# Assessment of unfertilized field strip efficiency by analytical models for linking soil surface source zones to surface water receptor zones

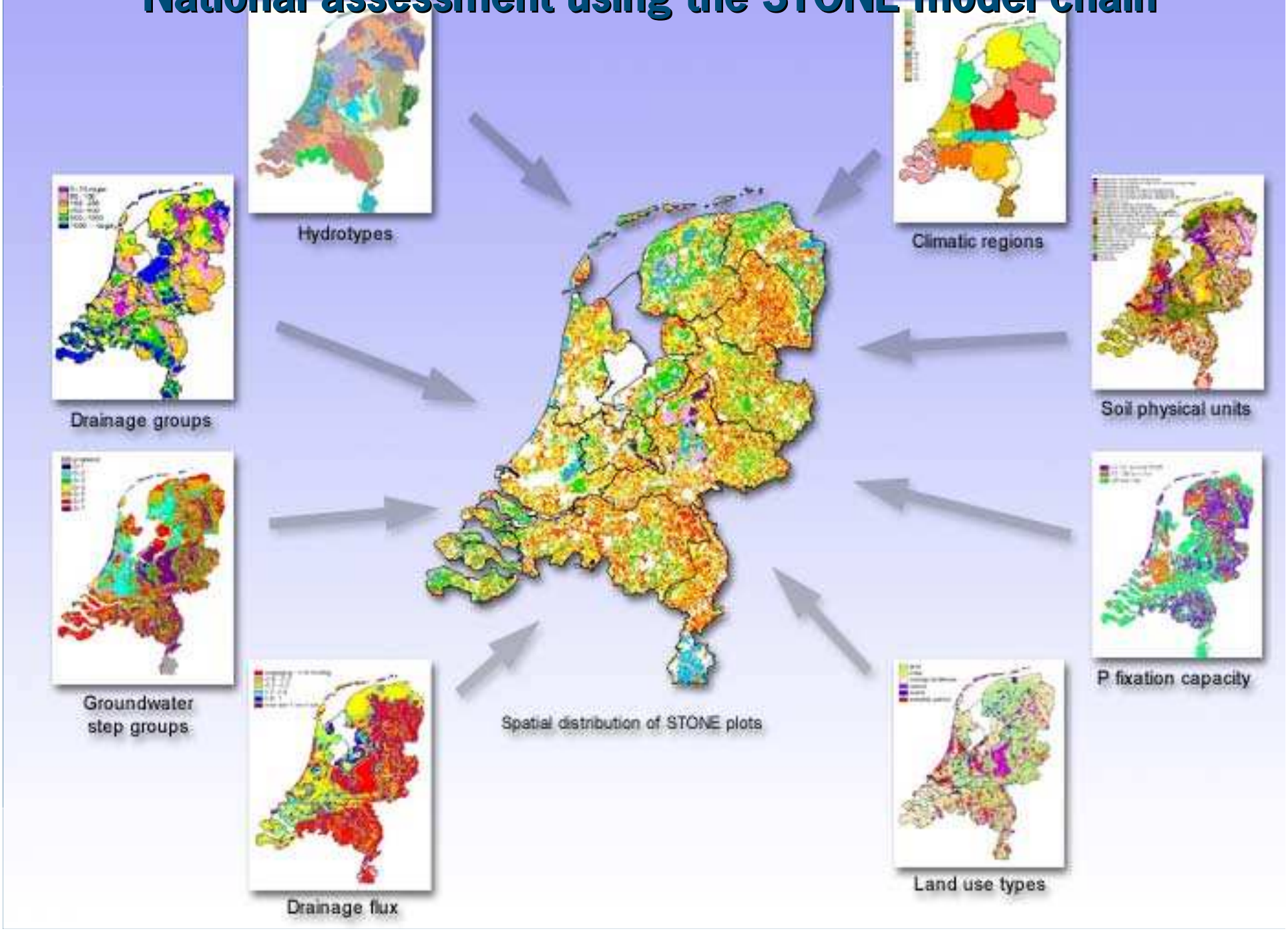
Piet Groenendijk
Marius Heinen

ALTERRA
WAGENINGEN UR

# Content

- Background
- Need for conceptual relations
- Examples of simple approaches
- Discussion
- Conclusions

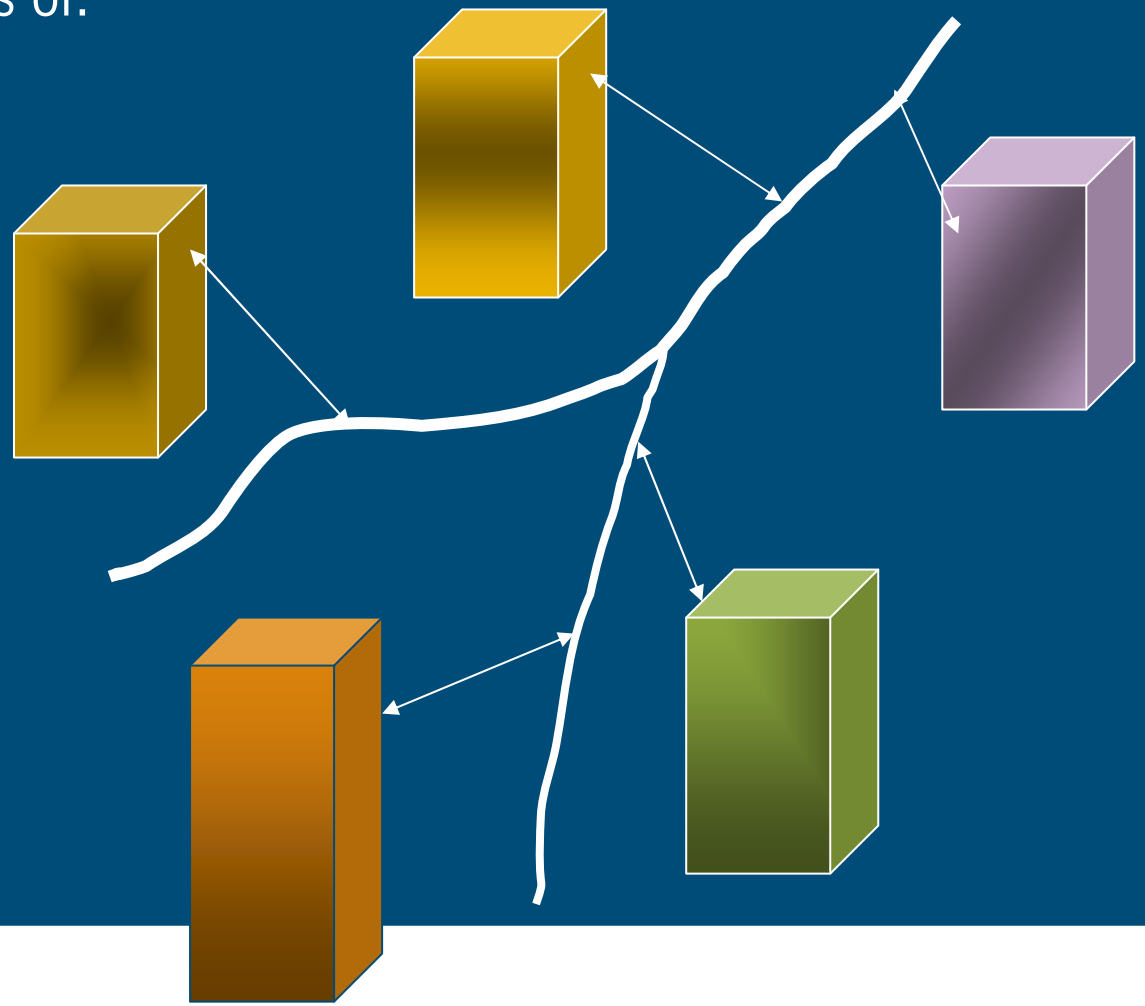
# National assessment using the STONE model chain



# Regional approach

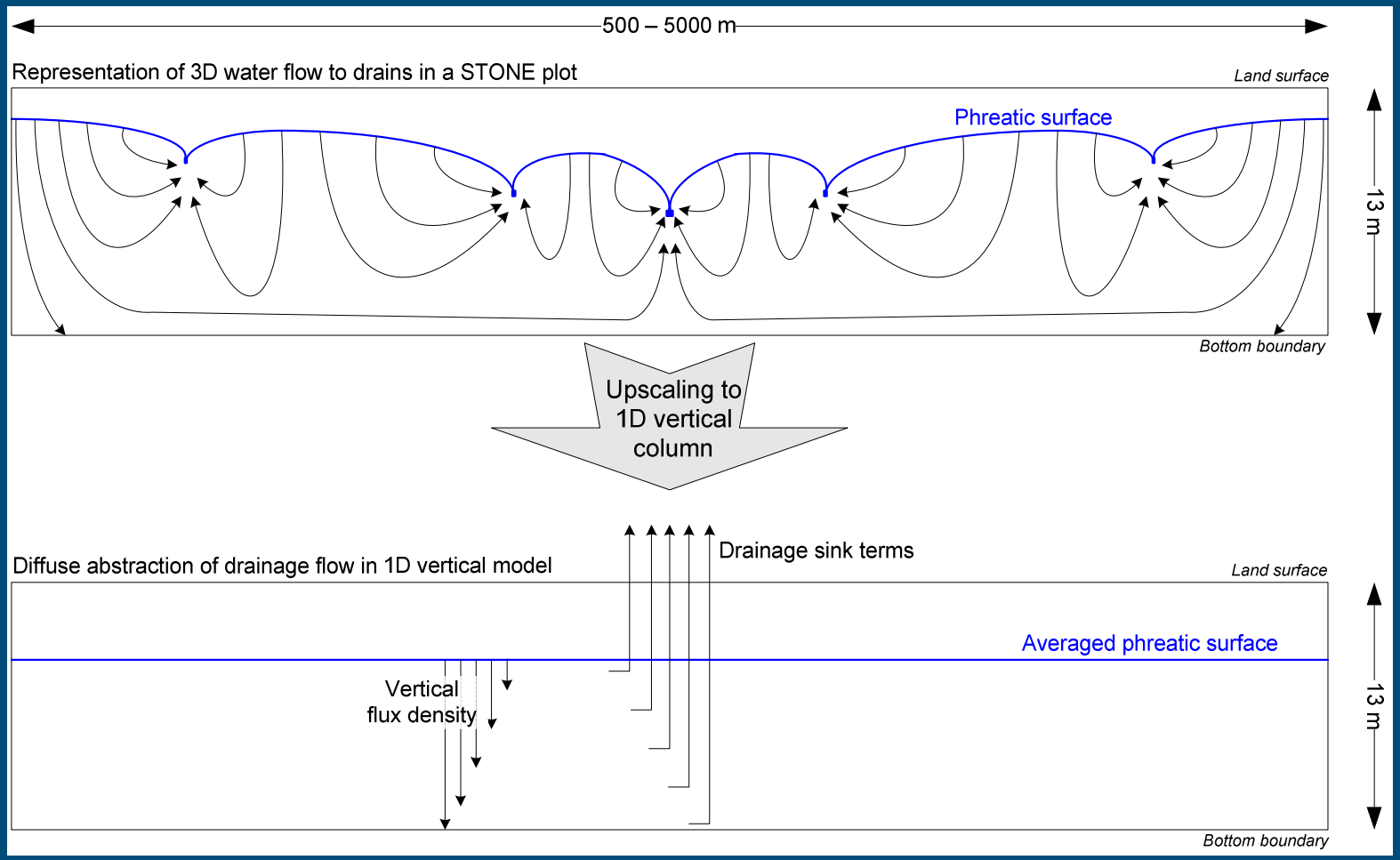
Calculation units: plots, HRU, Proxels, etc: combinations of:

- soil
- hydrology
- crops
- historical P-accumulation
- management
- fertilization
- relation with deep groundwater



ALTERRA WAGENINGEN UR

# Upscaling of field phenomena in a catchment model




ALTERRA
WAGENINGEN UR

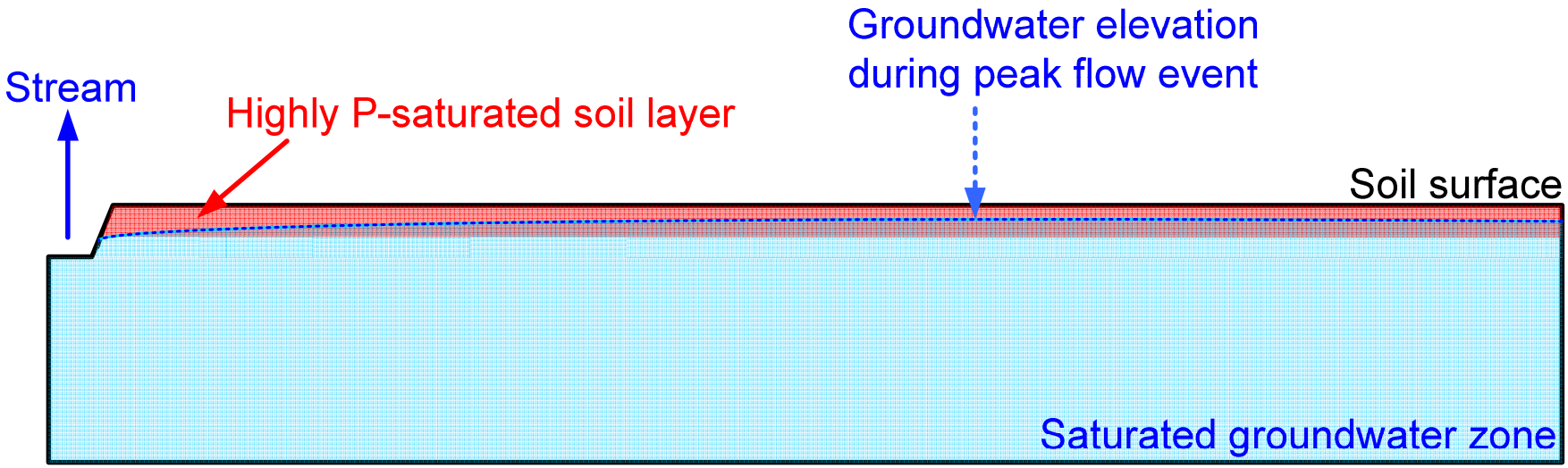
# Need for conceptual relations

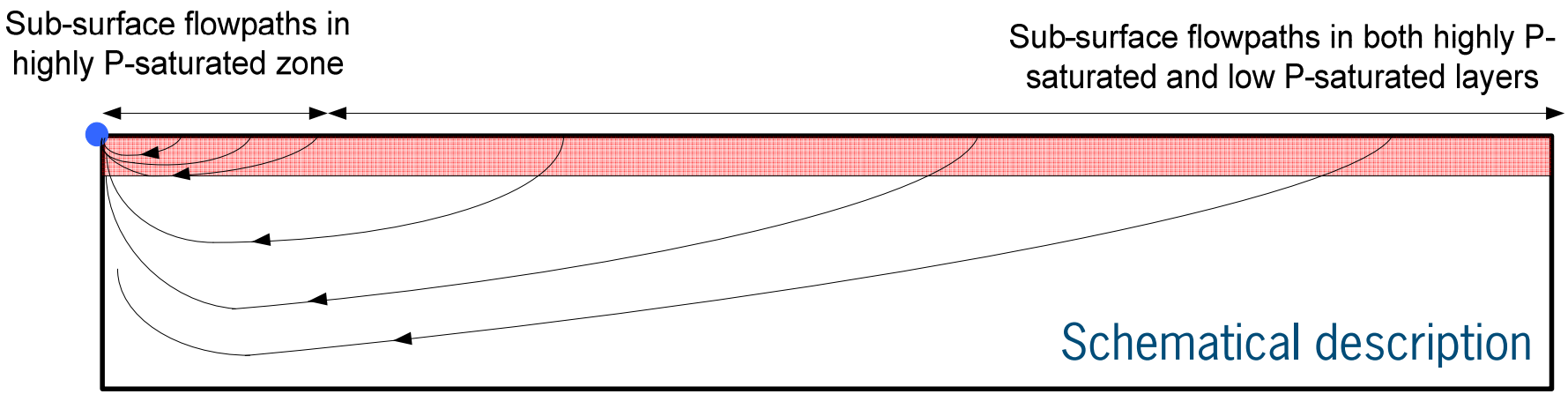
- Gaining insight in the key factors that control the processes or the effectiveness
- Quick scan (limited data availability) source areas
- Extrapolation of field specific processes to larger areas
- Bridging between scales (field <-> catchment)
- Spatial units in a catchment model larger than field size

# Examples

- Source area for sub-surface phosphate transport
- Effectiveness of unfertilized field edges
- Vegetative filter strips (White & Arnold, 2009)

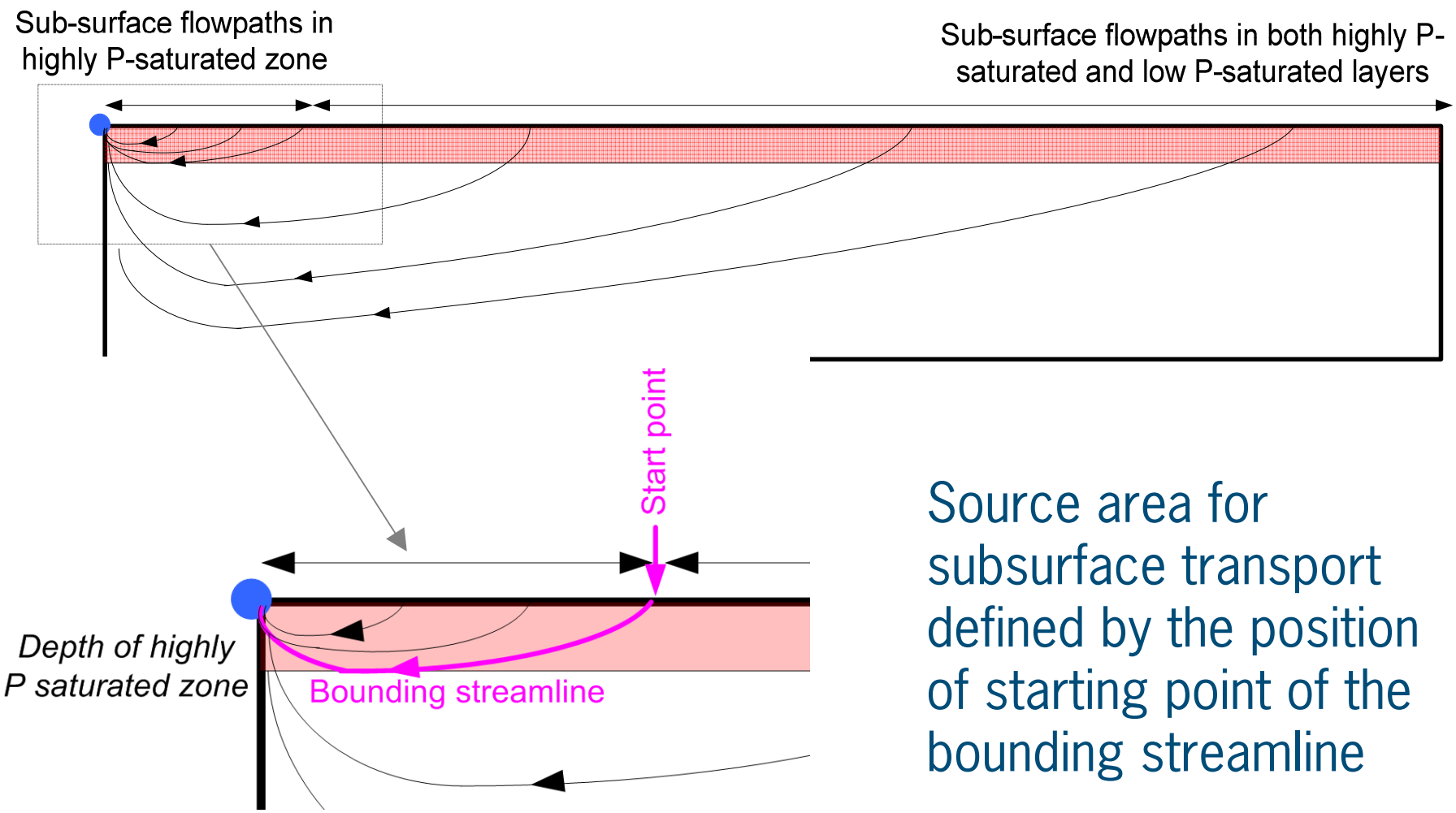
# Source area for sub-surface phosphate transport




ALTERRA
WAGENINGEN UR

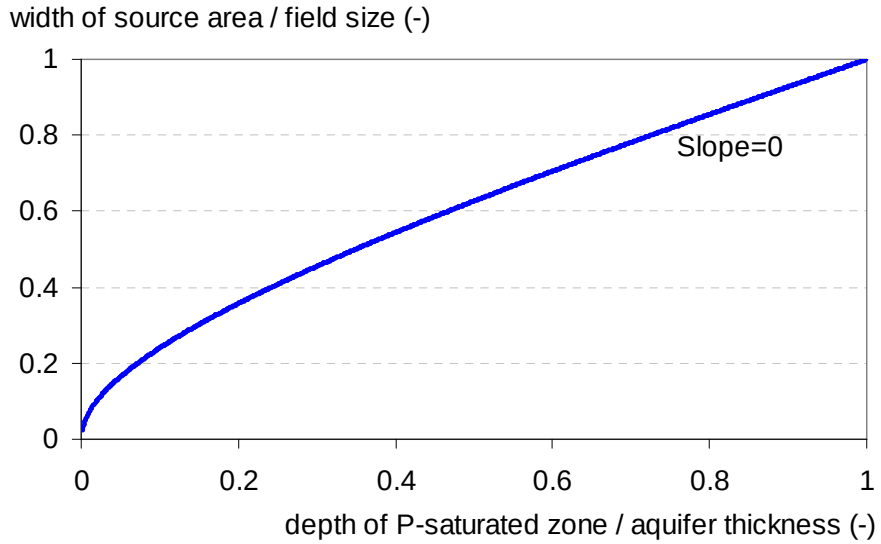
# Source area for sub-surface phosphate transport

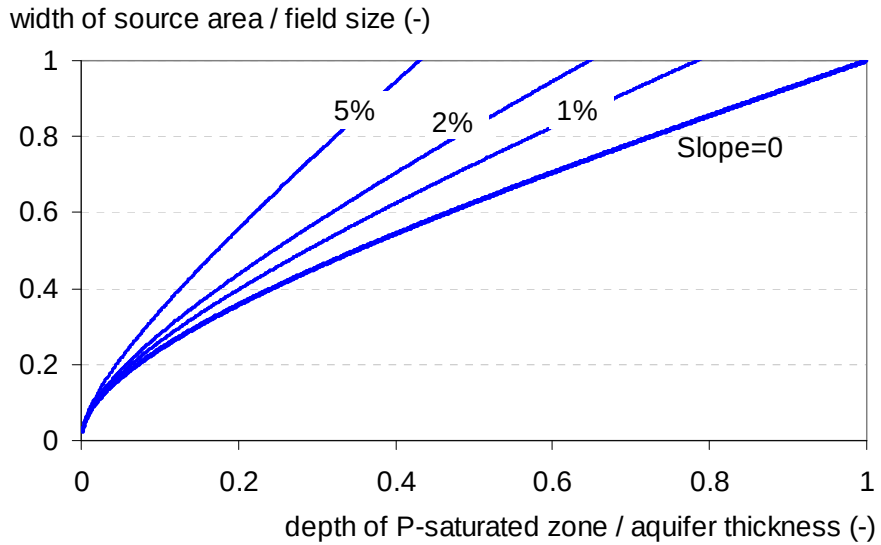



Source area for subsurface transport defined by the position of starting point of the bounding streamline

# Analytical expression can be derived for the width of a source area as function of:

- Field size
- Field slope
- Depth of P-saturated zone
- Depth of groundwater at critical discharge event
- Thickness of aquifer
- Soil hydraulic conductivity




**Many assumptions !!!**

ALTERRA
WAGENINGEN UR

# Effectiveness of unfertilized field edges on nitrate loads

- Dry buffer strips: unfertilised buffer strips along ditches

$$BSE = \frac{L_0 - L_{BS}}{L_0} 100\%$$

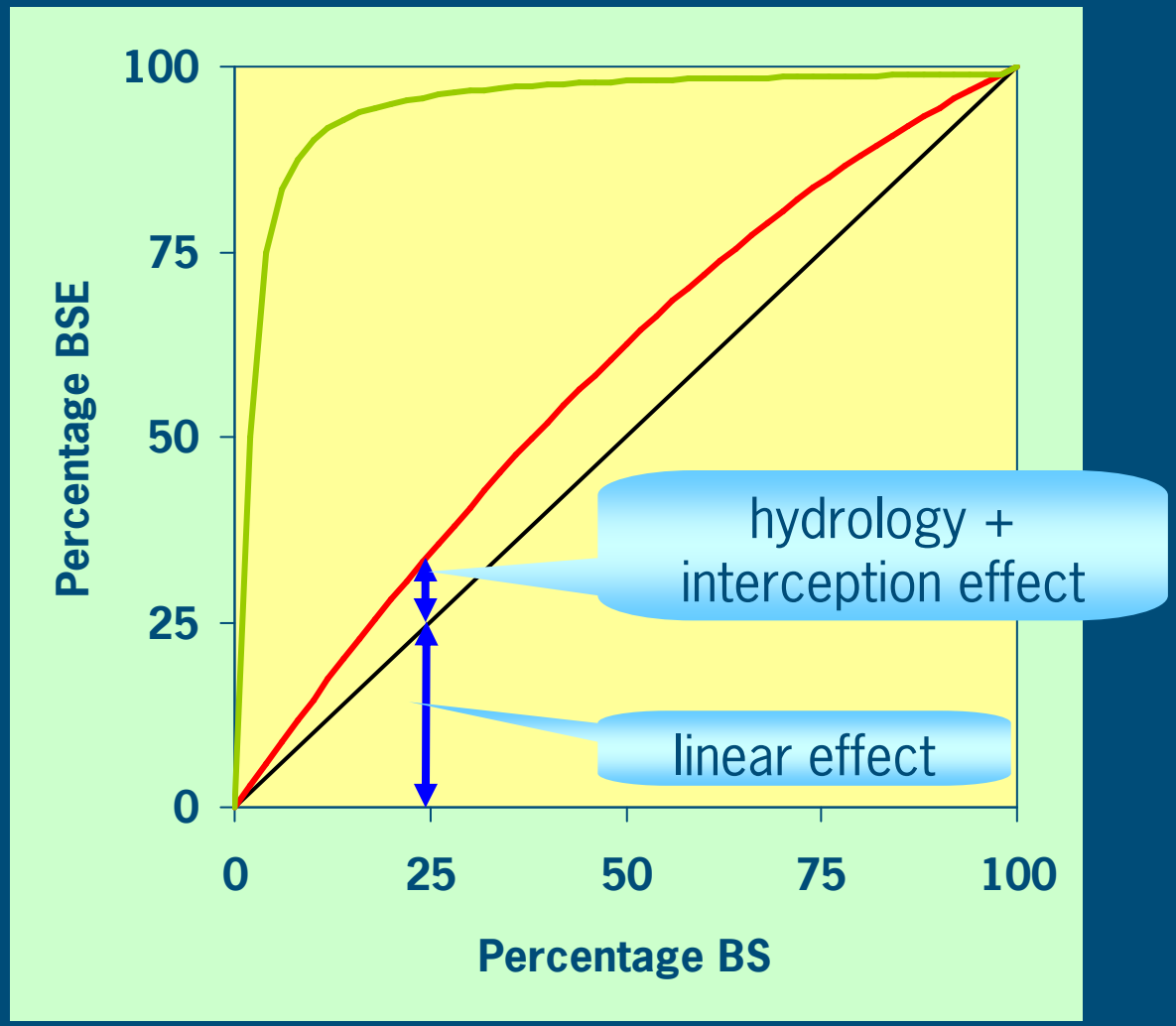
| | | |
|---|---|---|
| *BSE* | **B**uffer **S**trip **E**ffectiveness | % |
| $L_0$ | Load in reference situation (without BS) | kg ha$^{-1}$ |
| $L_{BS}$ | Load in situation with BS | kg ha$^{-1}$ |

ALTERRA WAGENINGEN UR

# Hypothesis

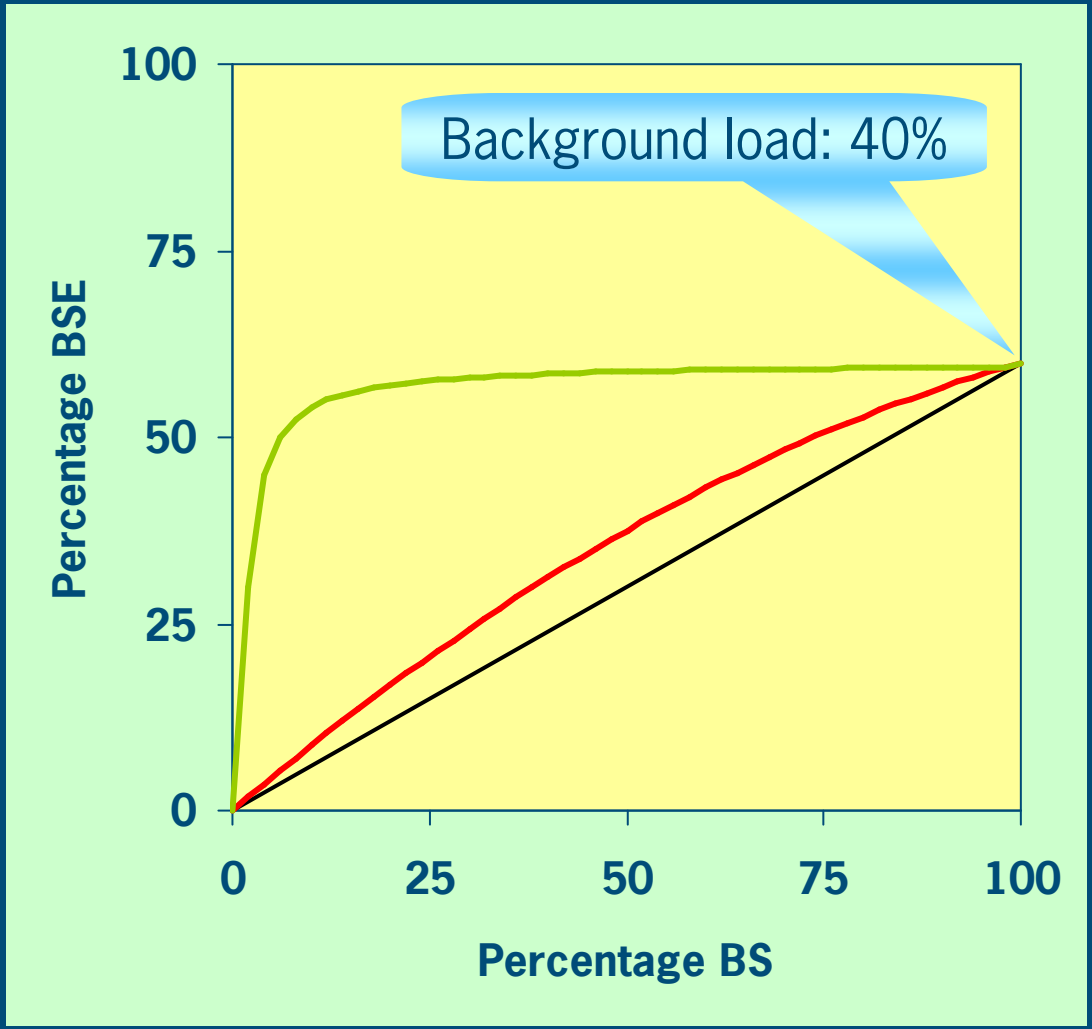
- Reduced fertilizer application: linear effect
  - y % not fertilized → y % less load towards ditch
- Hydrology effect
  - streamlines within BS have shorter residence times: no N and P → less load towards ditch
- Interception effect
  - streamlines starting outside BS may pass BS and N and P can be removed → less load towards ditch

# Hypothesis

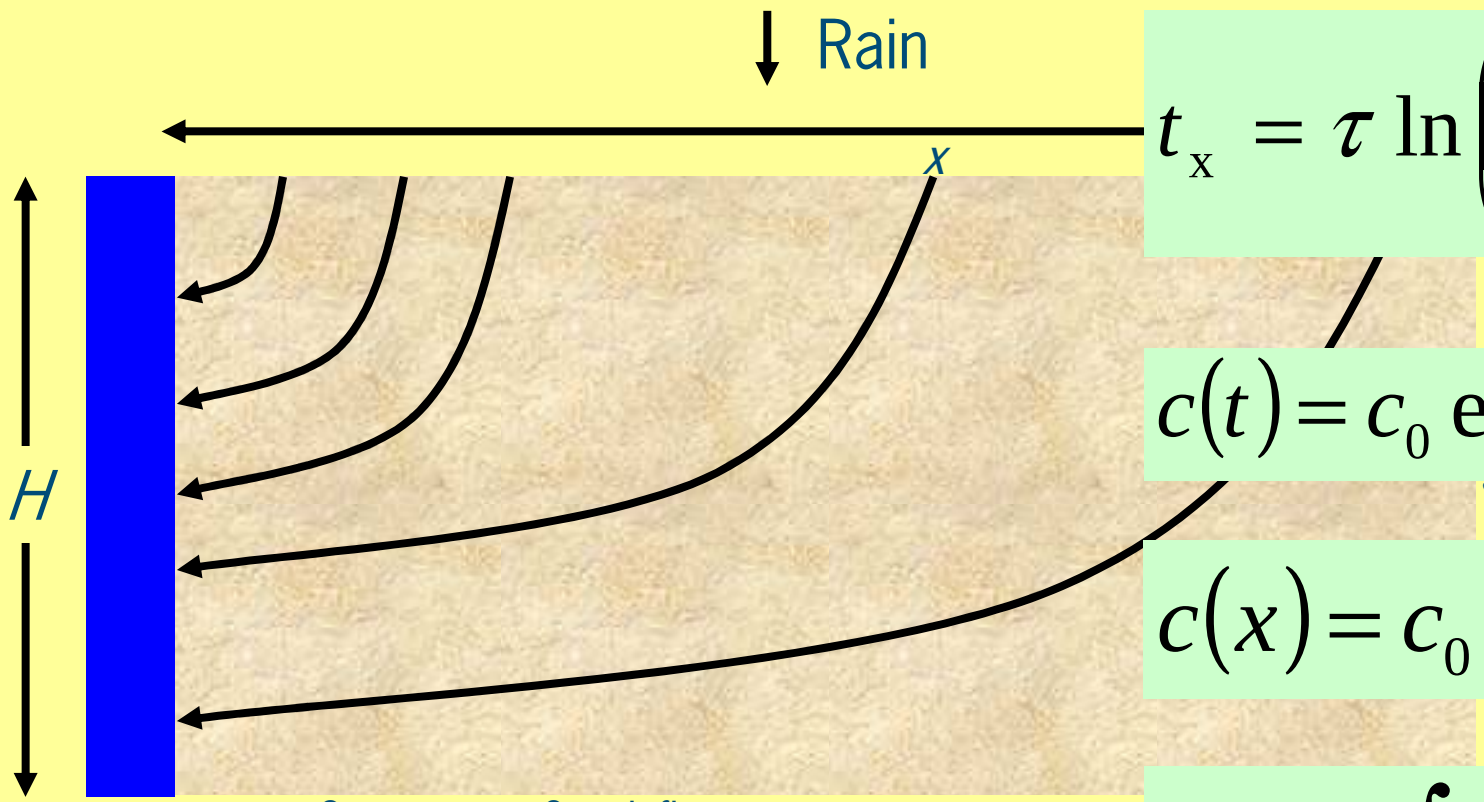



ALTERRA
WAGENINGEN UR

# Hypothesis: with background load



# Steady-state analysis: perfect drain, $L/H > 4$




$$t_x = \tau \ln\left(\frac{1}{1-x}\right)$$

$$c(t) = c_0 \exp(-kt)$$

$$c(x) = c_0 (1-x)^{k\tau}$$

$$L = R \int c(x)\,\mathrm{d}x$$

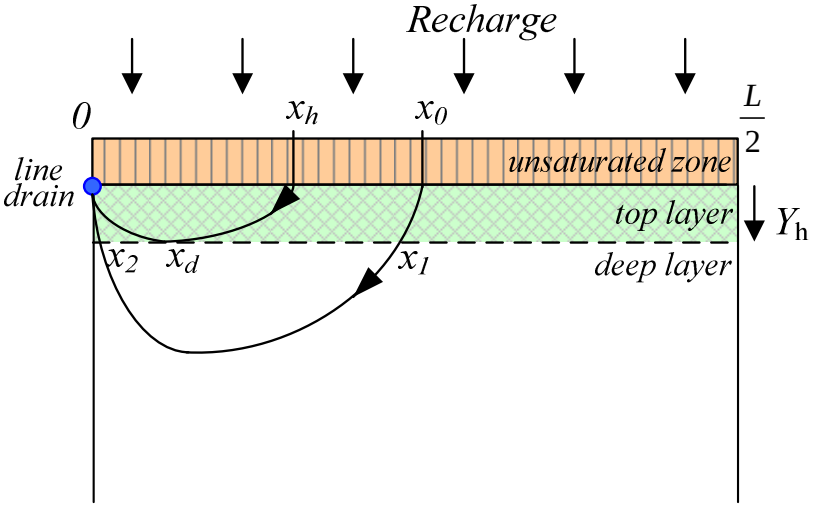
Seepage: > 0: inflow

**= 0: no flow**

< 0: outflow

# Other conditions:

## Deep aquifer




$$t_1 = \tau_L \, x_0 \tan(\tfrac{1}{2}\pi x_0)$$

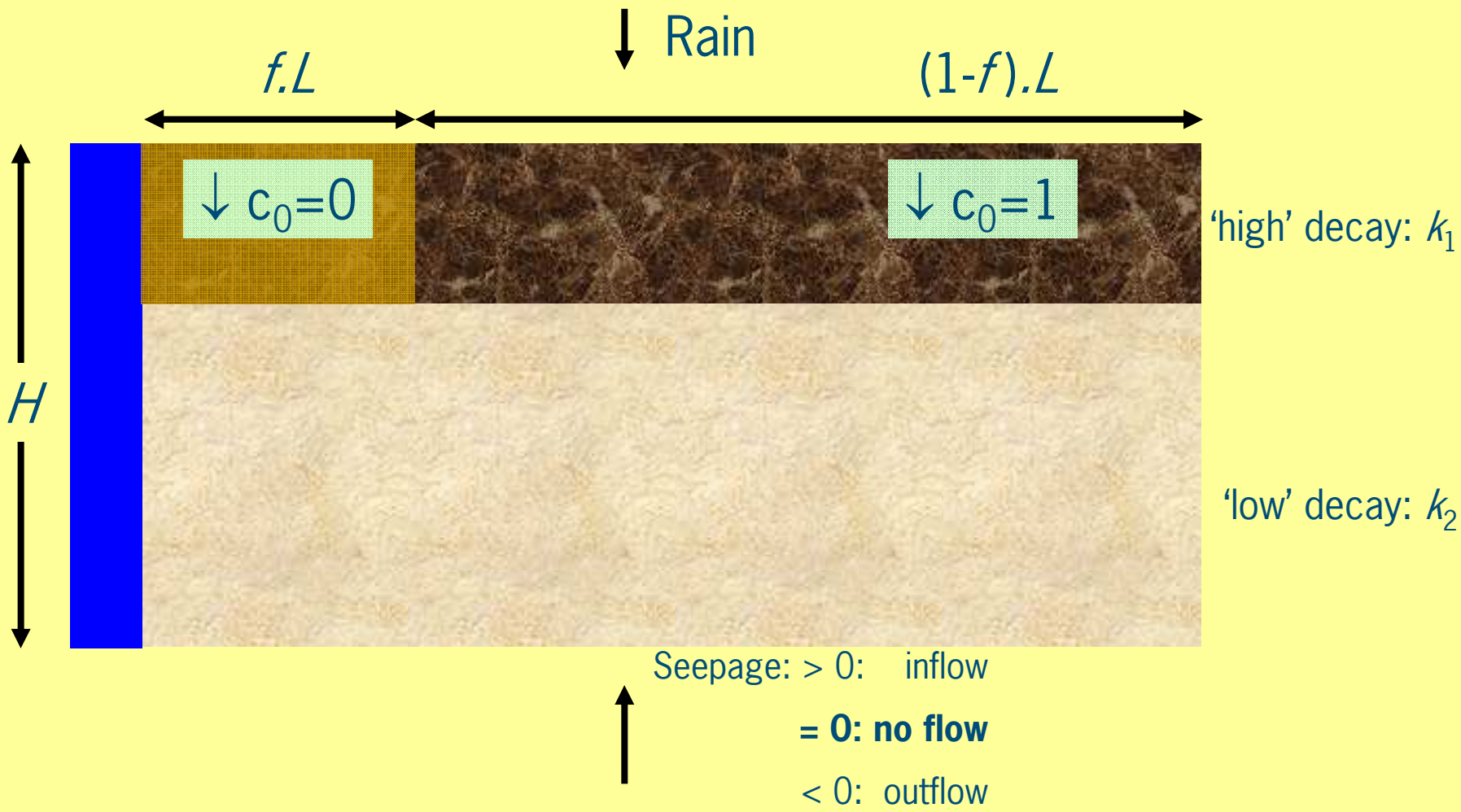
$$\tau_L = \frac{\varepsilon L}{4R}$$

## Monod

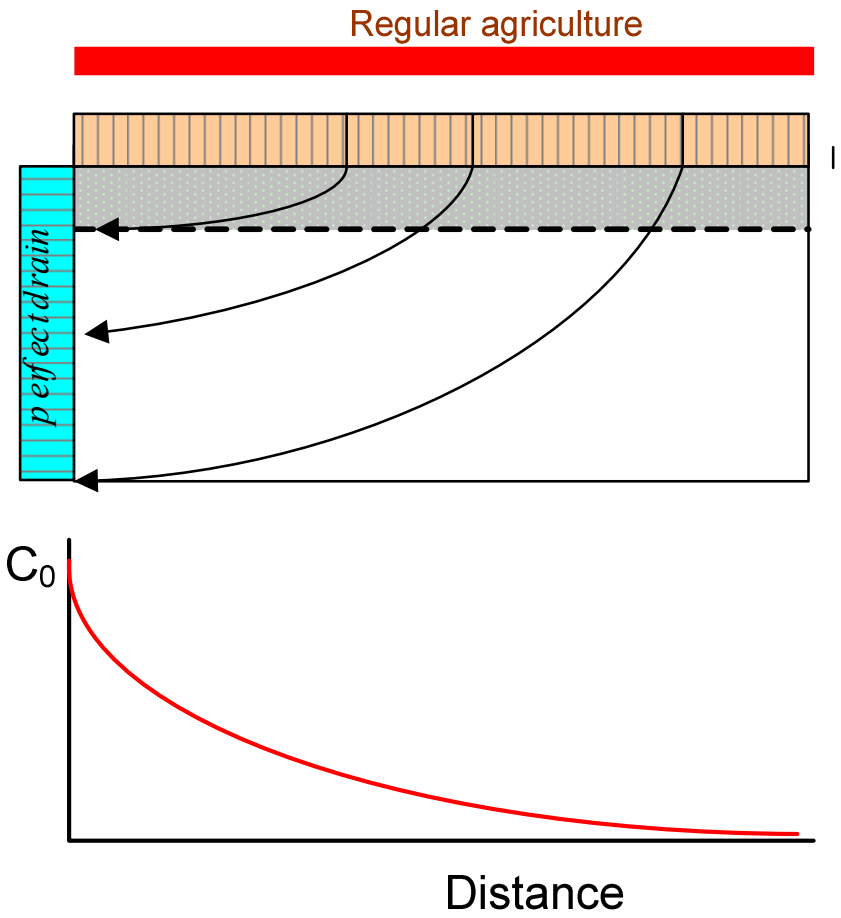
$$\frac{dc}{dt} = -k_0 \frac{c}{c_{1/2} + c}$$

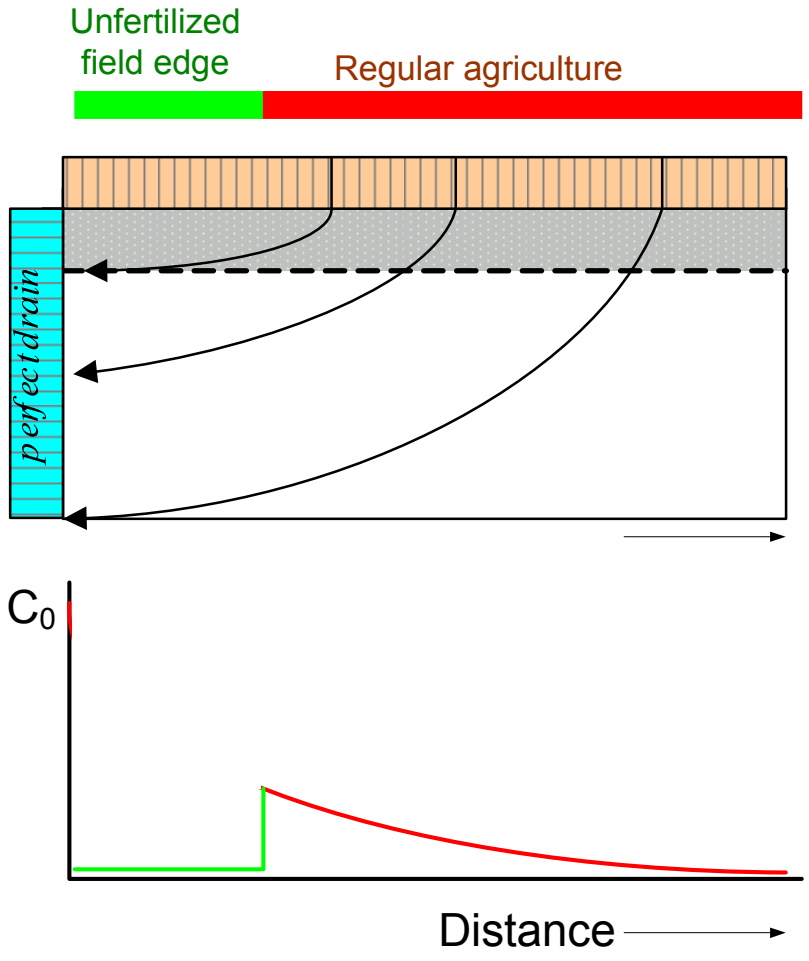
$$c = c_{1/2} W\left( \frac{c_0}{c_{1/2}} \exp\left(\frac{c_0}{c_{1/2}}\right) \exp\left(-\frac{k_0}{c_{1/2}} t\right) \right)$$

# Steady-state analysis: perfect drain, $L/H > 4$

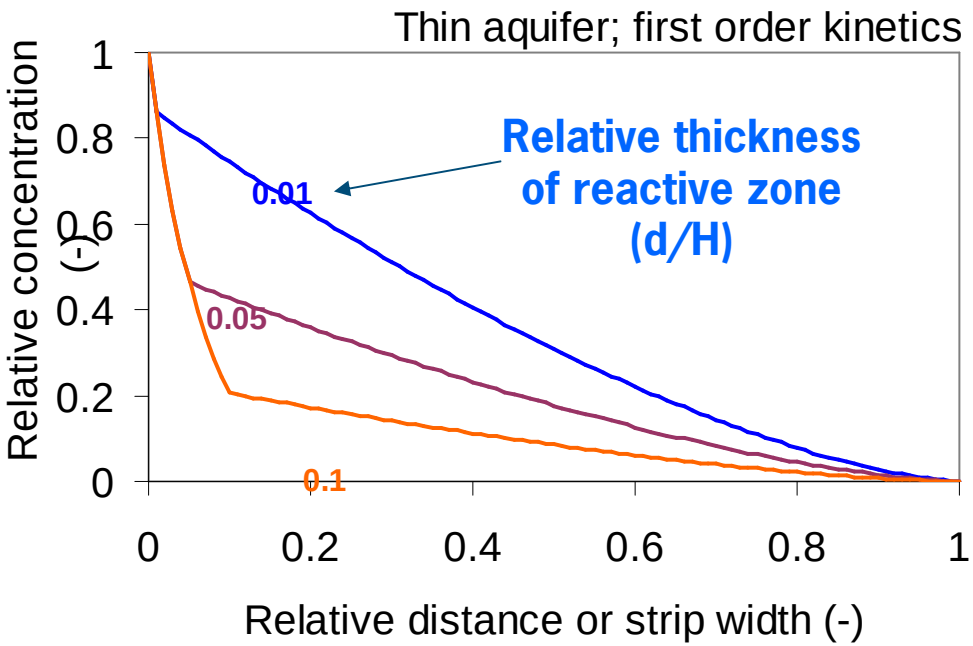


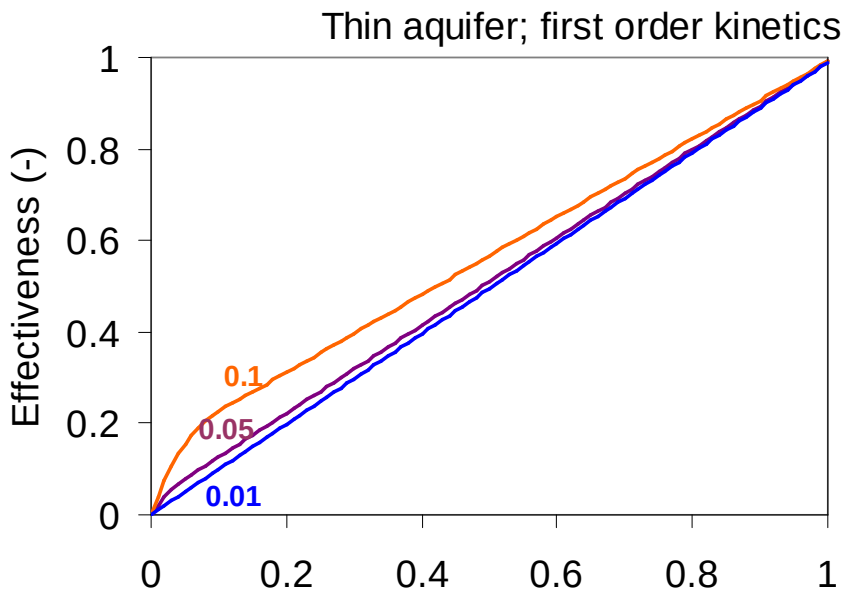
# Effectiveness



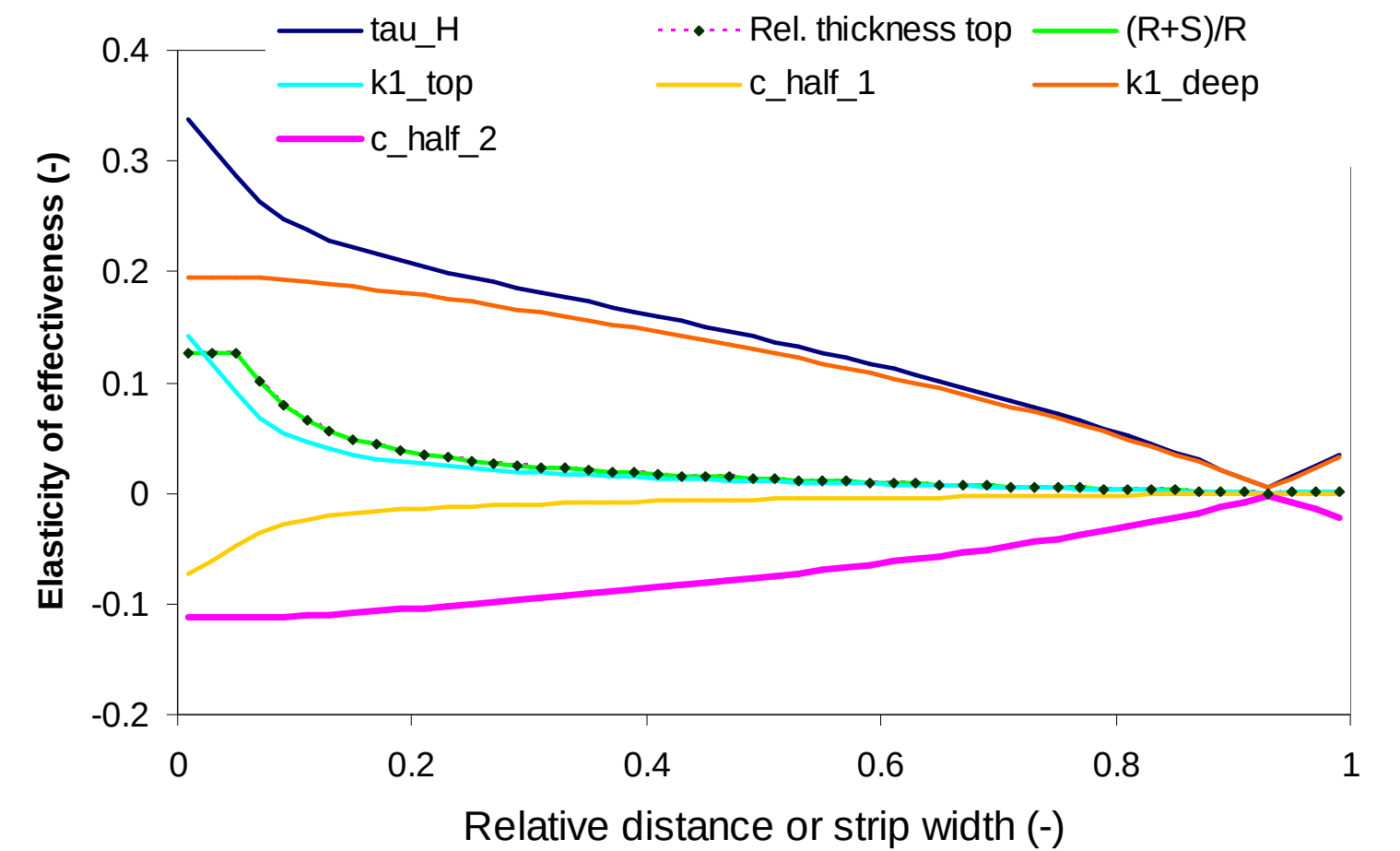
# Example: thin aquifer



# Elasticity: which parameters are most sensitive?

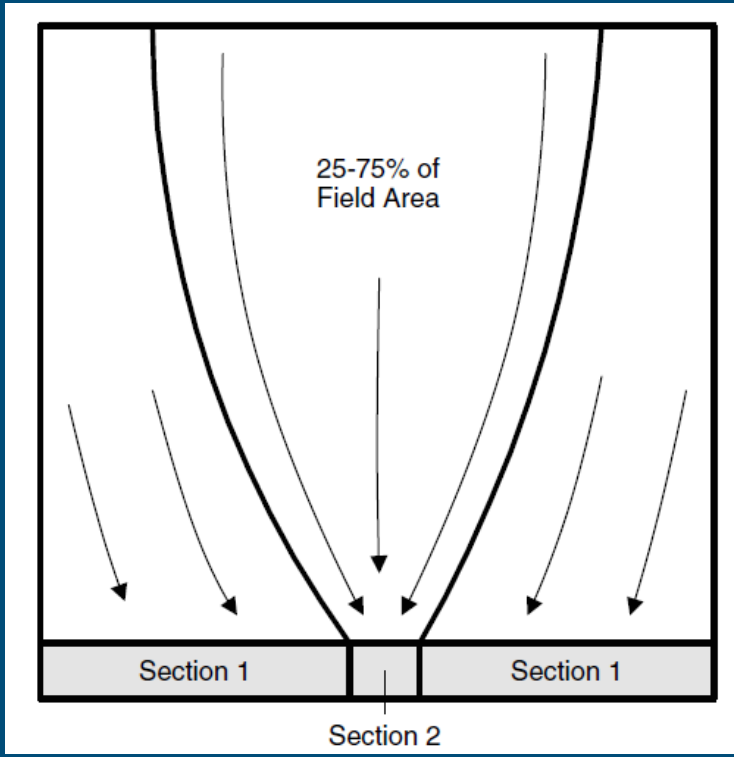
## Thin aquifer, Monod kinetics




ALTERRA
WAGENINGEN UR

# Example from literature

- Study by White & Arnold (2009)
- Vegetative filter strips (VFS)
- SWAT model (catchment scale)
- VFSs implemented at HRU level
- Two segment VFS is used
  - Section 1: filtered
  - Section 2: not filtered




*Tributary channel*

# Field phenomena in a catchment model (example 1)

- Three parameter submodel in SWAT to account for VFS

HYDROLOGICAL PROCESSES
*Hydrol. Process.* **23**, 1602–1616 (2009)
Published online 1 April 2009 in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/hyp.7291

**Development of a simplistic vegetative filter strip model for sediment and nutrient retention at the field scale†**

Michael J. White* and Jeff G. Arnold
*USDA-ARS Grassland, Soil, and Water Research Laboratory, Temple, Texas, USA*

# Discussion

- Extrapolation of field results: meta-modelling
  - Run the detailed process model for many combinations of inputs
  - Analyse the output
  - Find statistical relations between input and output

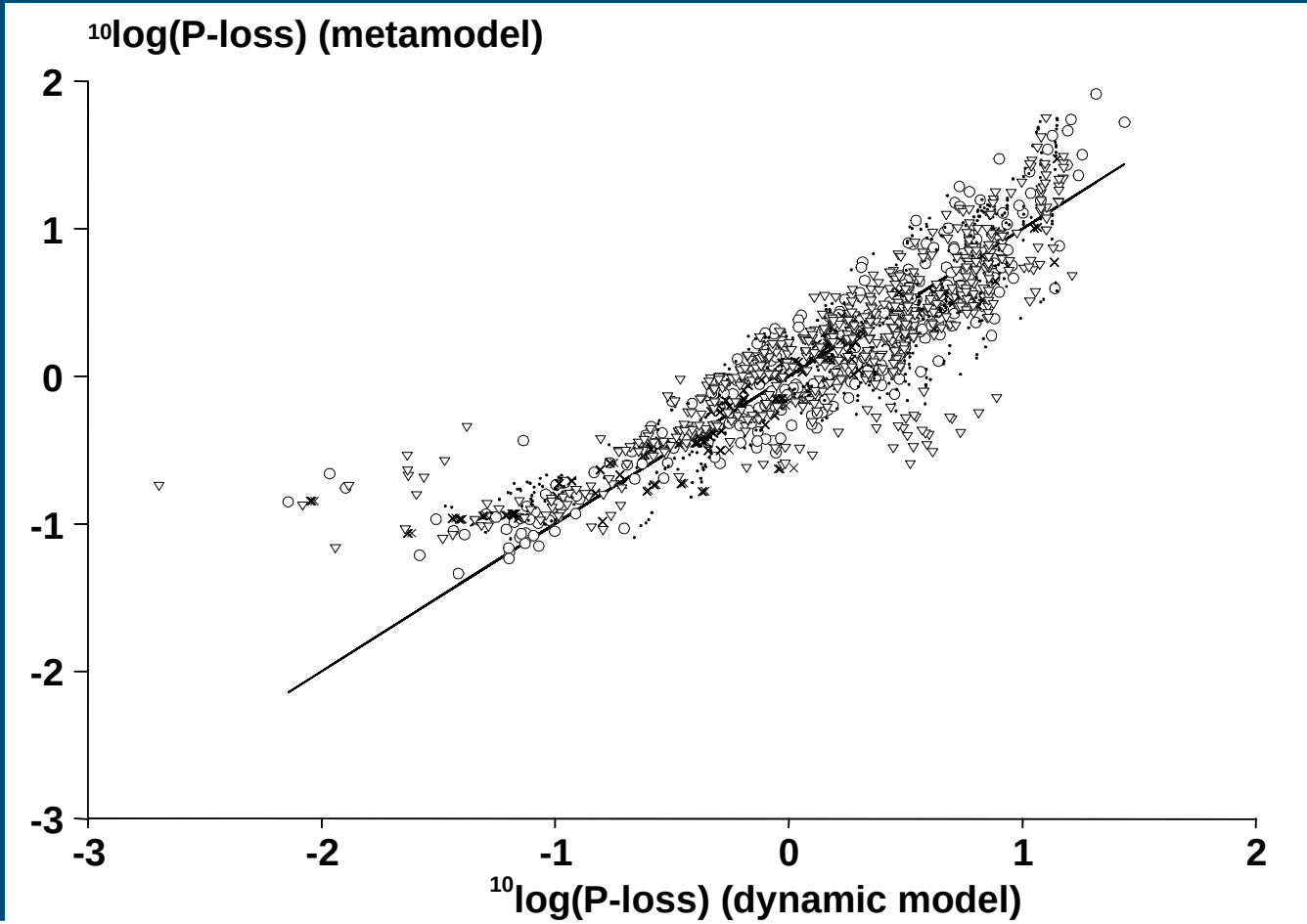
# Approximation by statistical relations

$$P - load\ on\ surfacewater =$$
$$c_0 + c_1 \exp\{\lambda\ MHW\} + c_2\ P_{accumulated} + c_3\ P_{surplus} +$$
$$c_4\ [P]^{\mu}_{background\ \ deep\ gr.w.} + c_5\ q_{groundwater\ rech.}$$

| Parameter | |
|---|---|
| *MHW* | Mean highest groundwater level |
| $\lambda$, $\mu$ | Exponental constants |
| $c_0$, $c_1$ | Constants dependent on soiltype and crop |
| $c_2$ | Constant dependent on soiltype |
| $c_3$,$c_4$,$c_5$ | Constants |

ALTERRA WAGENINGEN UR

# Meta-model: Approximation by statistical relations




ALTERRA
WAGENINGEN UR

# Discussion

but for field specific phenomena:

- Source areas
- Effectiveness of buffer strips

Template for the expressions of the meta-model would be very helpful

# Conclusions

There is a need for conceptual relations to account for field phenomena (effectiveness of buffer) in large scale models

Some relations have been derived for sub-surface transport, making use of groundwater flow theory

Can be extended to more complex situations

# Conclusions

Relations have a limited applicability, due to all the assumptions made

But:

Give insight in the governing processes and parameters

Can serve as a template for the statistical approximations of detailed models to be used for extrapolation

# Thank you