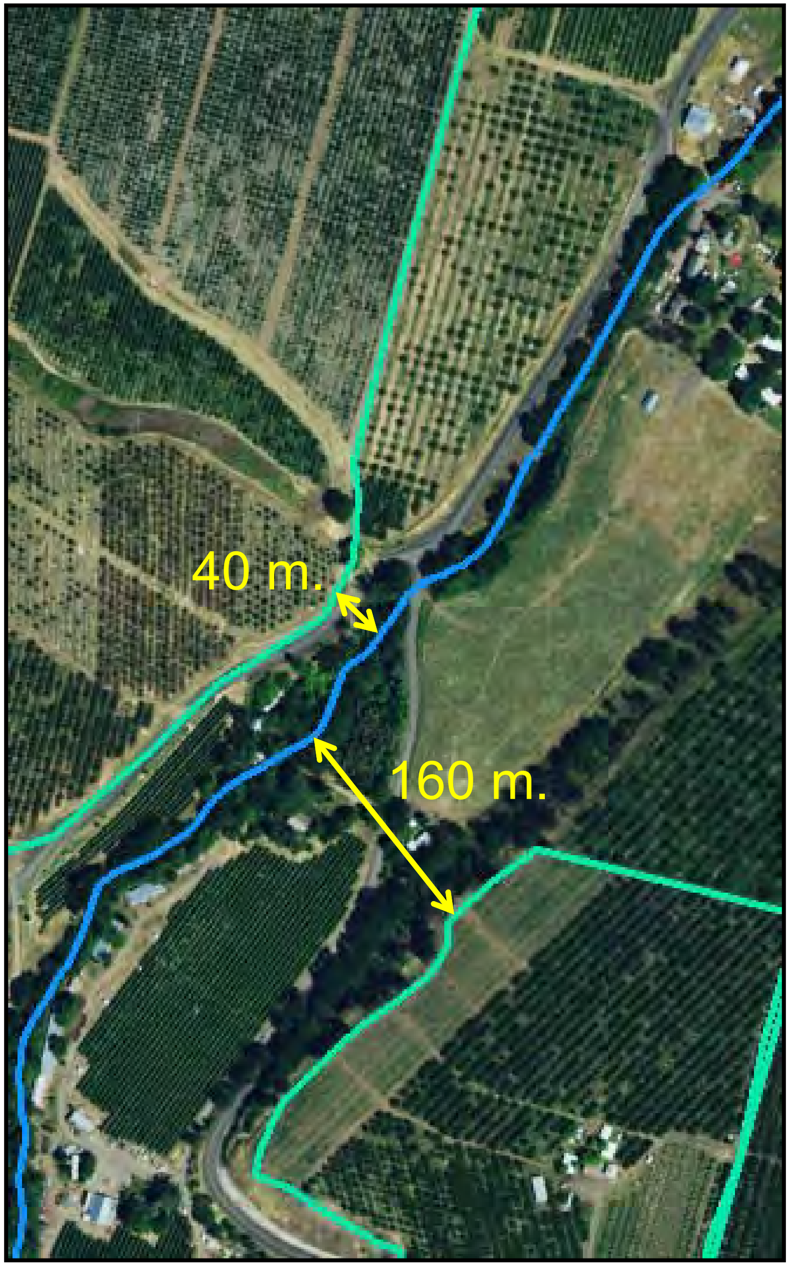
100 model simulations, for each simulation:

- randomly pick cherry fields to apply
- select date(s) randomly from application window
- make applications at max label rate
- capped treated area by observed annual application mass

Drift curve from AgDRIFT Tier III model (10 mph wind).

Wind always blowing towards stream.

Drift fraction based on proximity of treated field to stream



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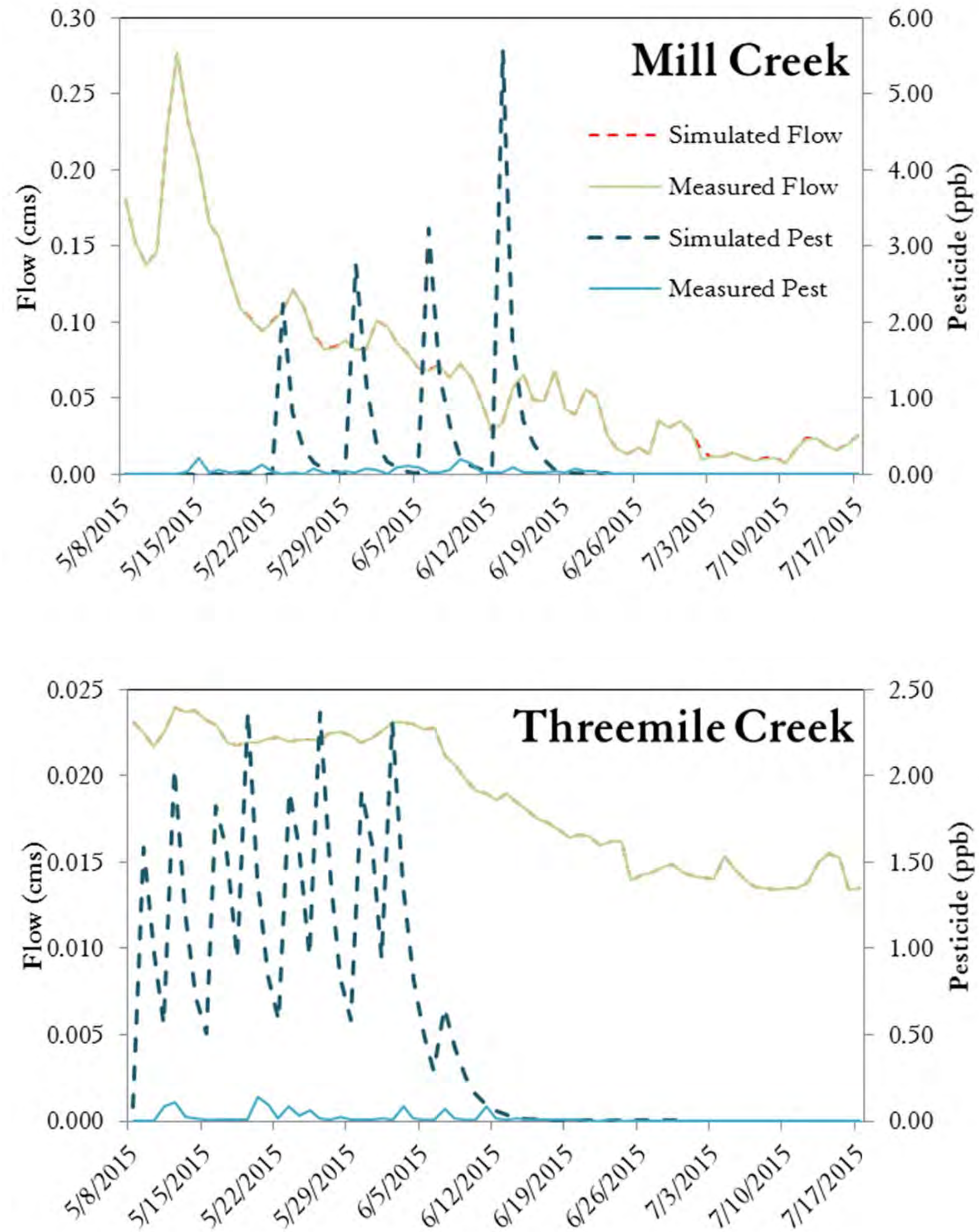
Modeling Experiment 1, Results

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

Mill Creek applications made during 4 days, Threemile Creek apps made during 9 days in the season.

Predicted concentrations are:

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



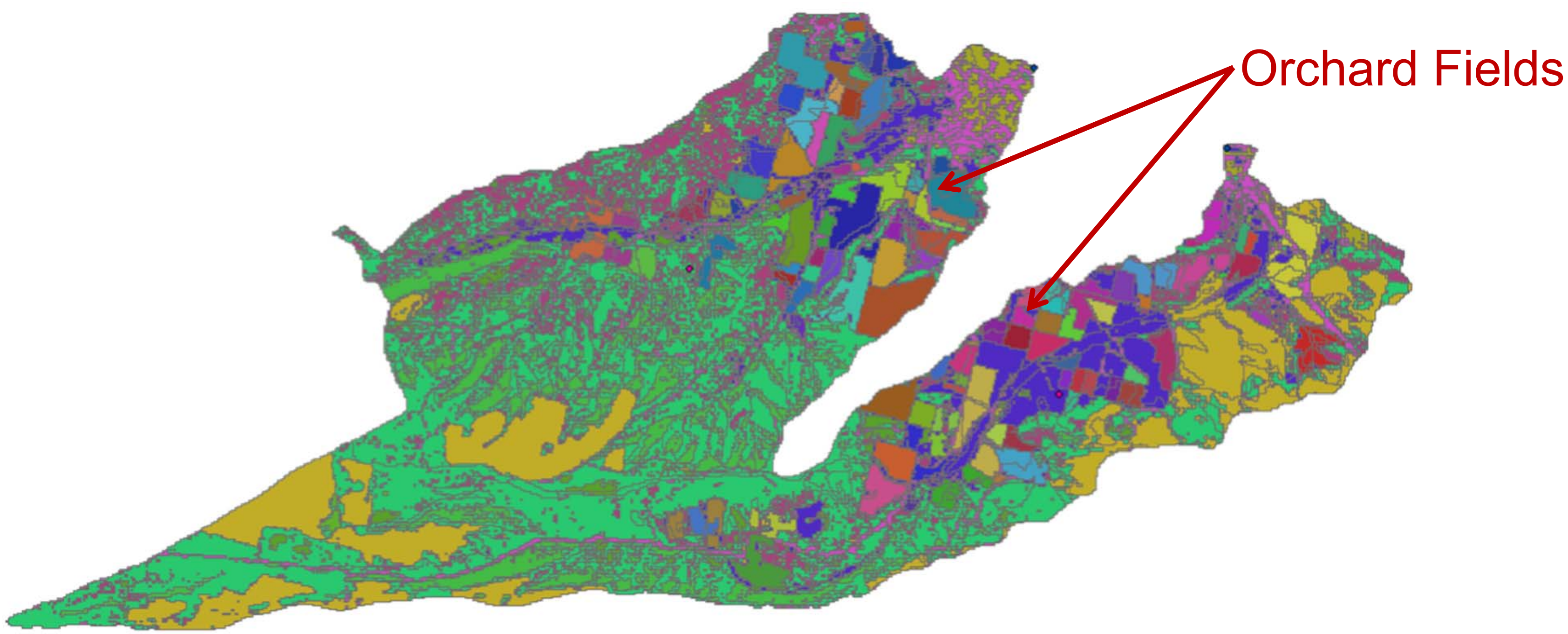
Modeling Experiment 2, Refined Application Data

Model's spatial delineation modified to match field boundaries.

Application made to 122 fields across 41 days as provided by applicator.

- Specific application dates and fields
- Treated area and rates set to match actual

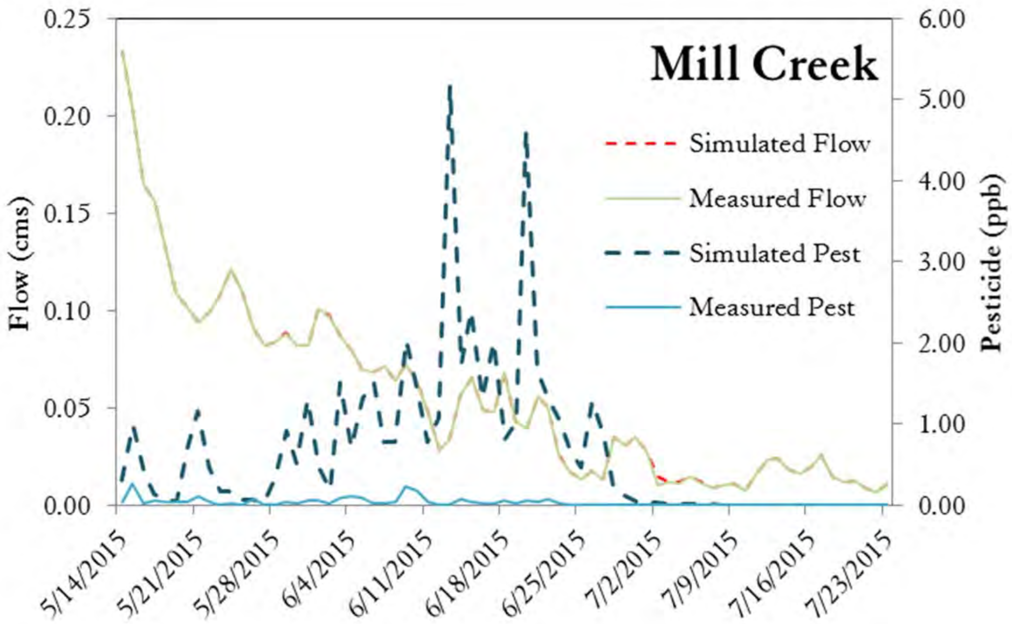
Waterbody area within drift proximity zones estimated through spatial analysis of fields and stream surface areas.

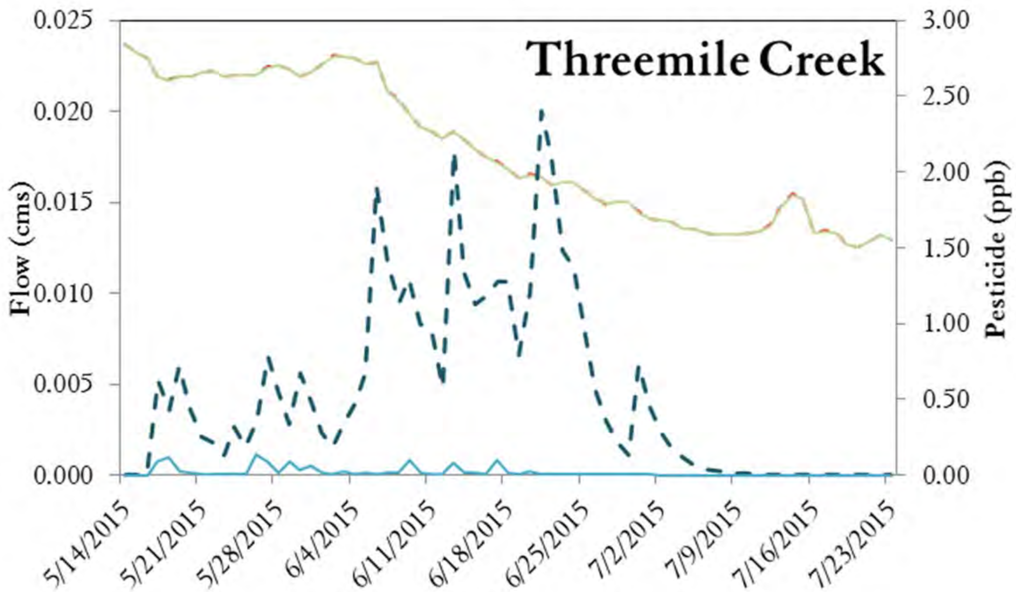


Modeling Experiment 2, Results

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.





Modeling Experiment 3, Wind Direction Data

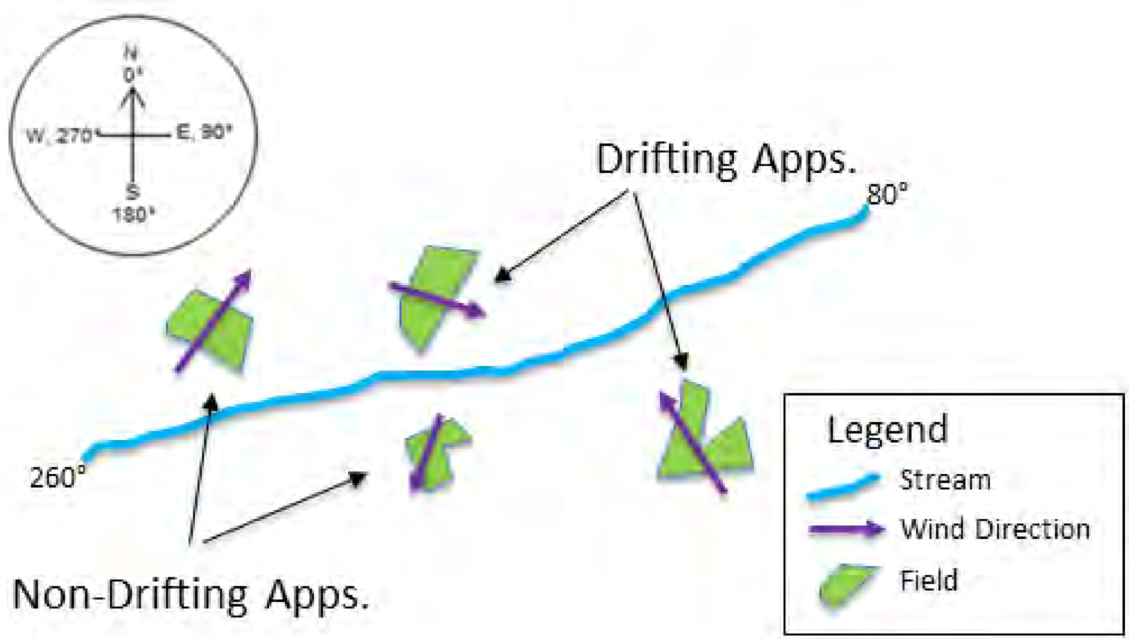
For each of the 122 fields, identify the closest wind station.

Stream direction generally along the 260° to 80° line (SW to NE)

All applications classified as "drifting" or "not drifting" events for exposure.

Drifting events occur if:

- Field north of the stream, and wind direction < 260° and > 80°
- Field south of the stream, and wind direction > 260° and < 80°



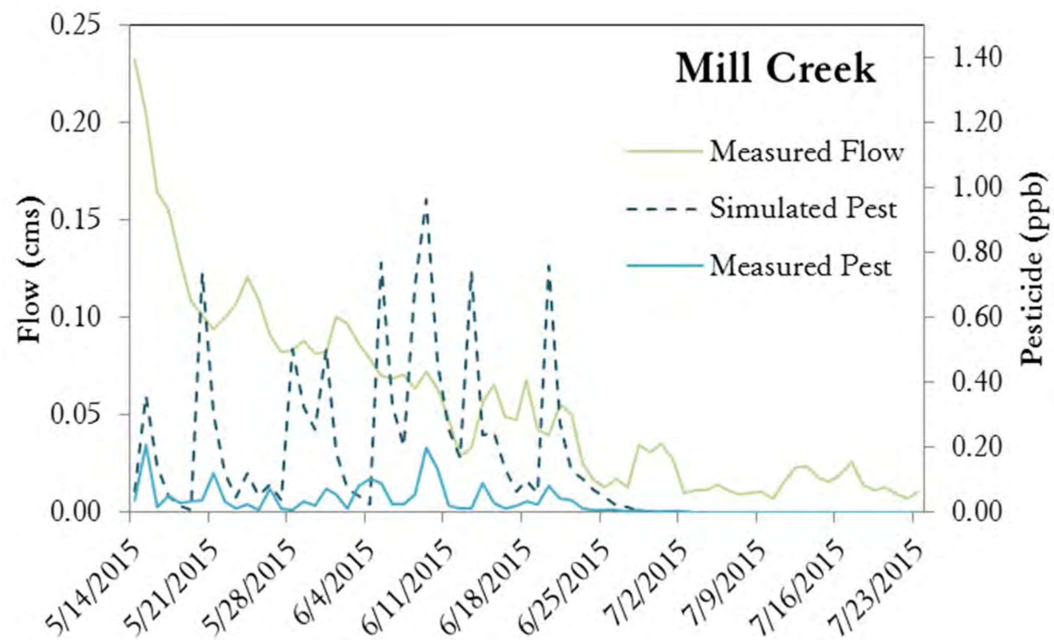
"Partial" drifting was not characterized.

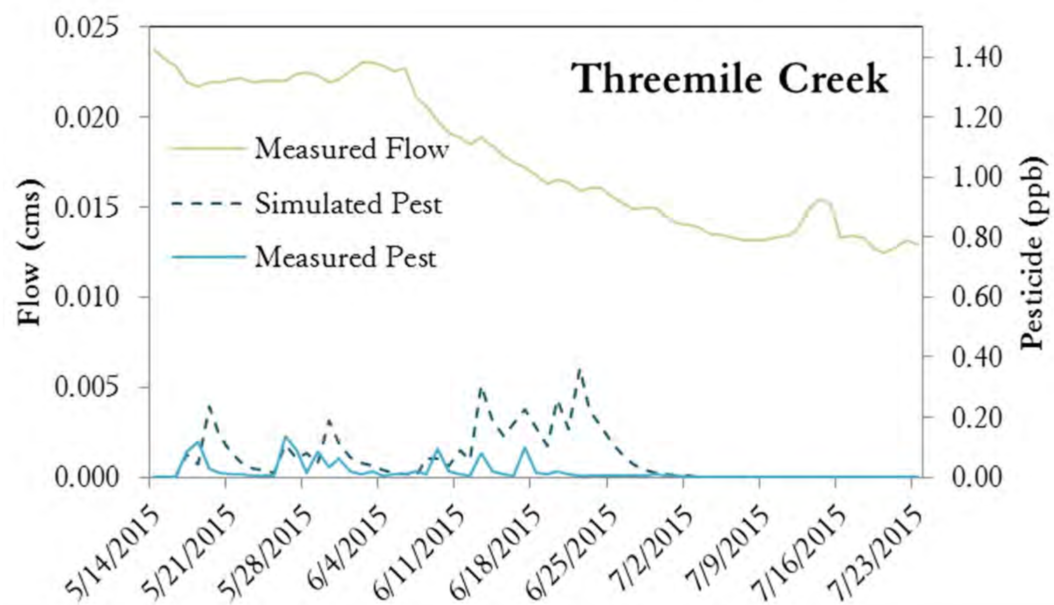
Modeling Experiment 3, Results

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 malathion concentrations.

Mill Creek: Max simulated concentration 4.6 times higher than observed

Threemile Creek: Max simulated concentration 2.6 times higher than observed



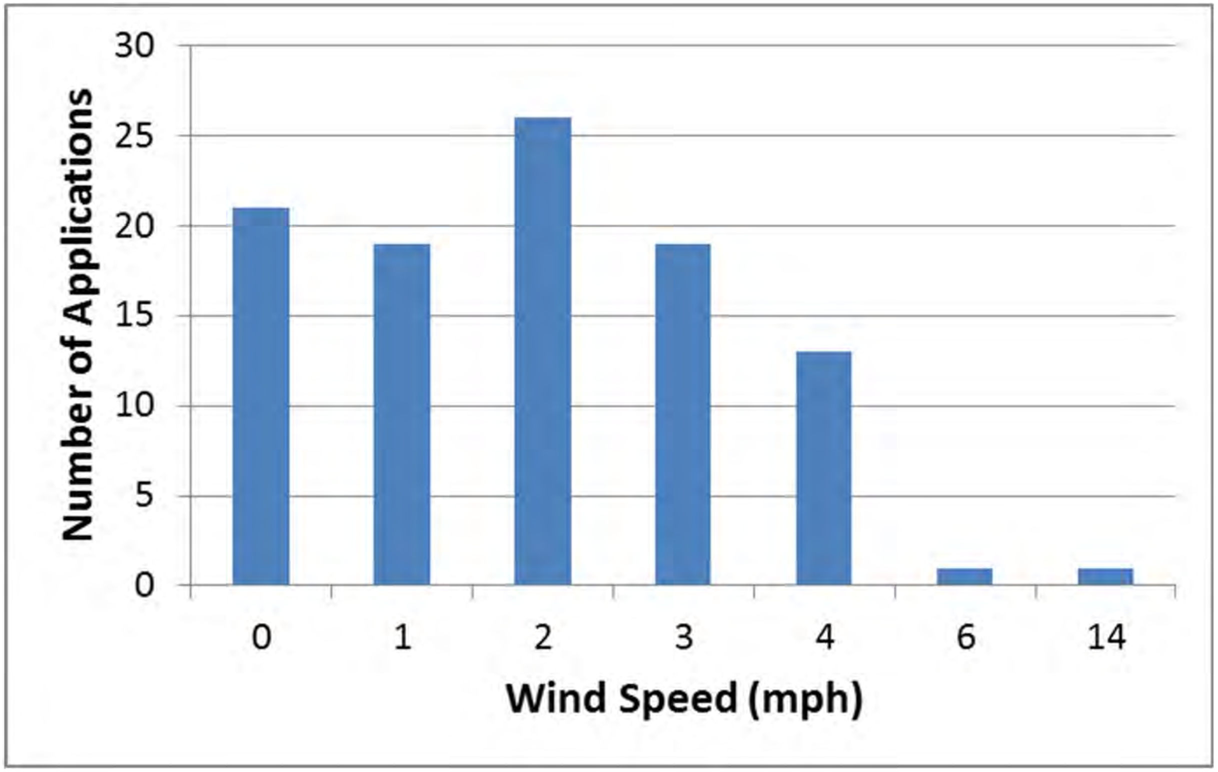


Modeling Experiment 4, Wind Speed Data

Applications occurred at speeds of 0, 1, 2, 3, 4, 6, and 14 mph.

97% of drifting application made at wind speeds less than 4 mph.

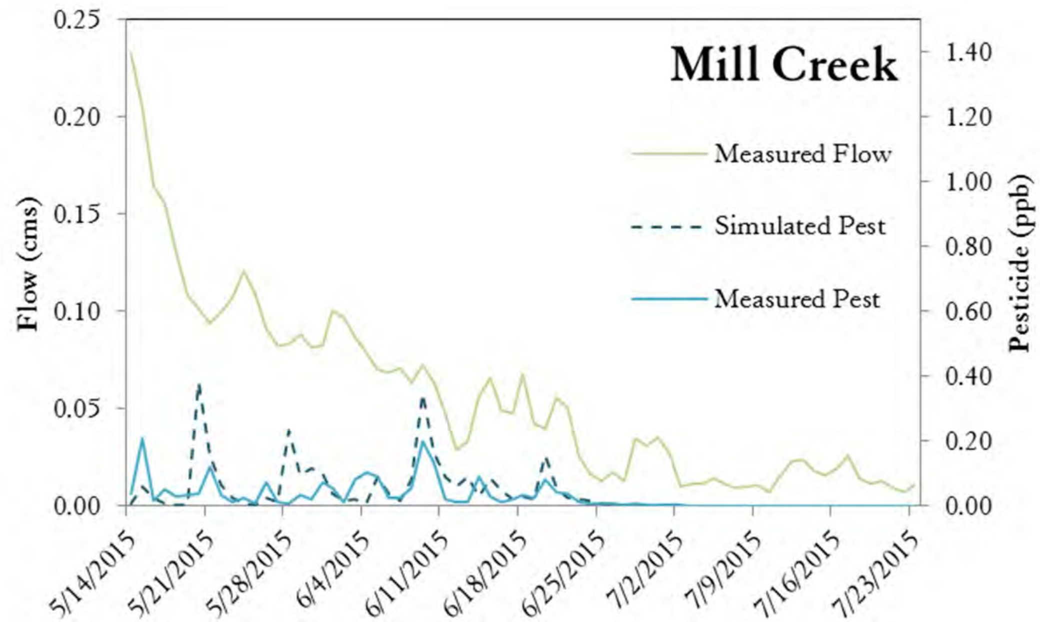
For "drifting" applications, developed application-specific drift curves and revised drift fractions incorporated in the SWAT model.

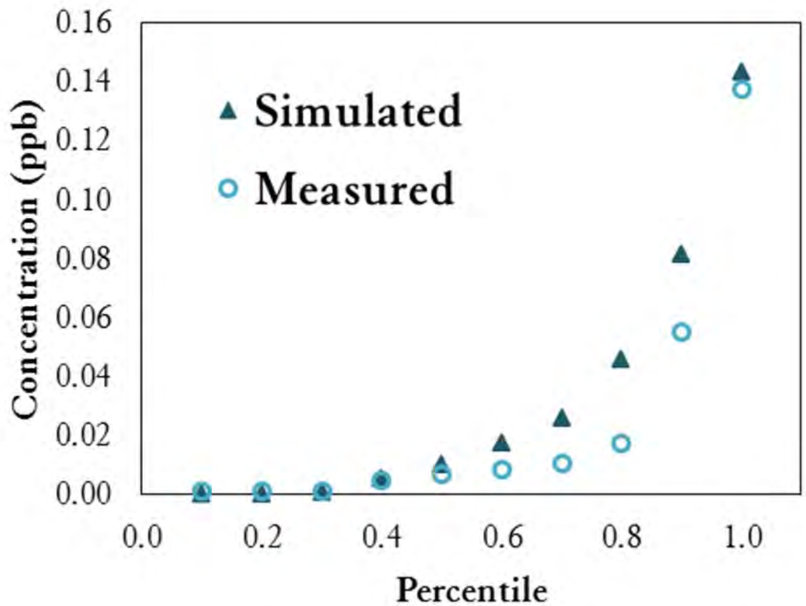


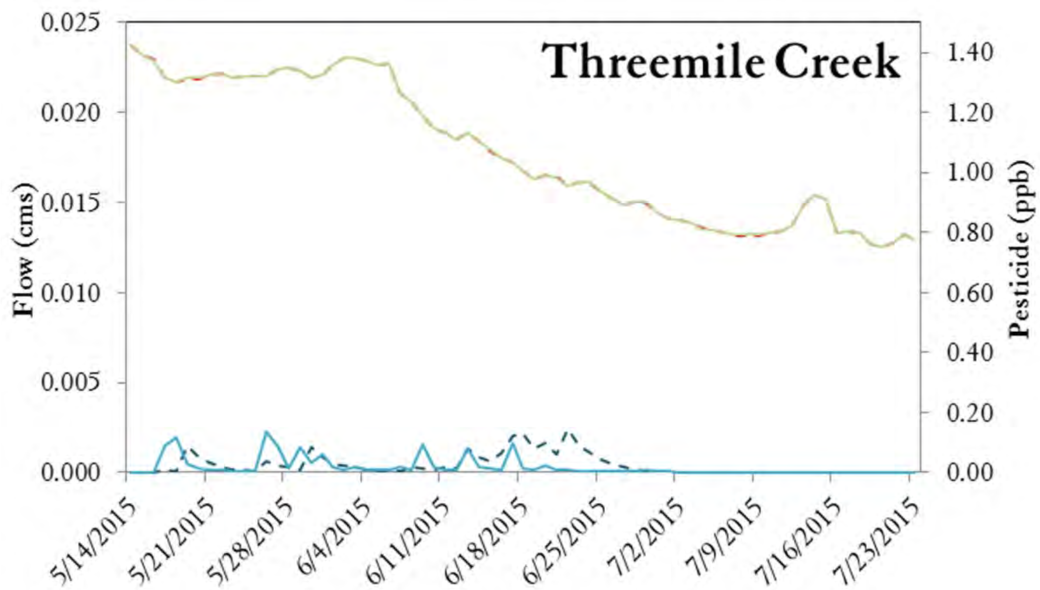
Modeling Experiment 4, Results

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.







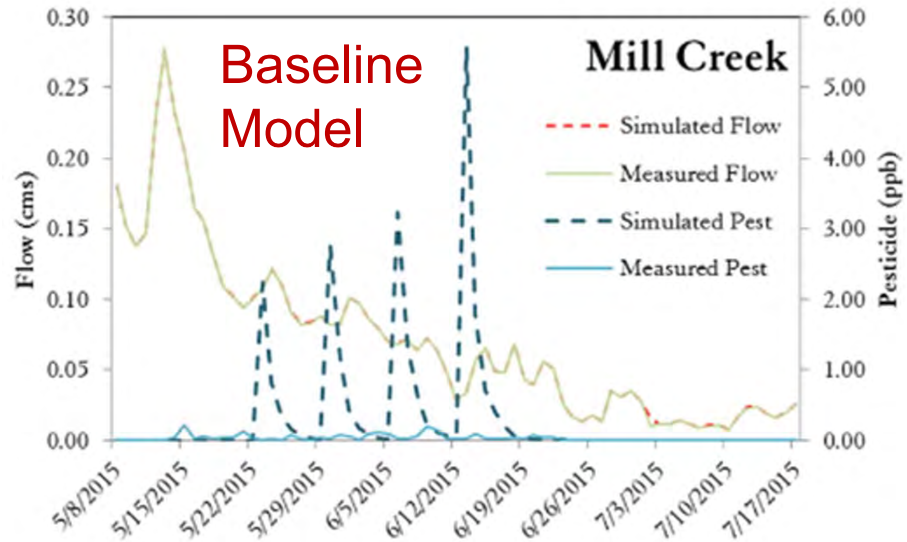
Summary and Conclusions

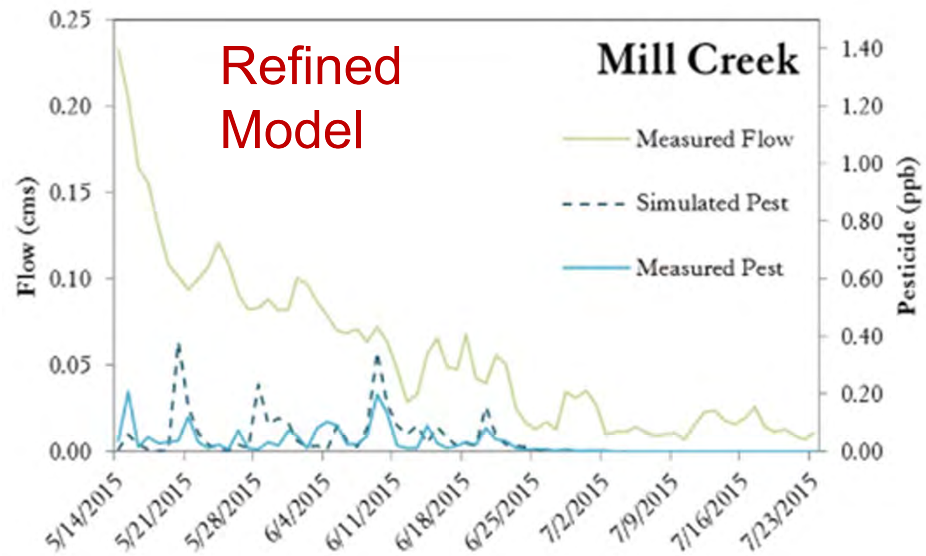
Spray drift can be an important potential source for aquatic pesticide exposure.

Modeling of spray drift contributions to exposure at the watershed scale is important for predicting pesticide concentration in flowing water bodies.

The 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.





References

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.

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Thank you.

For more information / www.stone-env.com

Contact / mwinchell@stone-env.com