Malathion residues in flowing waterbodies resulting from aerial drift in a high use intensity watershed, part II modeling

Naresh Pai[1], Michael Winchell[1], Ben Brayden[1], John Hanzas[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 deposition to surface water

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

Do these assumptions result in a overly conservative screen?

Can more precise data on pesticide application locations and environmental conditions lead to more accurate model predictions of aquatic pesticide exposure?

Approach

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

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

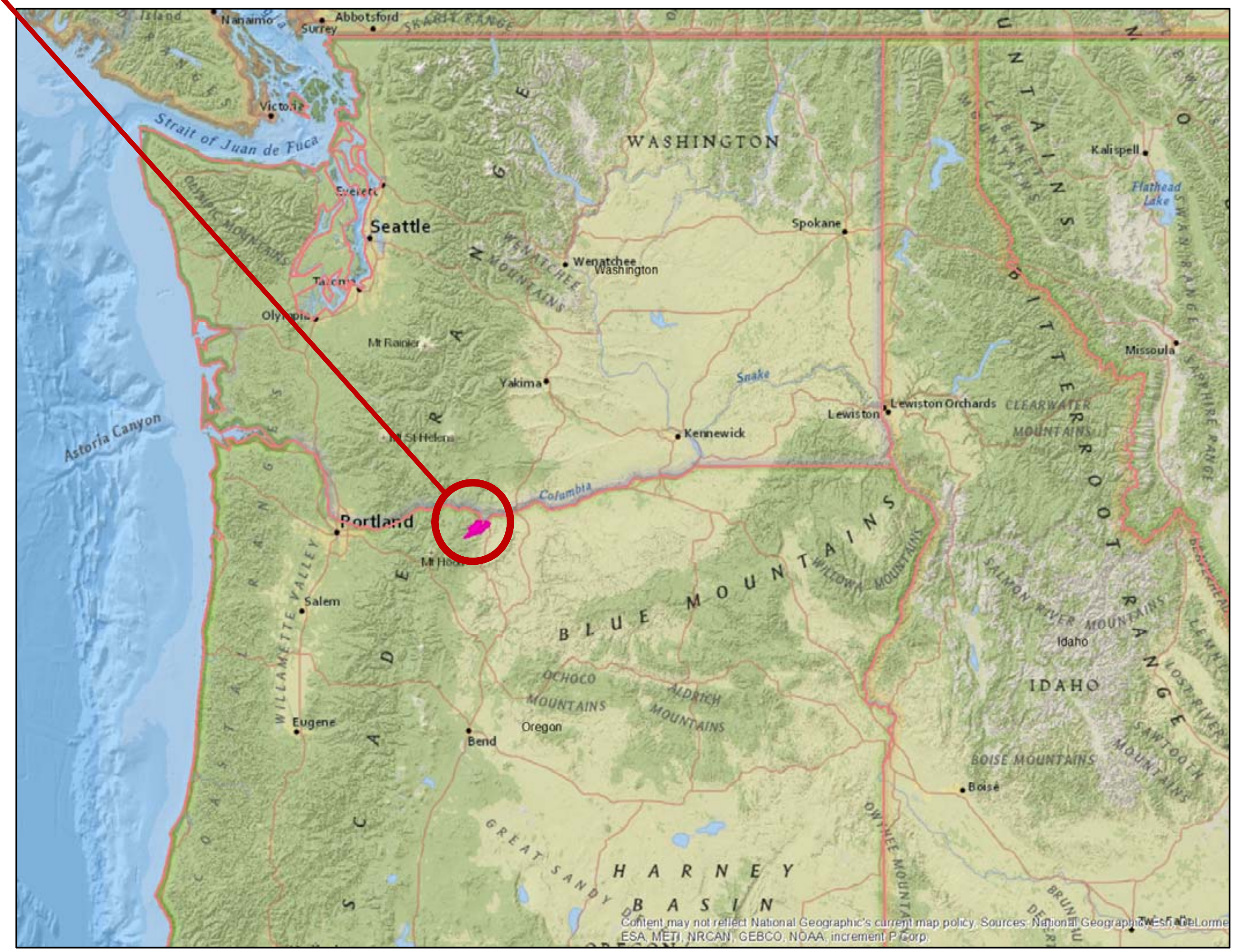
Parameterize a watershed model (SWAT) with baseline, conservative assumptions and compare predicted concentrations to monitoring data.

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.

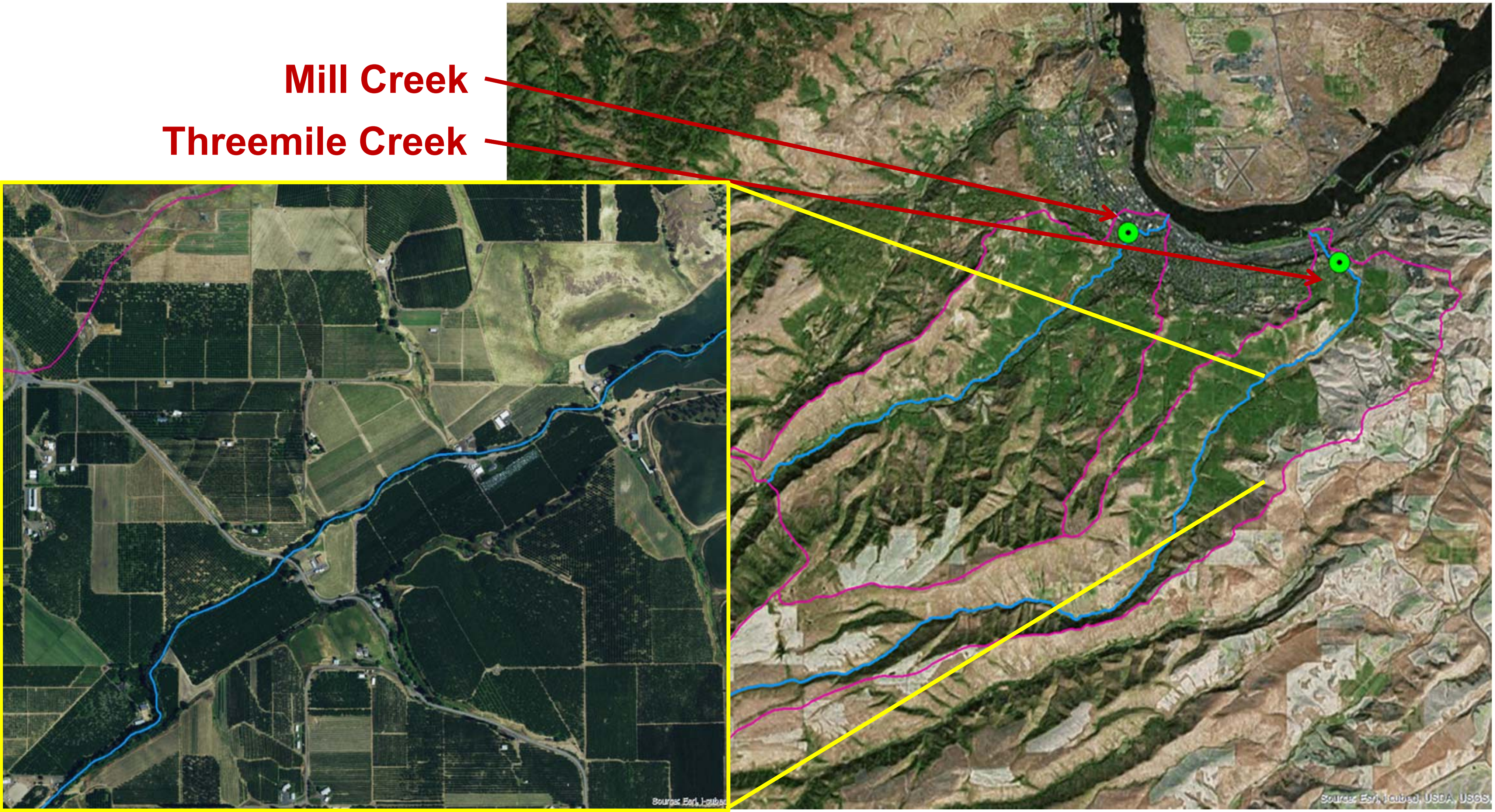
All applications are aerial, within a few weeks of harvest.

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

Study Location, Continued

Mill Creek: 51.4 km^2, 24% cherry orchards

Threemile Creek: 53.8 km^2, 25% cherry orchards

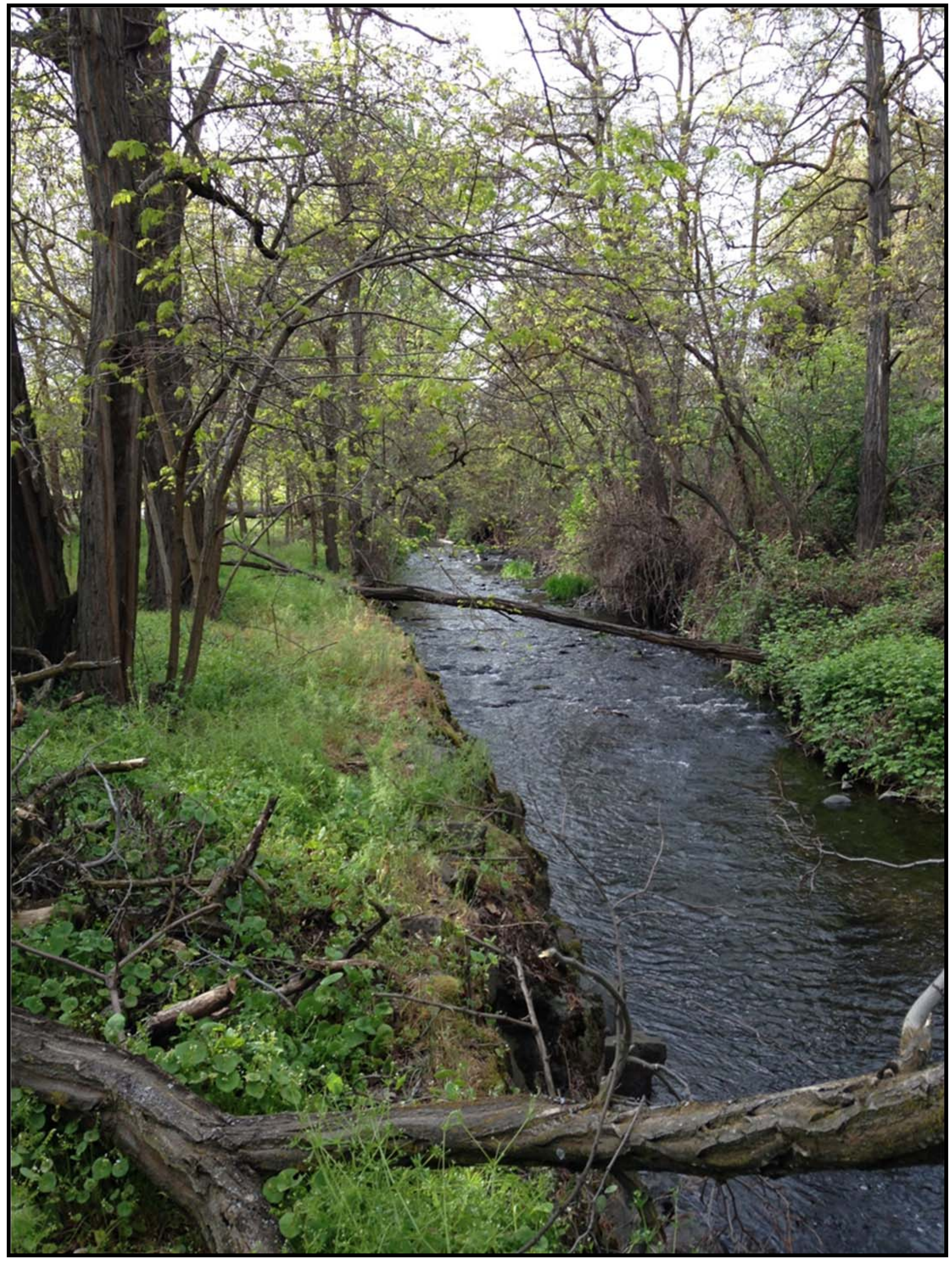


Field Study, Stream Monitoring

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

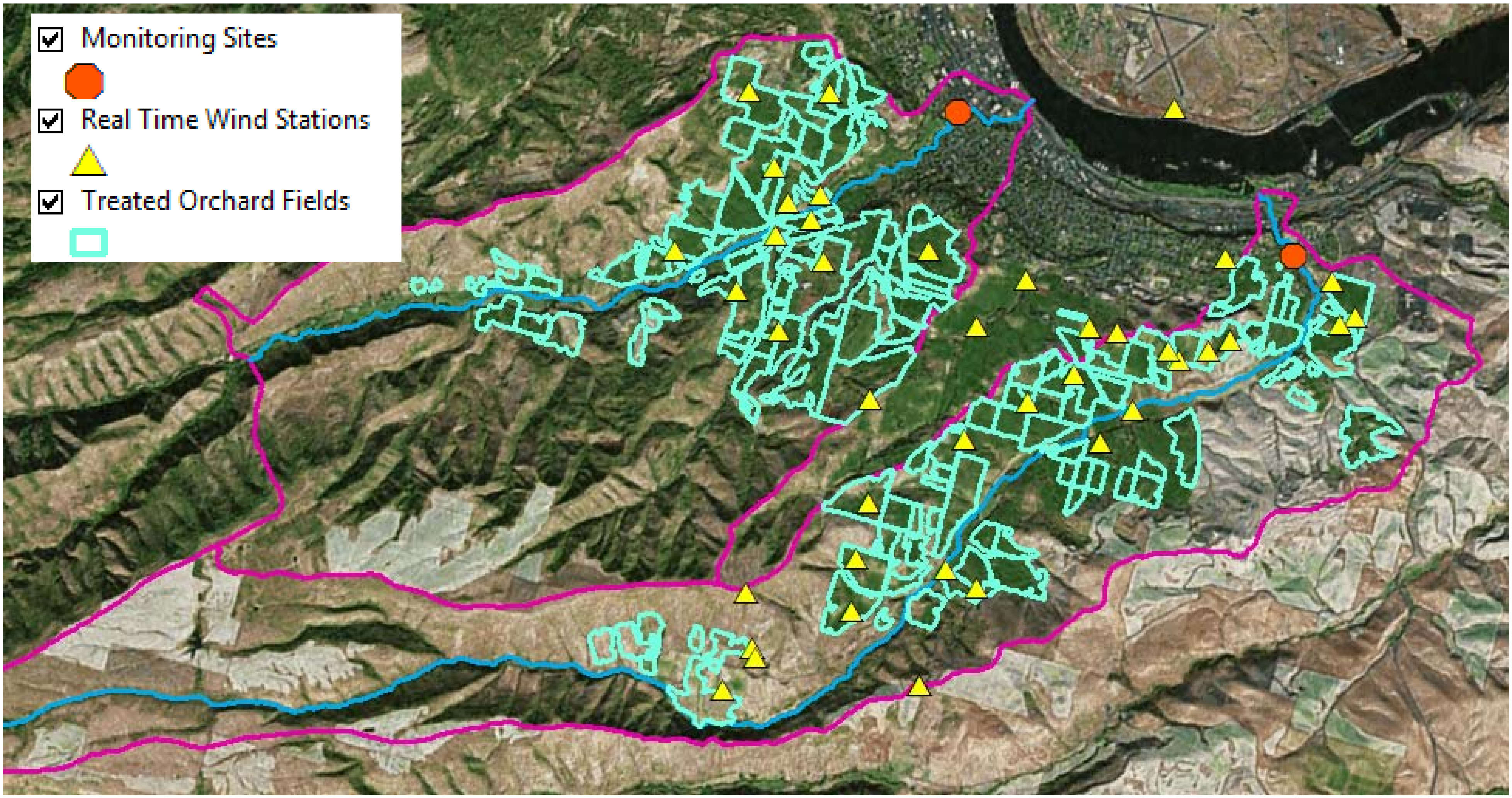
Pesticide concentration and flow were measured on a sub-daily (6-hour and hourly) basis during the entire malathion application season.

Stream width surveys were conducted several times throughout the study.



Field Study, Wind Dataset

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



SWAT Parameterizations

1
- 100% PTA
- Applications at max label rate and number of applications
- Conservative drift assumptions (10 mph wind always towards stream)

2
- Same assumptions as parameterization # 1 except…
- Seasonal use and application window set based on applicator data

3
- Same assumptions as parameterization # 2 except…
- Incorporate **actual dates and rates applied to specific fields**

4
- Same assumptions as parameterization # 3 except…
- Incorporate **wind direction** for each field and application, determine if a drift exposure event occurred

5
- Same assumptions as parameterization # 4 except…
- Incorporate **wind speed** for each field and application, use a refined drift fraction estimation

6
- Same assumptions as parameterization # 5 except…
- Incorporate **stream width** for drift deposition area for each field

Parameterization 1, Screening Level Modeling

Streamflow set to measured flow as upstream input.

100% percent treated area (PTA)

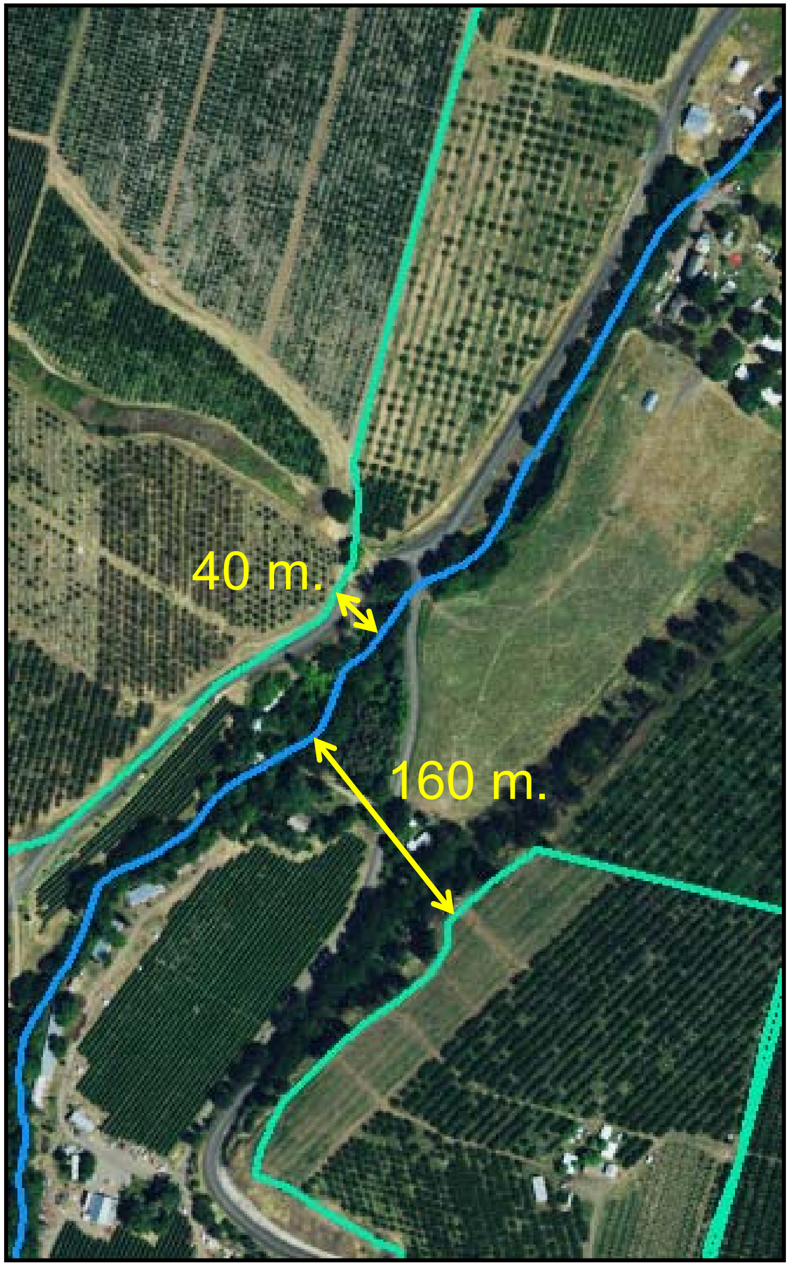
100 model simulations, for each simulation:

- select date(s) randomly from application window
- make applications at max label rate

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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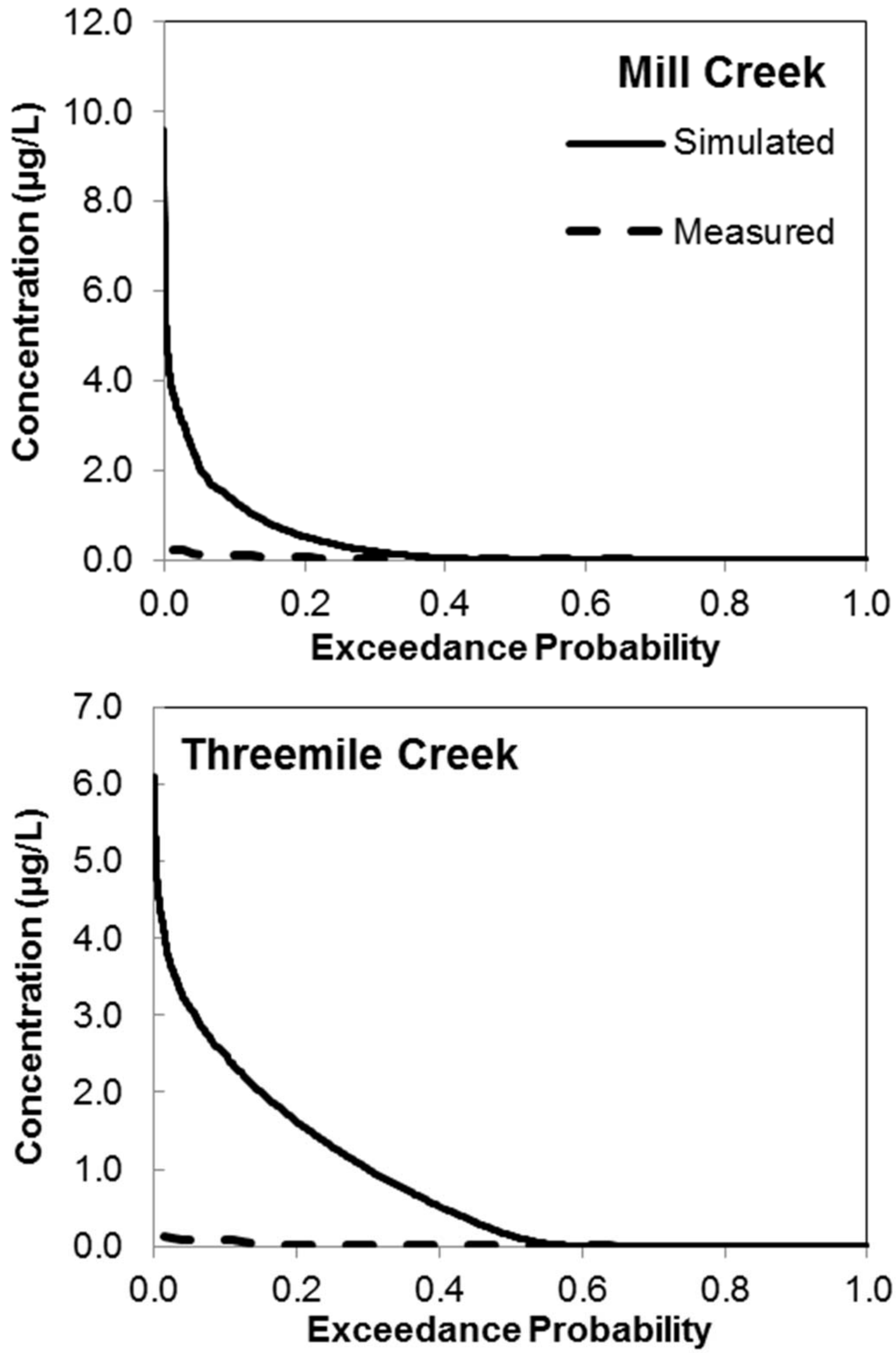
Parameterization 1, Results

Data from simulations compared against the average daily measured malathion concentrations.

Predicted concentrations are:

- Overly conservative (44x – 46x above observed max)

Parameterization 2 same as 1, except capped by observed annual application mass.

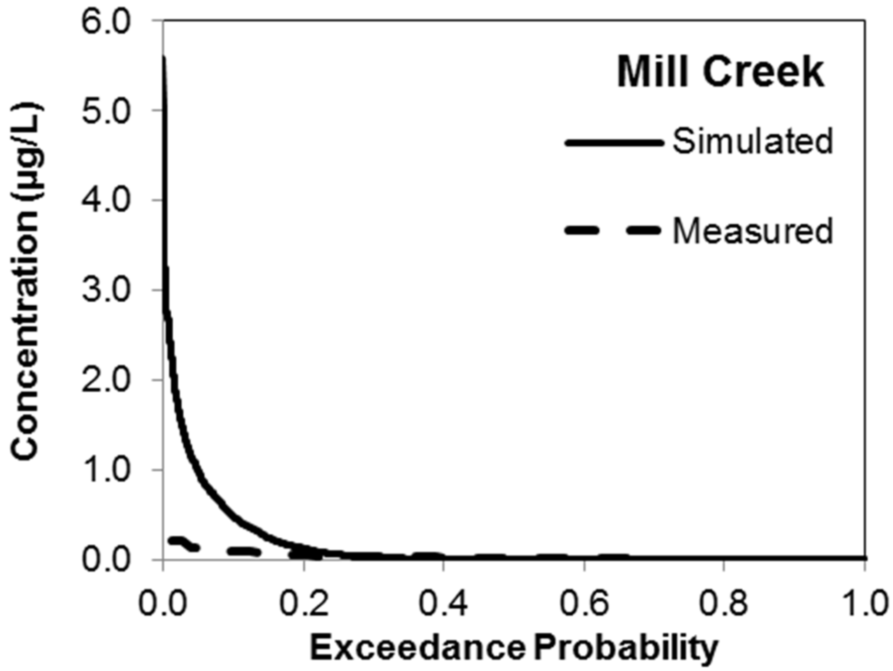


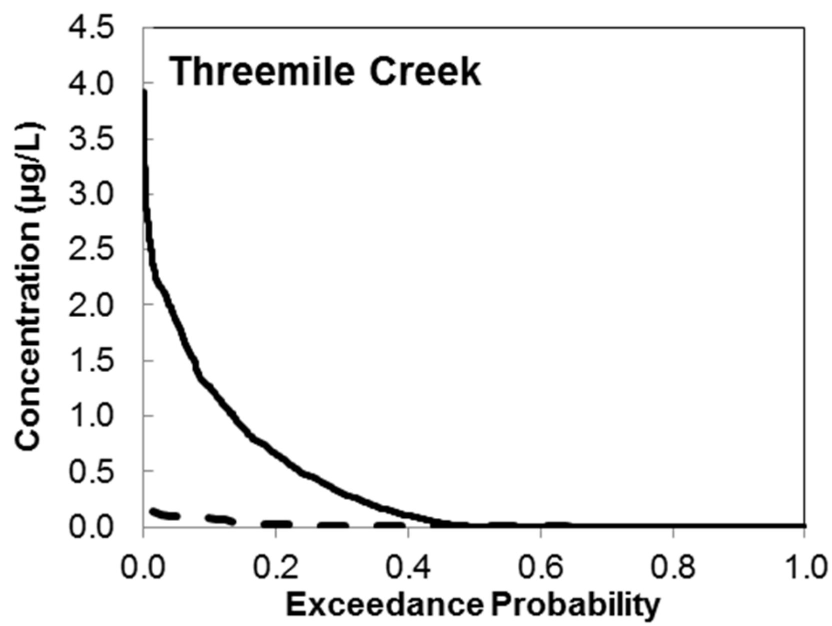
Parameterization 2, Results

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

Predicted concentrations are:

- Overly conservative (~27x above observed max)





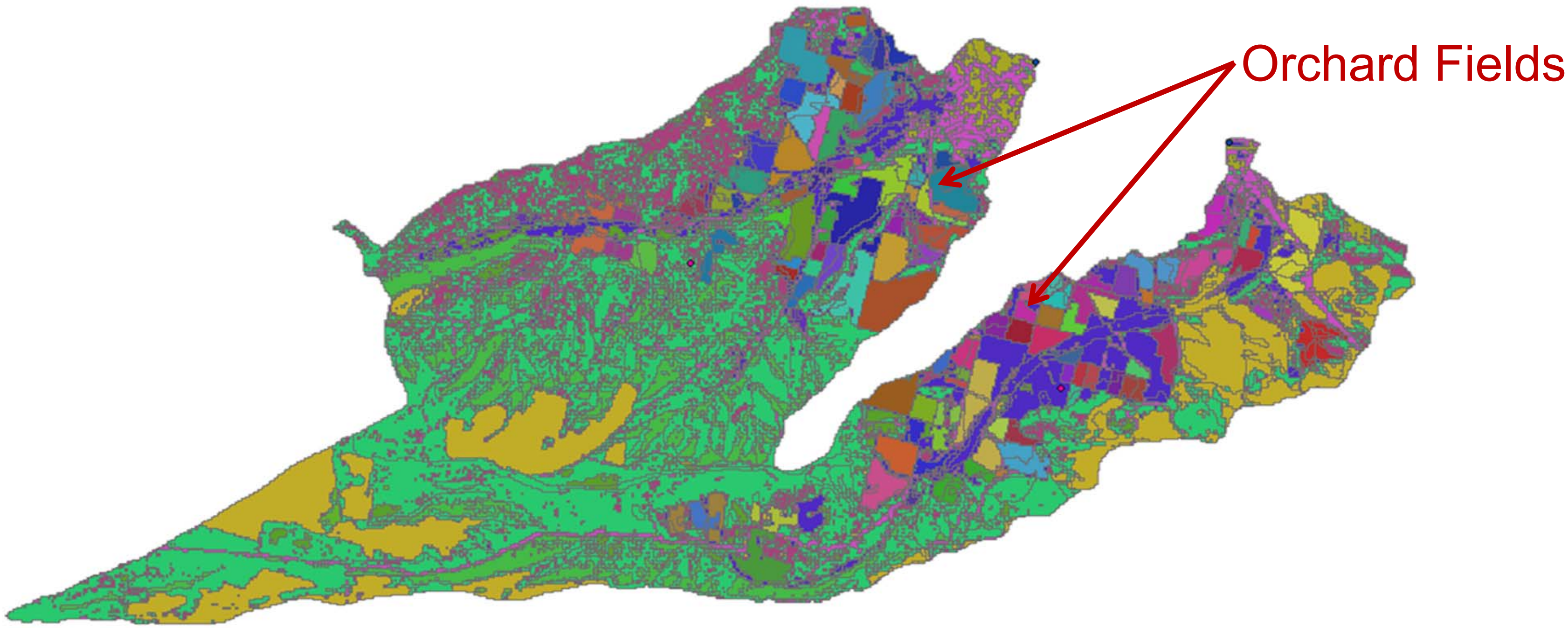
Parameterization 3, Refined Application Data

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.



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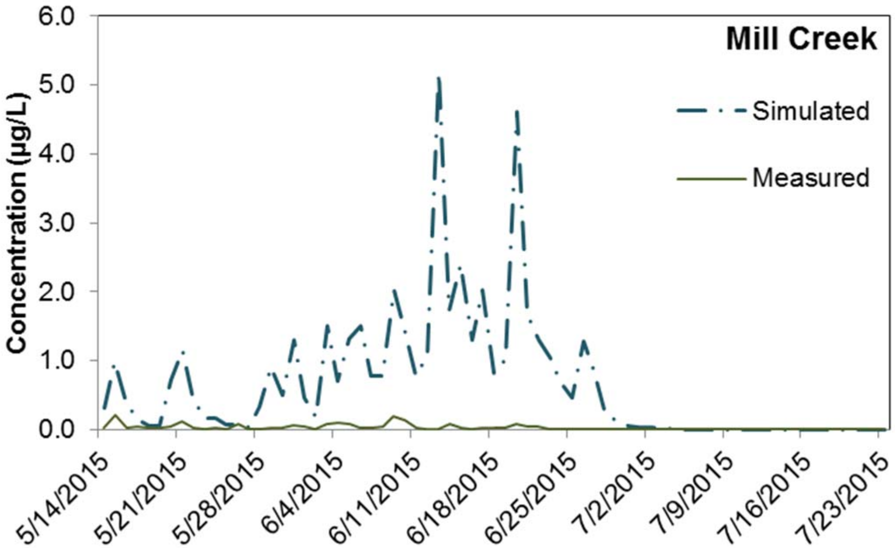
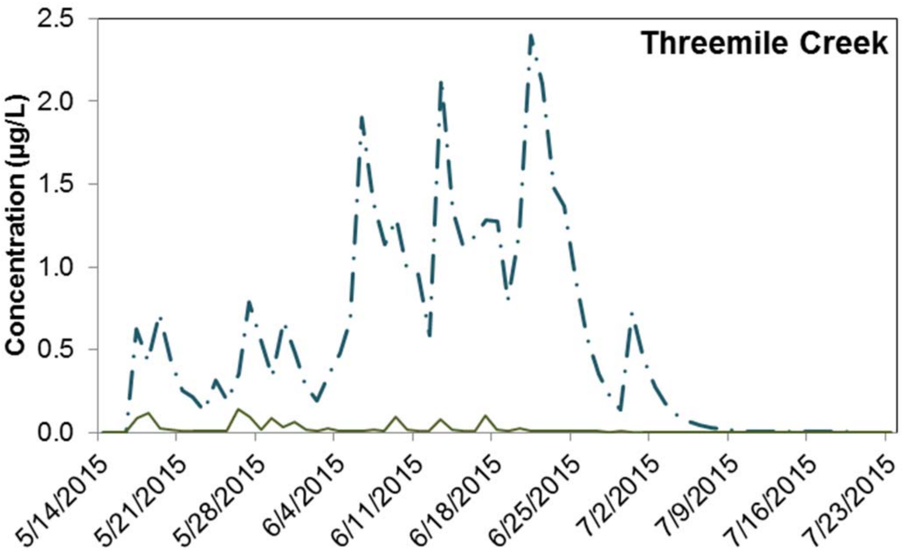
Parameterization 3, Results

The predicted concentrations still exceed the observed mean daily concentrations by nearly the same magnitude as the Parameterization 2 simulations.

The temporal pattern of peak concentrations is slightly improved.

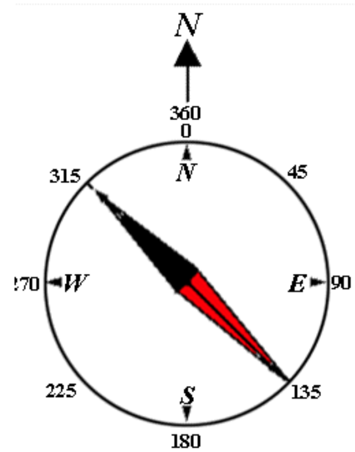




Parameterization 4, Wind Direction Data

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

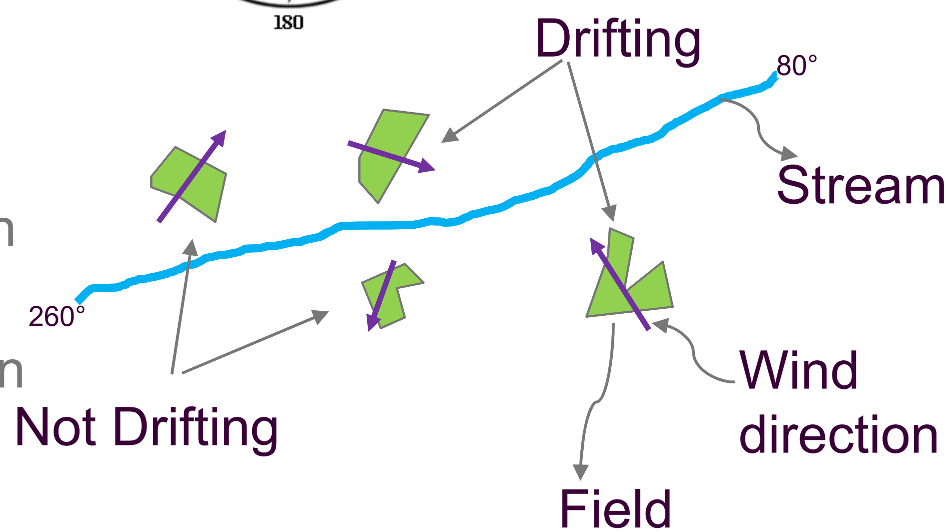
Stream direction generally along the 260 to 80° line (SW to NE)



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°



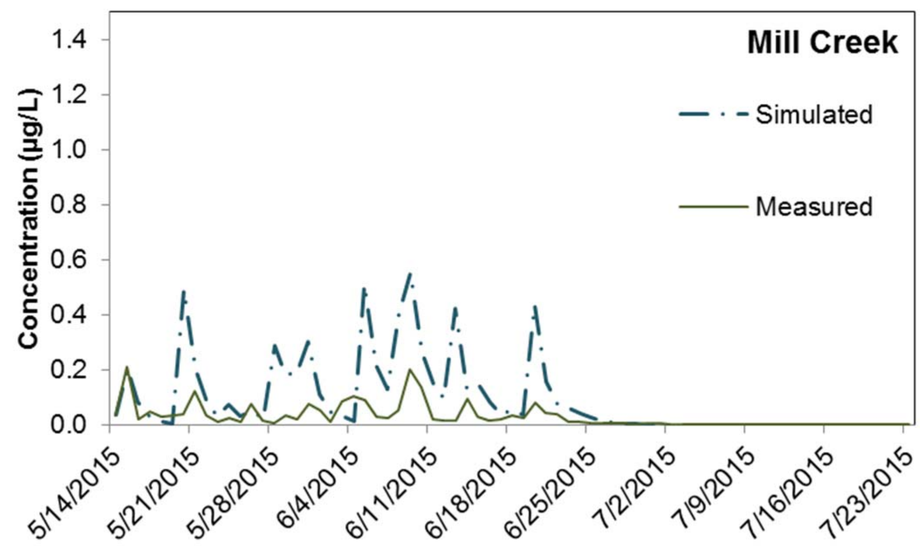
22% of applications classified as “drifting” simulated in the model

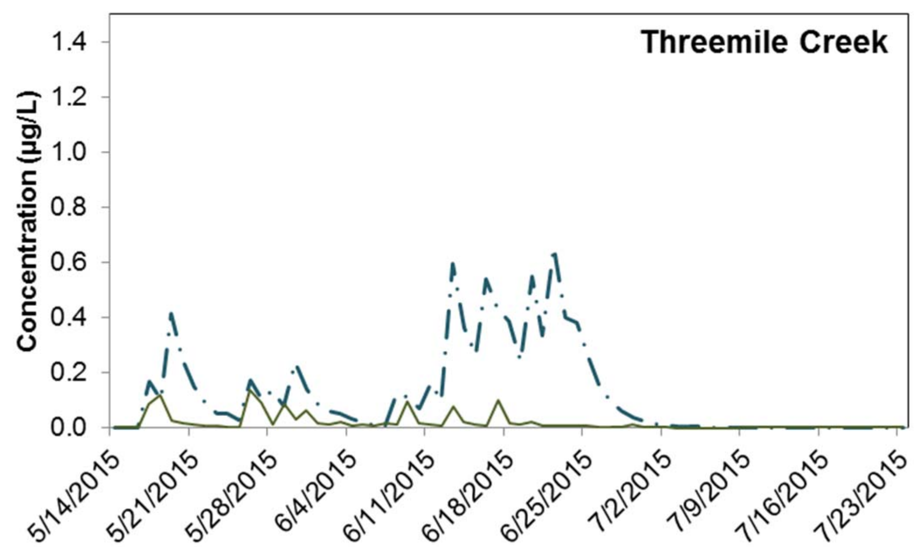
Parameterization 4, Results

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 2.6 times higher than observed

Threemile Creek: Max simulated concentration 4.6 times higher than observed



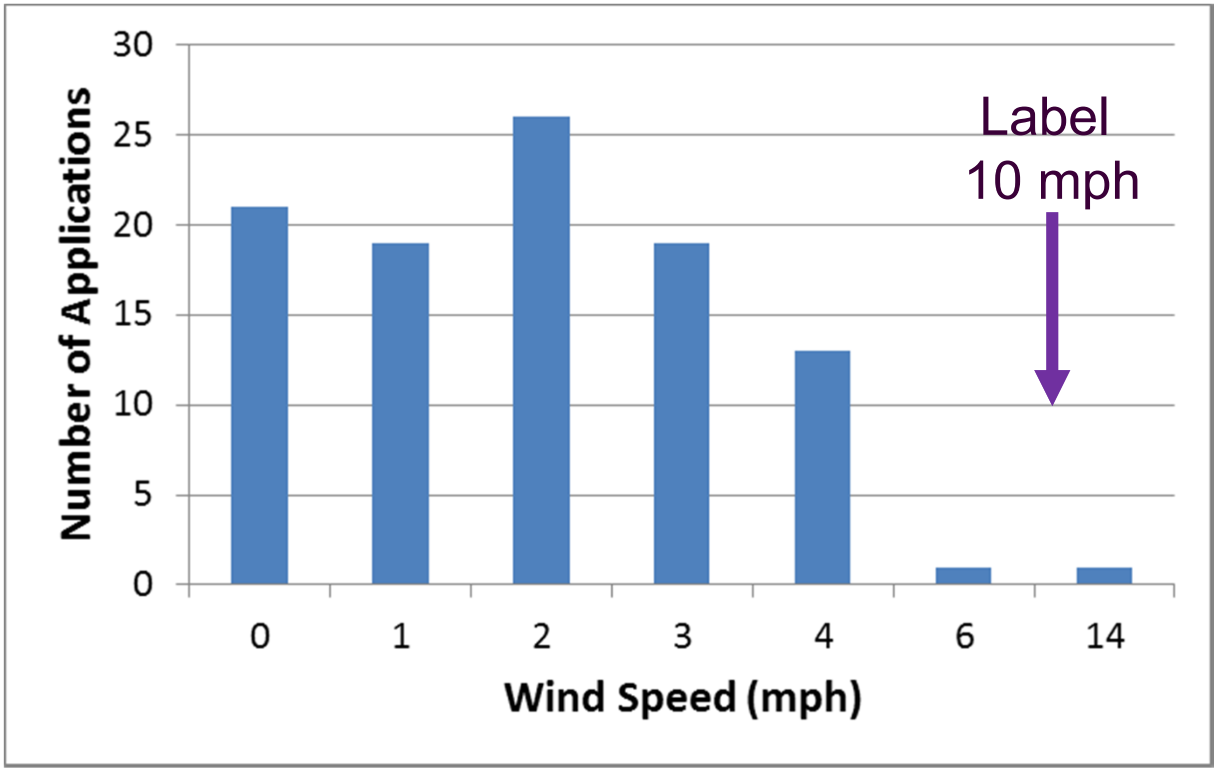


Parameterization 5, Wind Speed Data

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

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

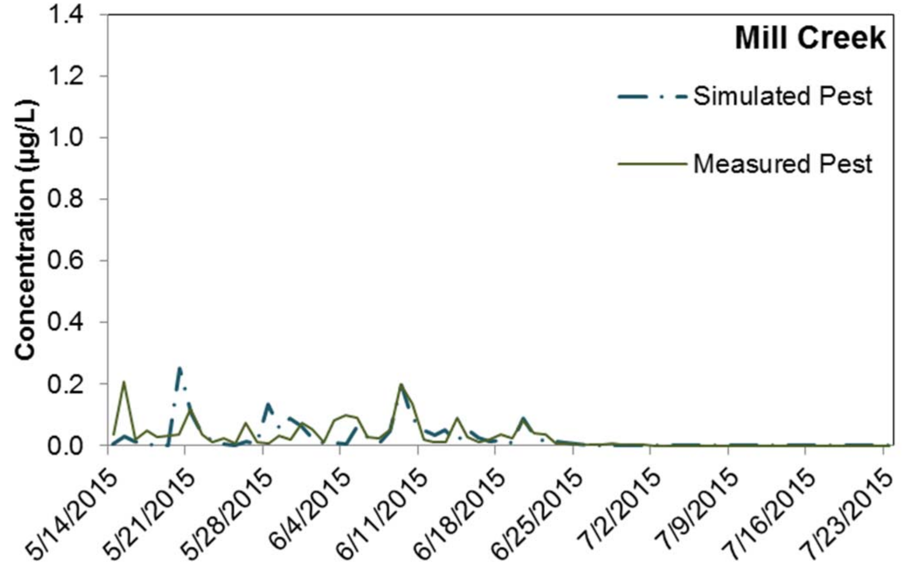
For “drifting” applications, developed application-specific drift curves and revised drift fractions incorporated in the SWAT model.

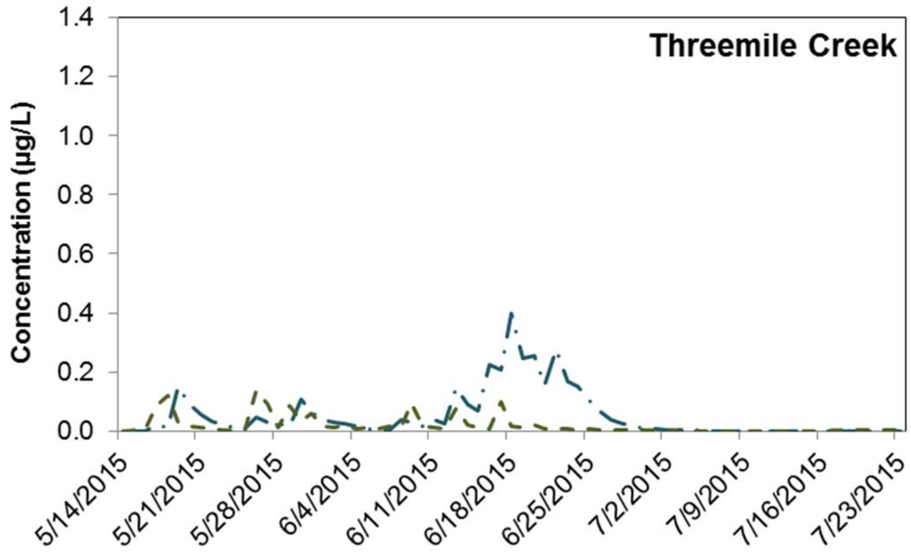


Parameterization 5, Results

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

Threemile Creek showed slight overestimation for a limited period (mid to end of June)





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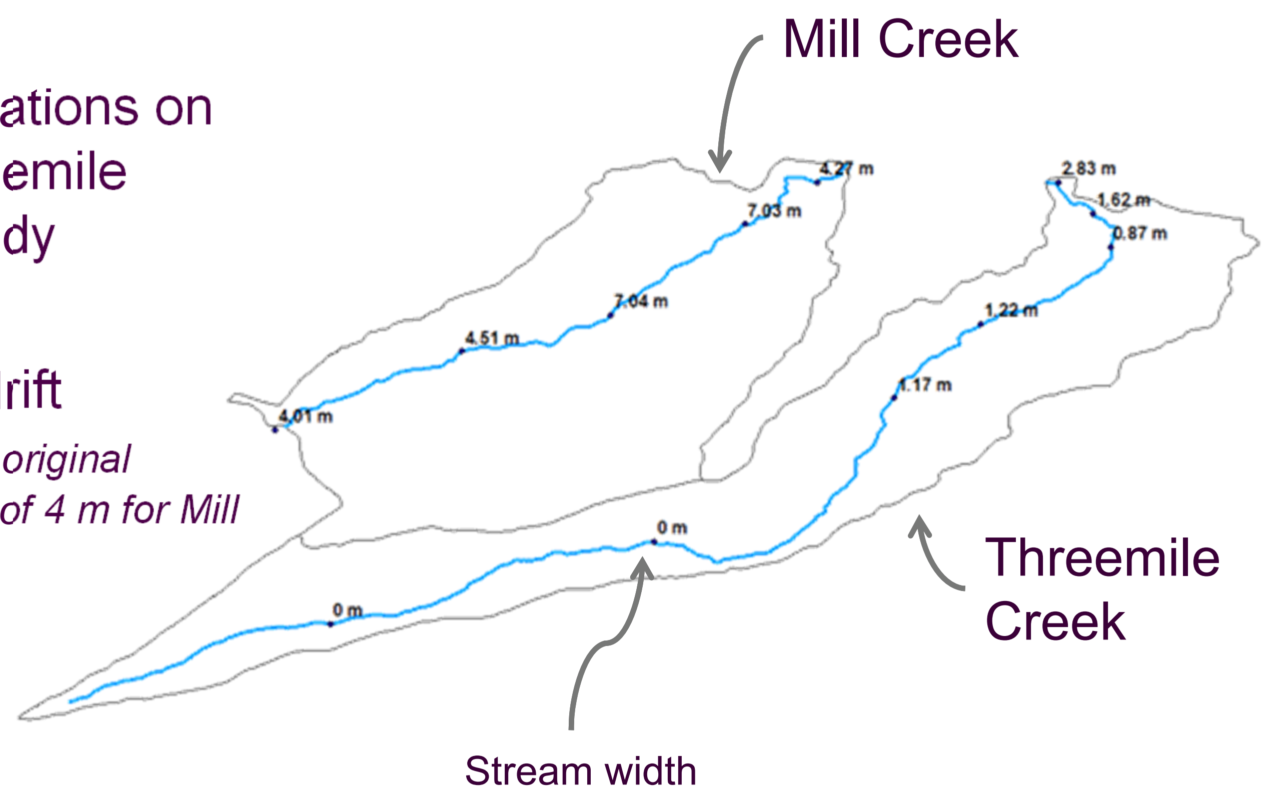
Parameterization 6, Stream Width

Same as experiment 3 but additionally uses stream width information

Stream width sampled at 6 locations on Mill Creek, 7 locations on Threemile Creek two times during the study

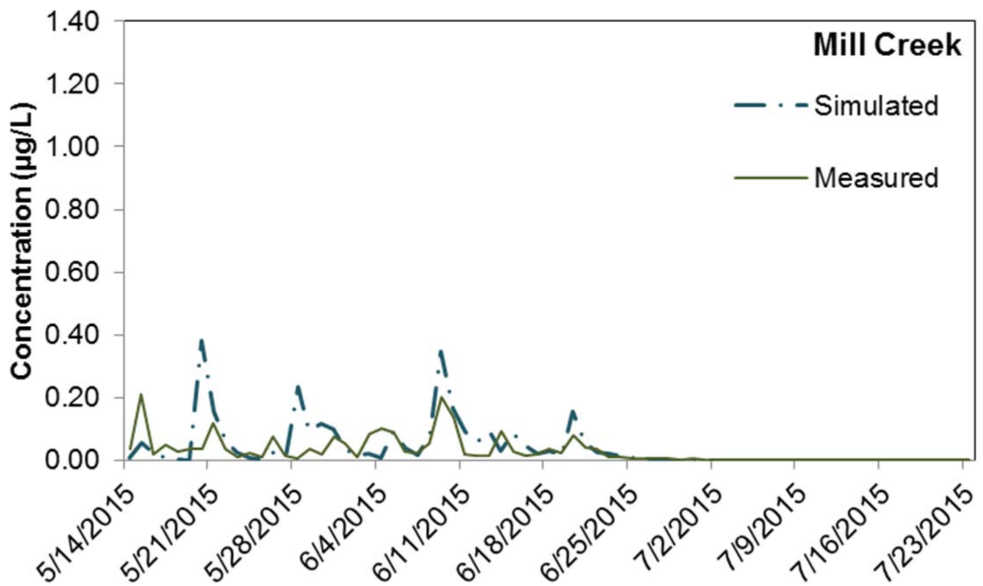
Stream widths used to refine drift waterbody area for each field (*original areas were based on estimated widths of 4 m for Mill Creek, 2 m for Threemile Creek*)

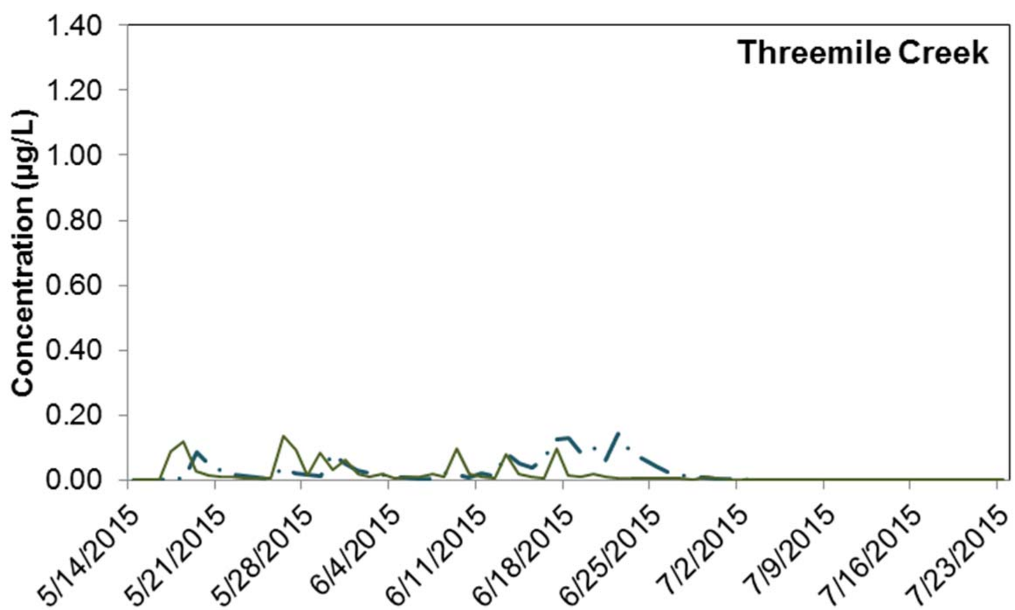


Parameterization 6, Results

Results show that the simulated concentrations increased slightly at Mill Creek and decreased at Threemile Creek

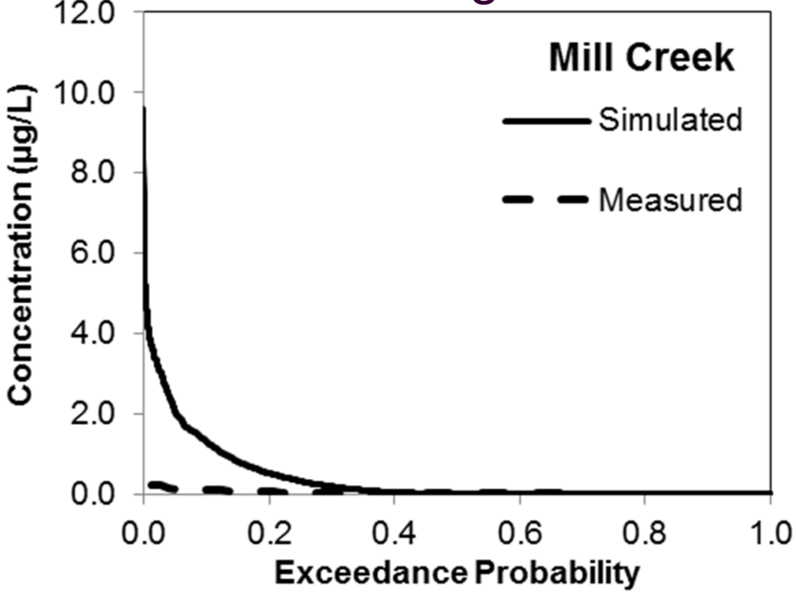
Stream surface area was not greatly different from the baseline model, so the improvements were minimal

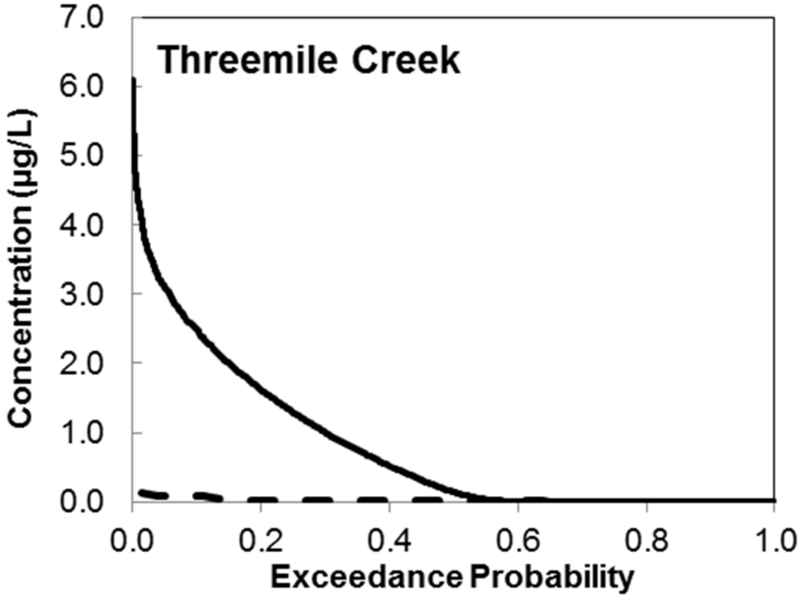




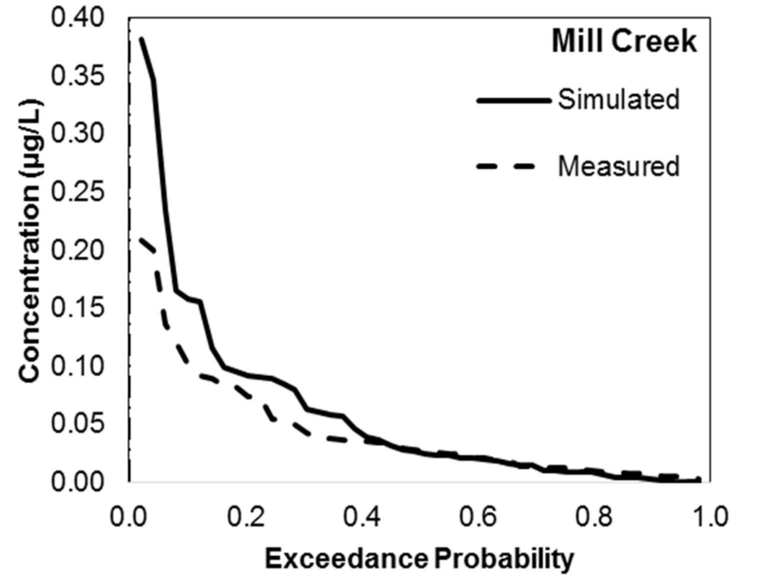
Recap

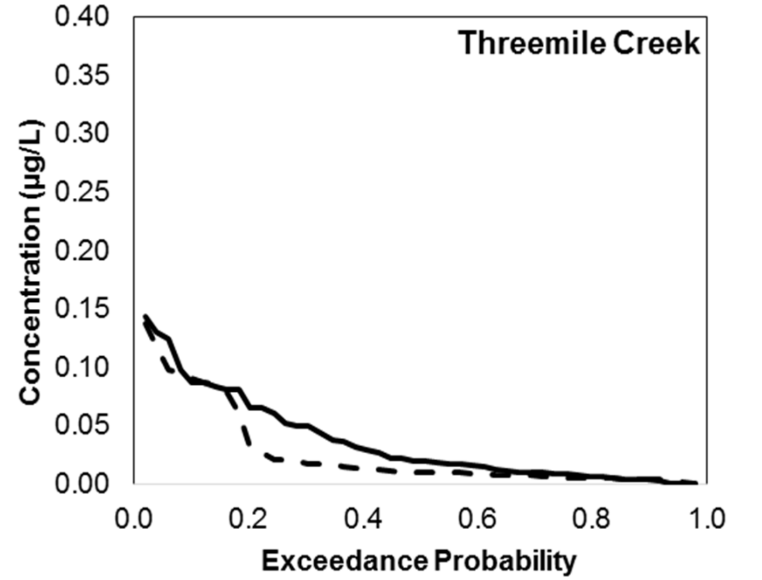
Screening Level





Stream Width





Major Takeaways

The assumptions made in screening level flowing water modeling can result in unrealistic exposure estimates from drift (~ 45X higher)

To improve model predictions, the annual mass of pesticide applied in the watershed should be constrained based on some use data (e.g. PUR, AgroTrak)

Assuming realistic wind conditions can still provide conservative yet realistic estimates of exposure

- Wind direction - 2.6x -4.6x higher
- Wind direction & speed - 1.2x-2.9x higher

The value of monitoring data can be increased greatly (e.g. for model validation) when corresponding use information is collected

Thank you.

For more information / www.stone-env.com

Contact / npai@stone-env.com