Modeling Transport of a Controlled Release Larvicide through Catch Basin Systems

American Chemical Society 2015 Fall Meeting – Boston, MA

17 August 2015

Naresh Pai[1], PhD

Michael Winchell[1], Ben Brayden[1], John Hanzas[1], Rob Dupree[2]

[1]Stone Environmental Inc., [2]Tumaini Controlled Release Technologies Inc.

Presentation Outline

Modeling Objective

Model Background

Pilot Study Modeling

Field Study Modeling

Scenarios

Future Refinements

Conclusions

Objective

Simulate long-term novaluron controlled release device (CRD) fate and transport in an urban catch basin system and receiving natural water body

Why SWAT?

Model requirements:

- Represent the environmental pathways of a catch basin system
- Simulate novaluron residues in a natural receiving water body
- Simulate the effect of long-term applications in combination with other factors such as climate and urban watershed characteristics

Soil and water assessment tool (SWAT) model can simulate:

- Catch basin components (conduits, catch basins, and pond)
- Pesticide transformation in each catch basin component
- 30+ years of daily transport

SWAT Soil & Water Assessment Tool

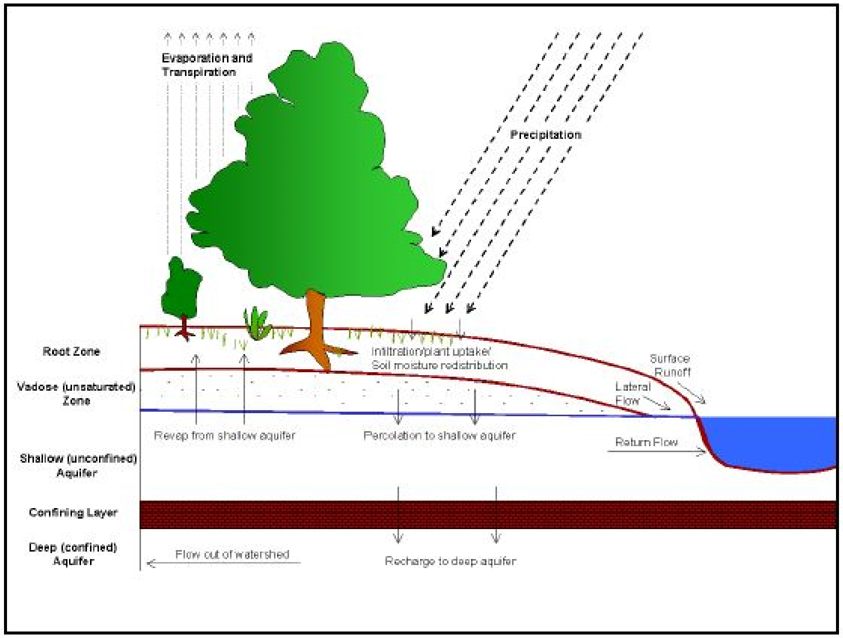
SWAT Background: Overview

Scientifically robust: 30+ years of active research and developmental work

Developed by USDA-ARS and Texas A&M

Endorsed by USEPA for water quality studies[1]

Used by state agencies to simulate pesticide transport[2]



Neitsch et al. (2011)

Applied to simulate several pesticides[3], e.g. Isoxaflutole, Atrazine, Diazinon, Chlorpyrifos, Metolachlor, Trifluralin, Isoproturon, Tebuconazole, Aclonifen, Flufenacet, and Metazachlor

[1] http://water.epa.gov/scitech/datait/models/basins, [2] *e.g. California Dept. of Pesticide Regulation (CDPR; Zhang and Zhang 2011),* [3] *References available upon request*

STONE ENVIRONMENTAL

SWAT Background: Study Area Conceptualization

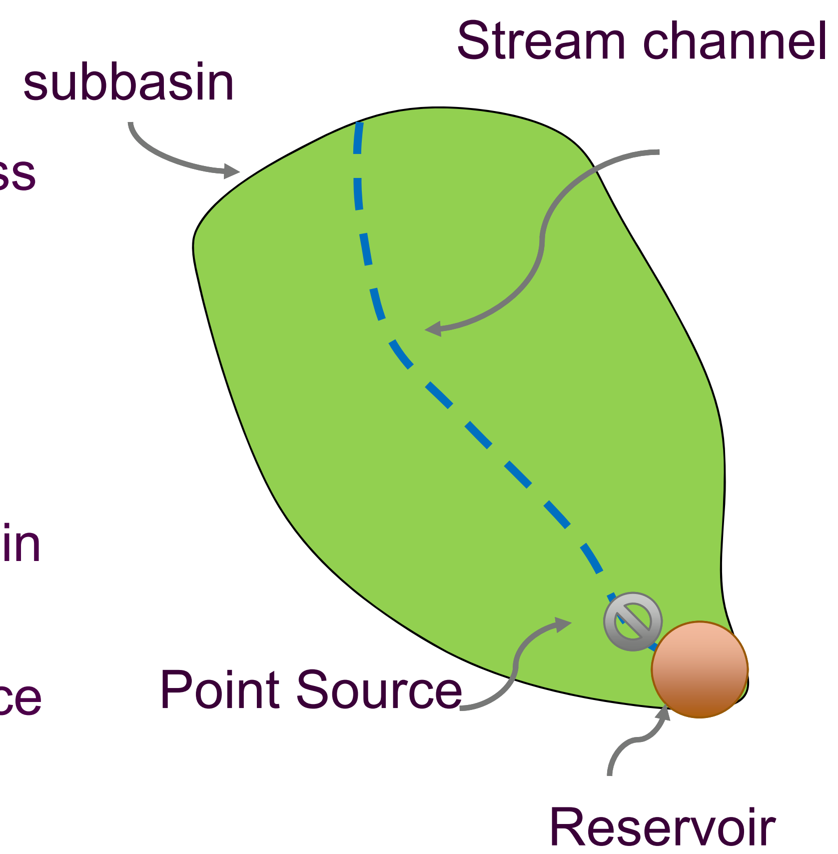
Semi-distributed model: divides study area into subbasins, HRUs (hydrological response units), and stream channels

Each subbasin contains several HRUs (e.g., grass and impervious) and one stream channel

Runoff from HRUs routed to stream channel

Stream channel connects to downstream subbasin

Stream channel can optionally have a point source chemical input and reservoir



SWAT Background: Catch Basin as Small Reservoirs

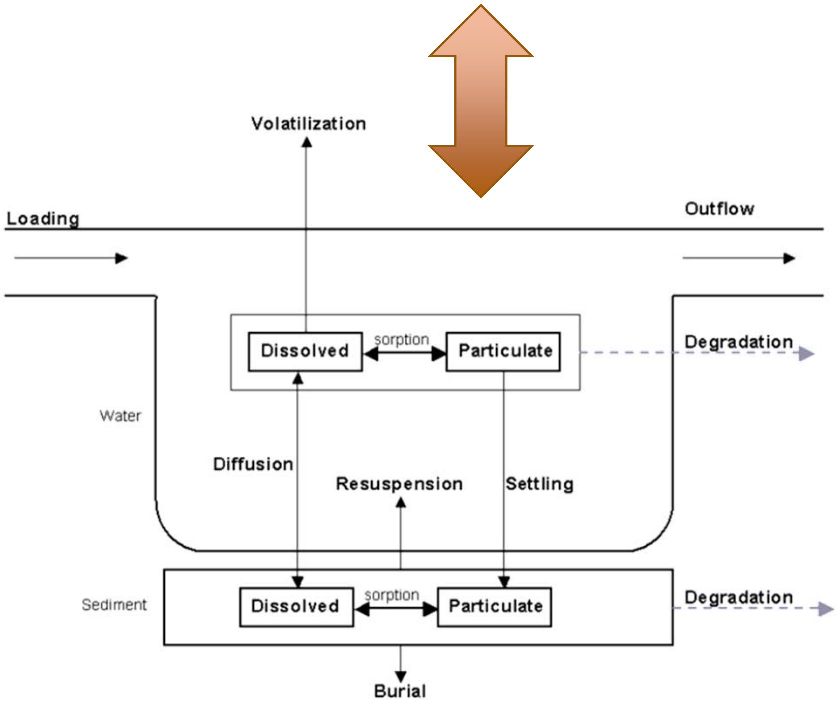
1-dimensional well-mixed layer of water and sediment on top of a single layer sediment bed

Dimensions customized to represent catch basin

- surface area and depth
- depth to outlet conduit

Flow in and out of reservoirs through streams parameterized as conduits

Setup as uncontrolled reservoir to remove water above outflow conduit in a single day



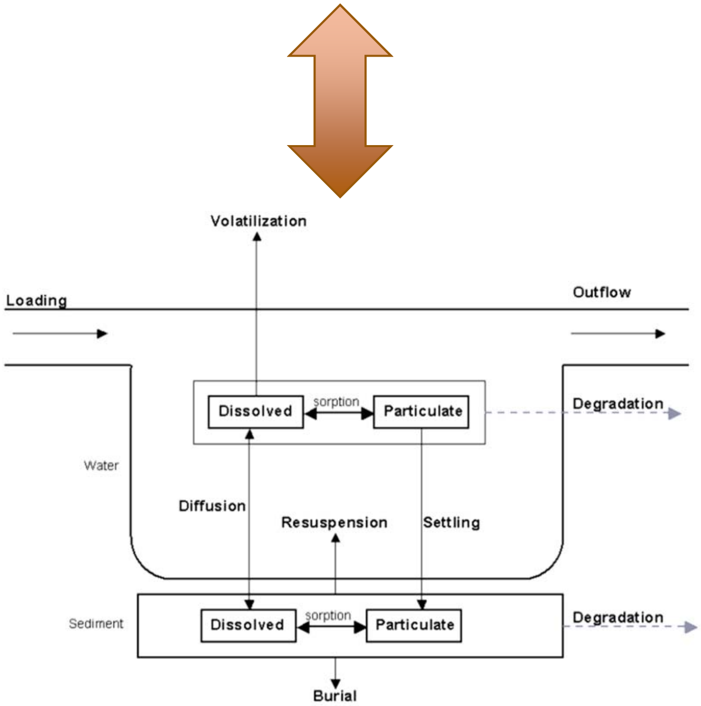
SWAT Background: Pesticide Processes

Pesticide can enter with flow from inflow conduit

Uses pesticide e-fate properties to partition into soluble and sorbed fraction

Transformation processes in water column: degradation, diffusion, volatilization, and settling

Transformation processes in benthic layer: degradation, re-suspension, burial, and diffusion



STONE ENVIRONMENTAL

Modeling Approach

Setup SWAT for pilot study and develop strategies for simulating CRD release

Setup SWAT for field study and calibrate with monitoring data

Simulate calibrated model for 30-years with alternative scenarios

Pilot Study Modeling: Overview

Catch basin filled with water in a Stone laboratory

Dosed with two Mosquiron® 0.12 CRD blocks

Water sampled at days 9, 15, 22, 36, 50, 64, 85, 99, and 113 after application

Samples analyzed for total novaluron concentration (dissolved + sorbed)

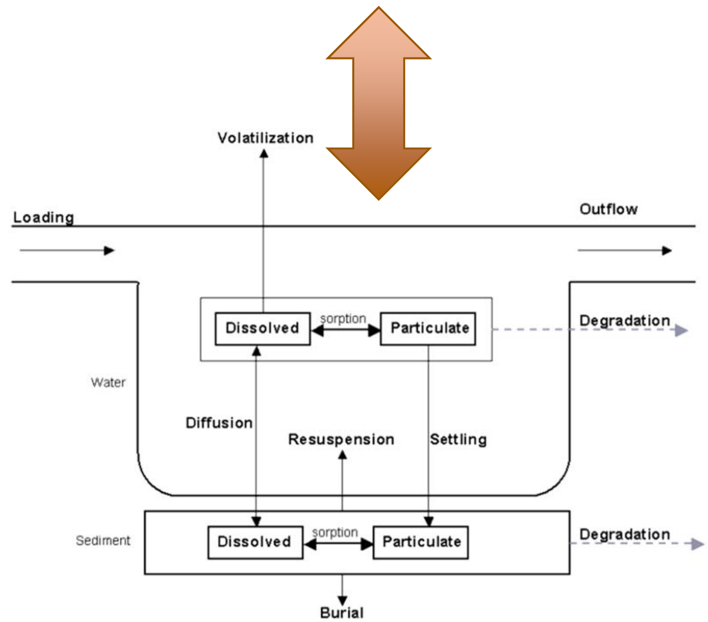
Pilot Study Modeling: SWAT Setup

Custom SWAT model developed to simulate only a single catch basin

Point source used to dose the catch basin with novaluron

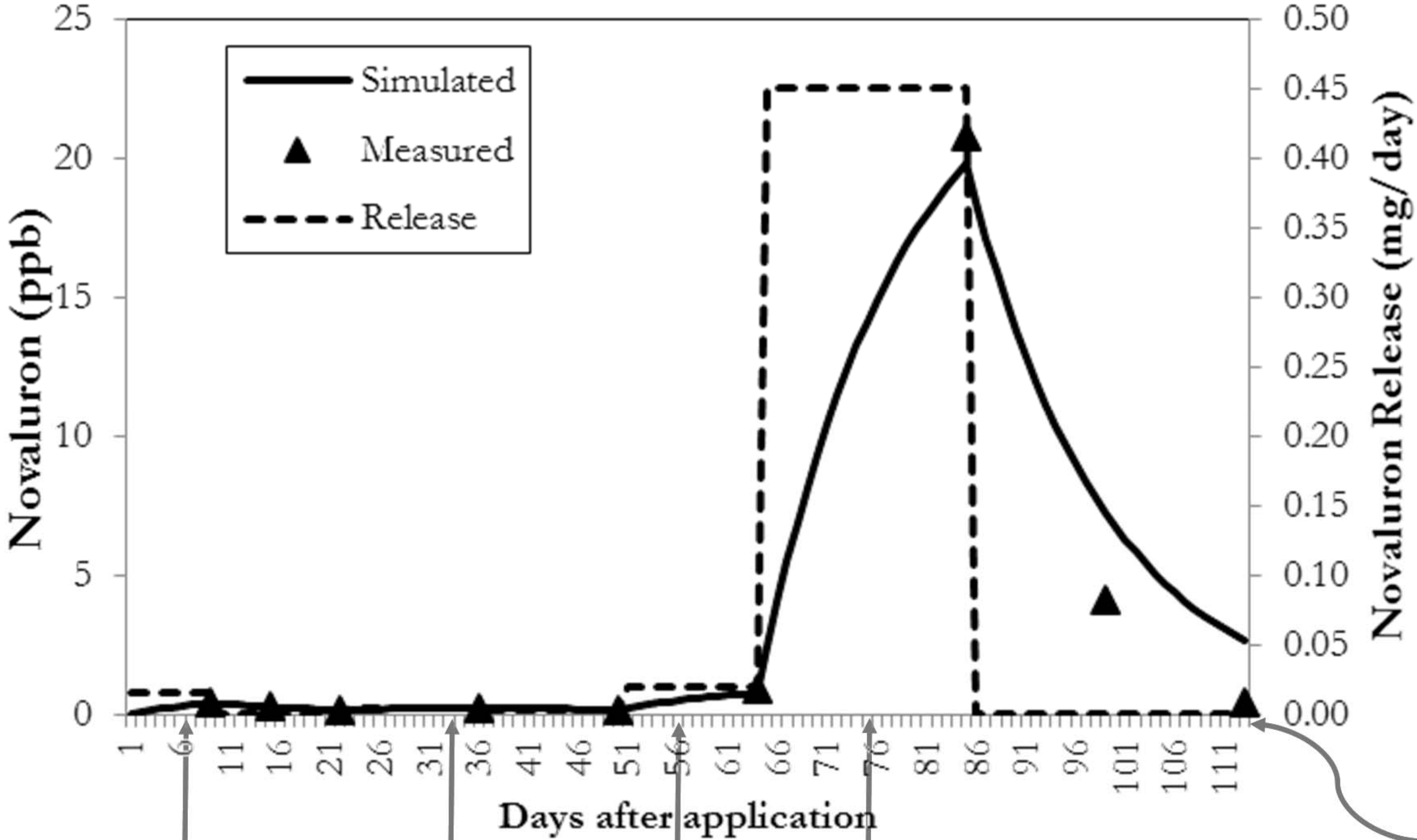
E-fate properties based on previous EPA ecological risk assessment study[1]

Dosing rate (g/day) calibrated to match observed data



[1] *EPA. 2010. Ecological risk assessment to support the proposed new use of Novaluron on sweet corn. Decision # 432482. Washington, D.C.: U.S. Environmental Protection Agency, Environmental Fate and Effects Division (EFED)*

Pilot Study Modeling: Results



0.02 mg/day

0.01 mg/day

0.02 mg/day

0.45 mg/day

Only 22.7% of CRD released to water column at the end of 113-days

Non-linear release rate

Pilot Study Modeling: Takeaways

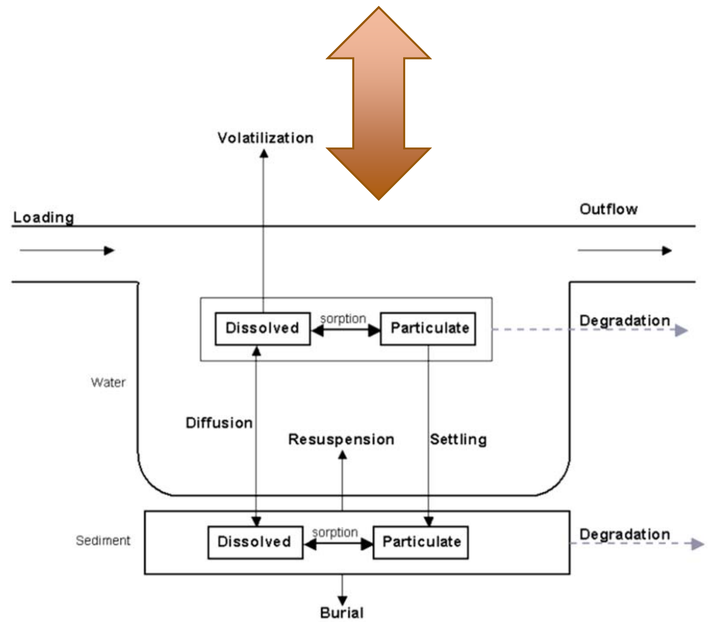
CRDs exhibit non-linear release

Developed strategies within SWAT for handling this non-linear release

Tested sensitivities of various pesticide transformation parameters

Release curve not directly transferred to field study because:

- it would result in the majority of chemical (77.3%) never releasing from the CRD
- there are no runoff events in pilot study



Field Study Modeling: Overview

Study site: 35-acre urban drainage area in Vermont

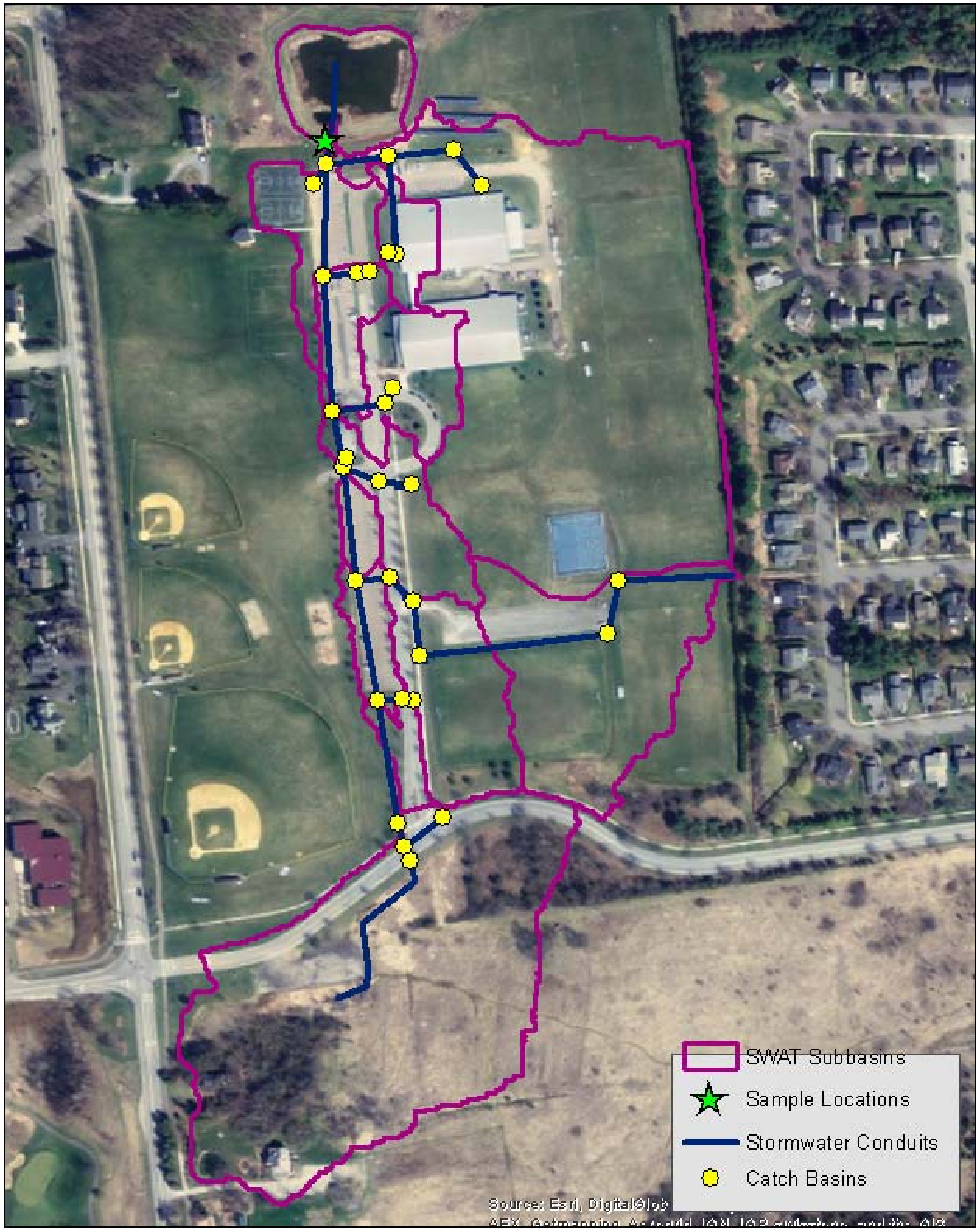
30 interconnected catch basins draining to a 0.7 acre pond

Catch basins dosed per label rate: 91 novaluron CRDs

Study period: 57 days

Hourly flow measured at outlet pipe

Novaluron concentration measured at outlet pipe (12 times) and in the pond (11 times) during the study period



STONE ENVIRONMENTAL

Field Study Modeling: SWAT Parameterization

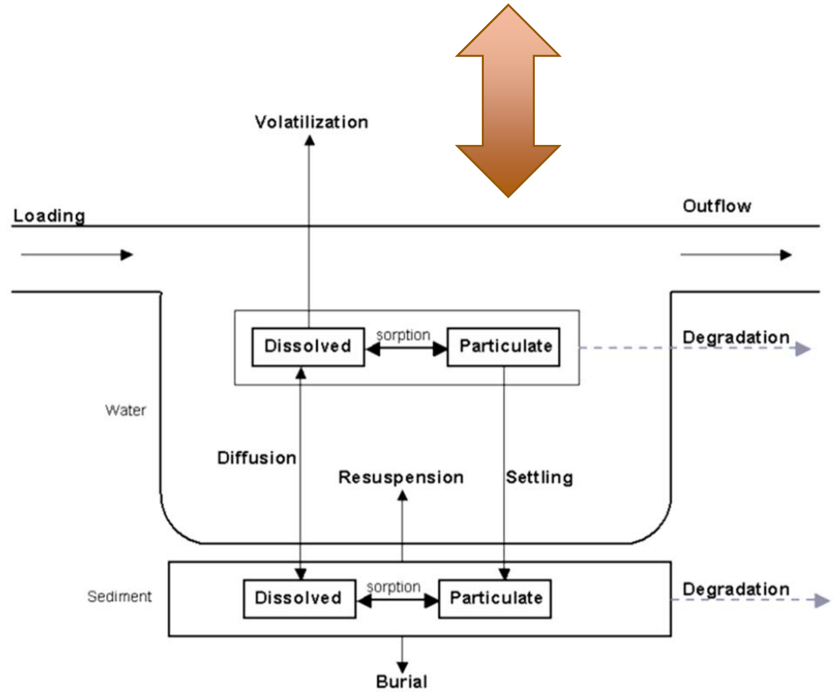
30-year daily precipitation, minimum and maximum temperature records from nearby weather station

Flow calibrated to achieve correct surface runoff

100% of pesticide mass input through point source dosing of catch basins

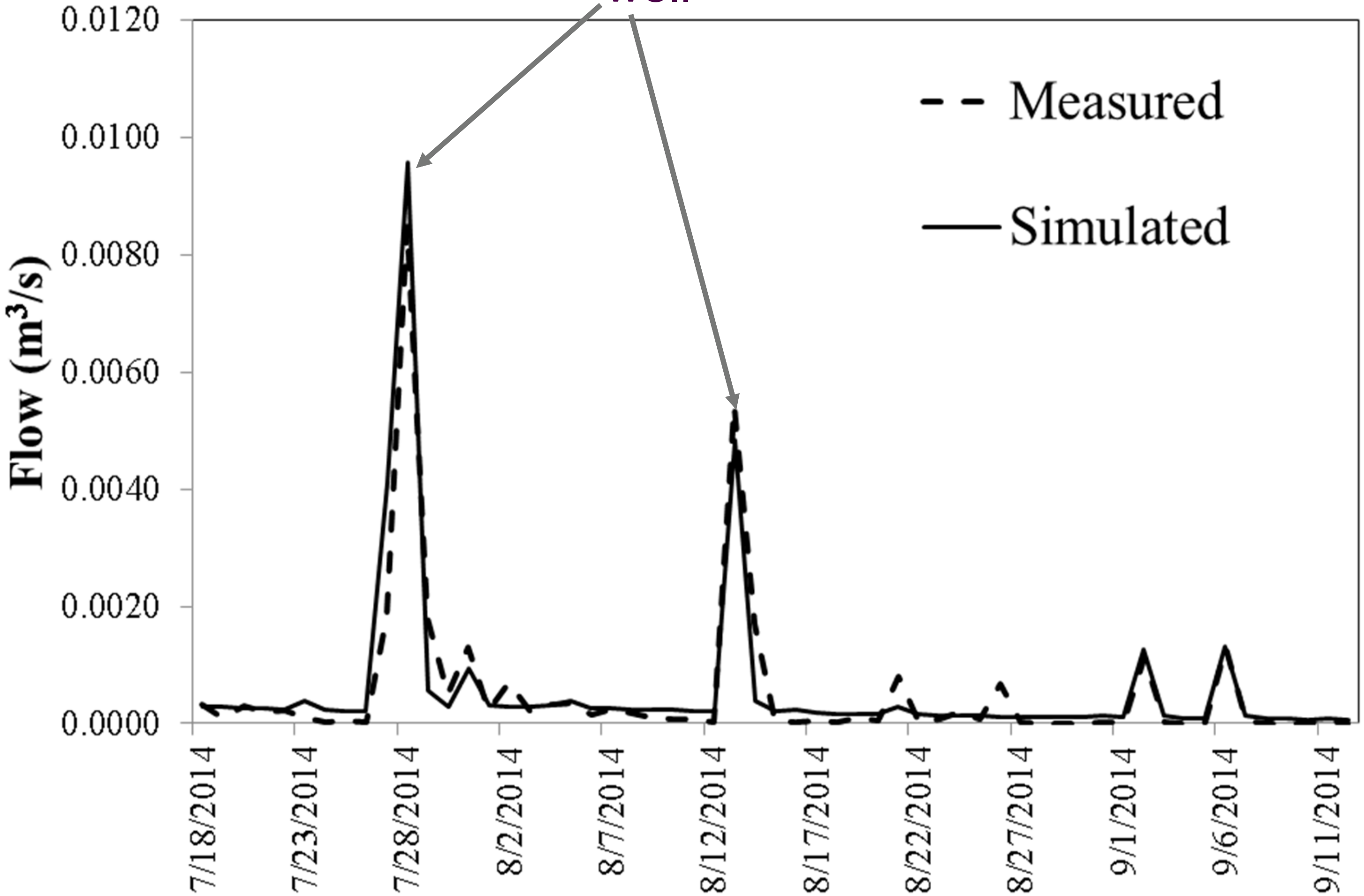
Increased settling and reduced re-suspension to transfer majority of mass to benthic layer

CRD release curve calibrated to match monitoring data



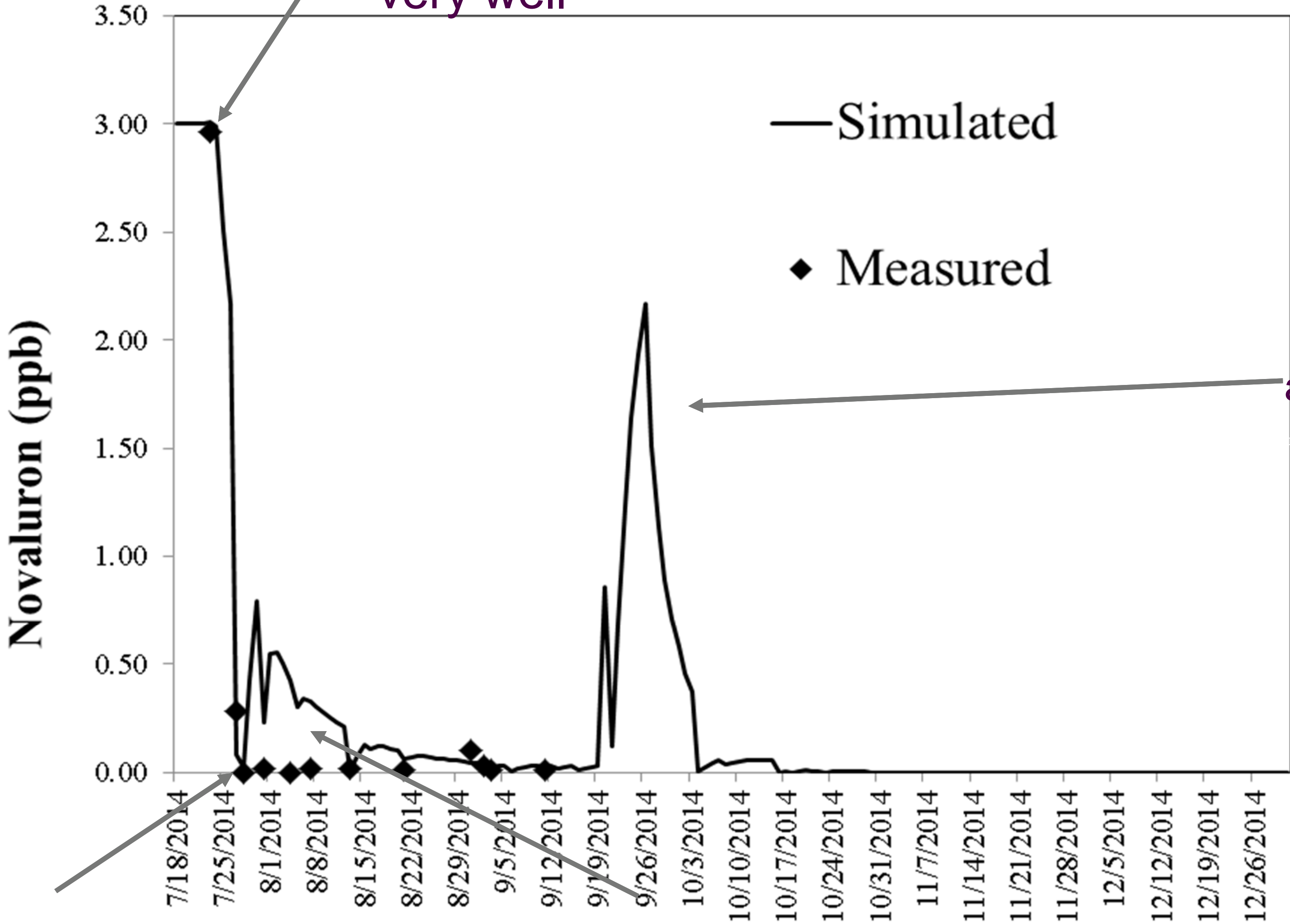
Field Study Modeling: Flow Results at Outlet Pipe

peaks simulated very well



Field Study Modeling: Concentration Results at Outlet Pipe

Initial flush simulated very well



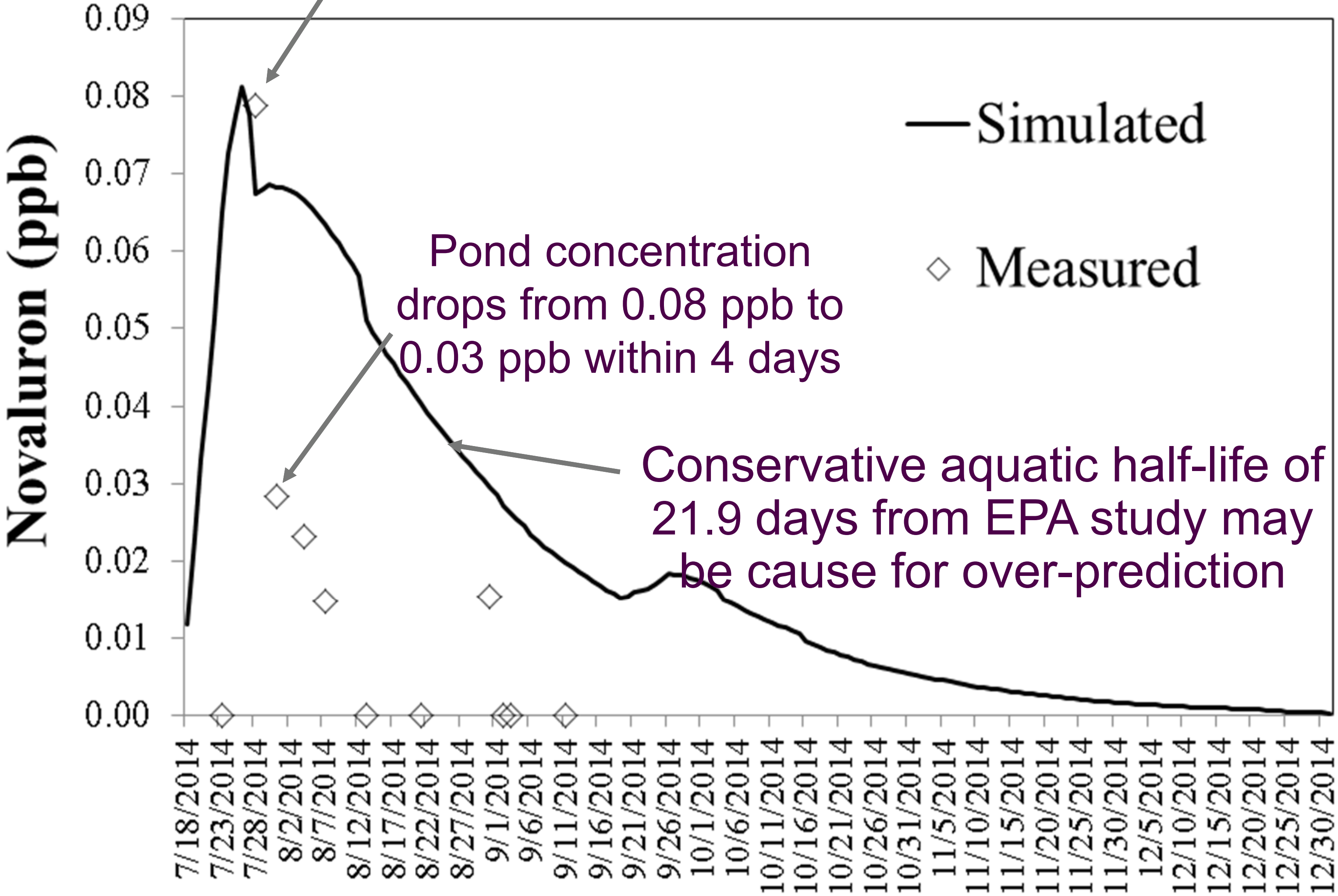
Late season spike around 9/19 and 10/3 parameterized based on pilot study data

Concentration drops after initial flush

Slight overestimation for event 3, 4, and 5

Field Study Modeling: Results in Pond

Initial peak simulated very well, otherwise generally conservative but within same order of magnitude



Scenarios

<u>Objective</u>

Evaluate the effect of long-term CRD applications on estimated environmental concentrations (EECs) in a natural water body

Approach:

Four scenarios simulated

25 simulations per scenario with application date randomized

Each simulation included a 30-year daily model run (1985-2014)

Two CRD applications per year (May and August)

Scenario Description

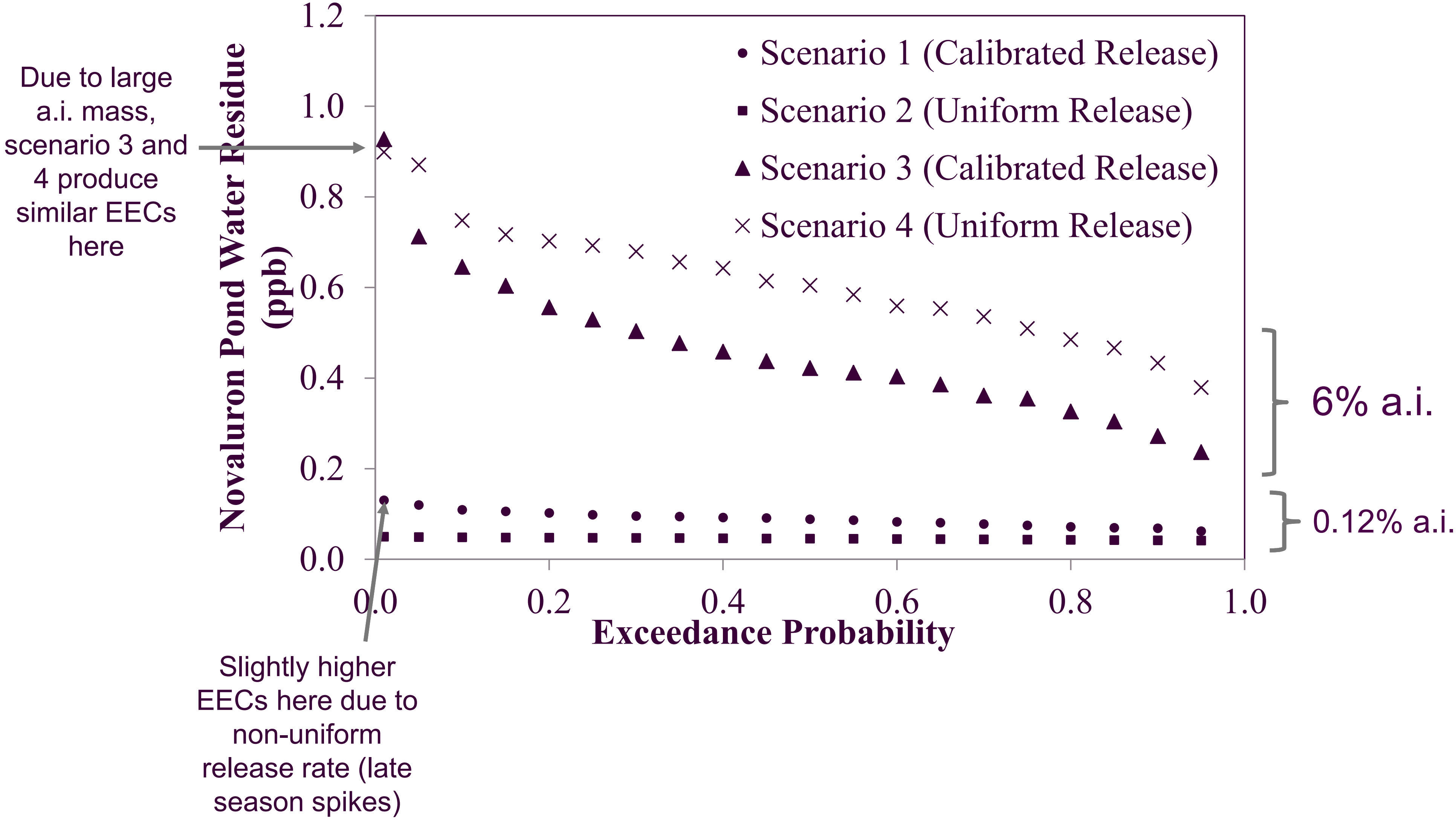
Scenario 1: release rate based on field calibrated curve

Scenario 2: uniform release rate over a 90-day period

Scenario 3: increased active ingredient from 0.12% to 6% (hypothetical product), use calibrated release curve

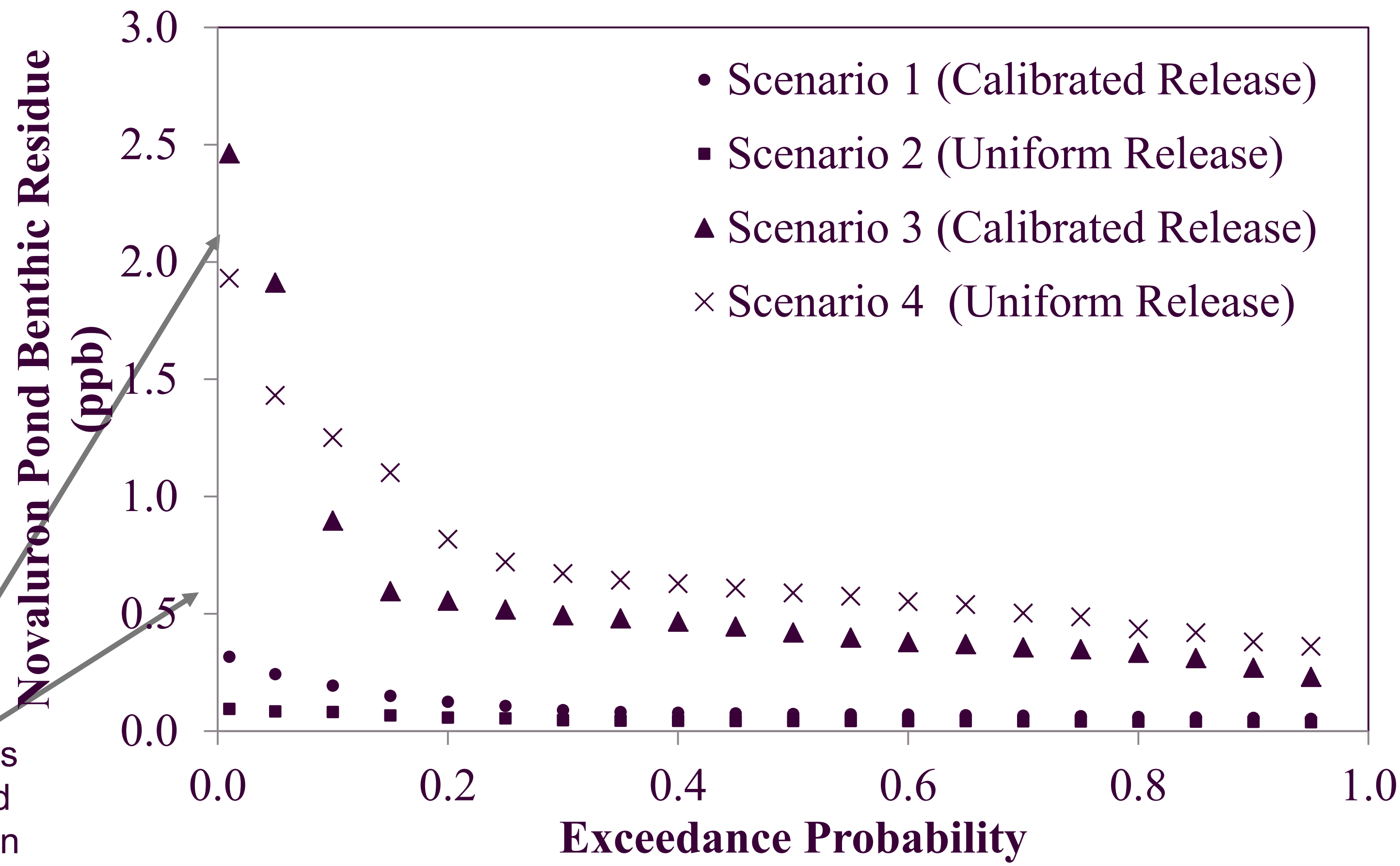
Scenario 4: increased active ingredient from 0.12% to 6% (hypothetical product), use uniform release

Scenario Results: Pond Water Column (Annual Maximums)



STONE ENVIRONMENTAL

Scenario Results: Pond Benthic Layer (Annual Maximums)



Concentrations higher in pond benthos than in water column (Note: these are not calibrated)

Future Refinements

Longer monitoring data: A single 57-day season with 12 sampling events may not capture transport under all hydrologic conditions

Total Vs. Soluble Vs. Sorbed: Useful to measure soluble and sorbed concentrations separately, since novaluron is strongly sorbed to sediment

More pond sampling: sampling pond more frequently and in the benthic layer would be useful for developing a more refined pond model

Coupled Models: Testing a coupled SWAT and pond-specific model such as VVWM, or AGRO

Conclusions

Novaluron CRDs show a complex non-linear chemical release behavior

SWAT model developed for a 14-ha field site was able to simulate transport of novaluron CRDs in a 30 catch basin urban system

Flow rate and novaluron concentration were simulated adequately at outlet pipe; pond concentration generally conservative but within the same order of magnitude as observed

Long-term simulations show concentration under 0.2 ppb and 0.5 ppb in water column and benthic layer, respectively

Scenario simulation showed that a 50X increase in a.i. fraction (i.e. 0.12% to 6%) would result in following increases in the 90th percentile water column EECs:

- 6x increase (0.11 ppb to 0.65 ppb) for non-linear release
- 15X increase (0.05 ppb to 0.75 ppb) for uniform release

Thank you.

For more information / www.stone-env.com

Contact / Naresh Pai, npai@stone-env.com