

# A new model to predict concentrations of pesticides in ditches and streams

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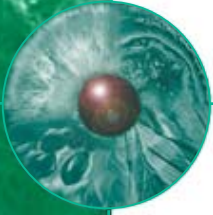
**DEFRA Project PL0549**

## Rationale

- If compound fails FOCUS steps 1-3, higher-tier risk assessment could be necessary
- Possible approach: detailed, site-specific landscape level exposure estimations
- Current modelling tools used in FOCUS:
  - are designed and applied at field scale or small ditch segment
  - can be difficult to parameterise at their specific scale of application
  - difficulties in linking models in a landscape setting

## Rationale (cont'd)

- Use large scale hydrological models (10s - 100s km<sup>2</sup>) but these have limitations to:
  - require digitised information and use of GIS
  - require large amount of data
  - often complicated to parameterise
  - may only consider one relatively large water body and ignore smaller ones like ditches
- Alternative: use a model for small catchments that provides detailed descriptions of hydrology and pesticide fate in soil and surface water bodies



## Objective

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Develop a new model to simulate pesticide exposure within local surface water bodies in support of higher tier environmental risk assessment

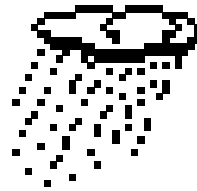
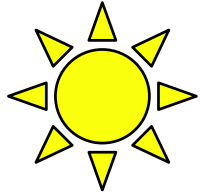
## Model specifications

- Spatially distributed
  - discretise landscape in fields and water bodies
- Optimised data requirement (parameterisation vs accuracy)
- Account for pesticide entry via:
  - spray drift
  - surface runoff
  - interlayer flow
  - drainflow
  - (groundwater recharge)

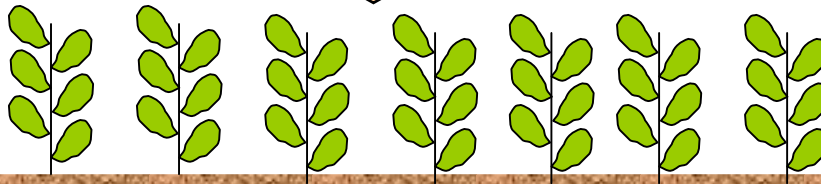
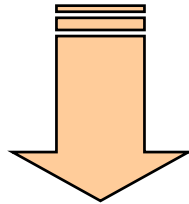
## Model specifications (cont'd)

- Applicable to catchments of a few km<sup>2</sup>
- Designed for
  - temperate climate with relatively wet winters
  - predominantly drained fields
- Landscape with high density of ditches
- Hourly time step to increase temporal estimates of pesticide concentrations in surface water bodies

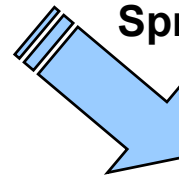
# Surface water exposure to pesticides



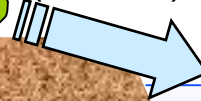
Pesticide application



Spray drift



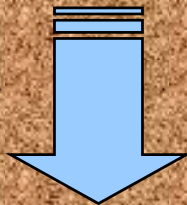
(Runoff)



Edge of field

Soil

Leaching



Lateral flow



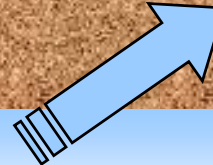
Drain discharge

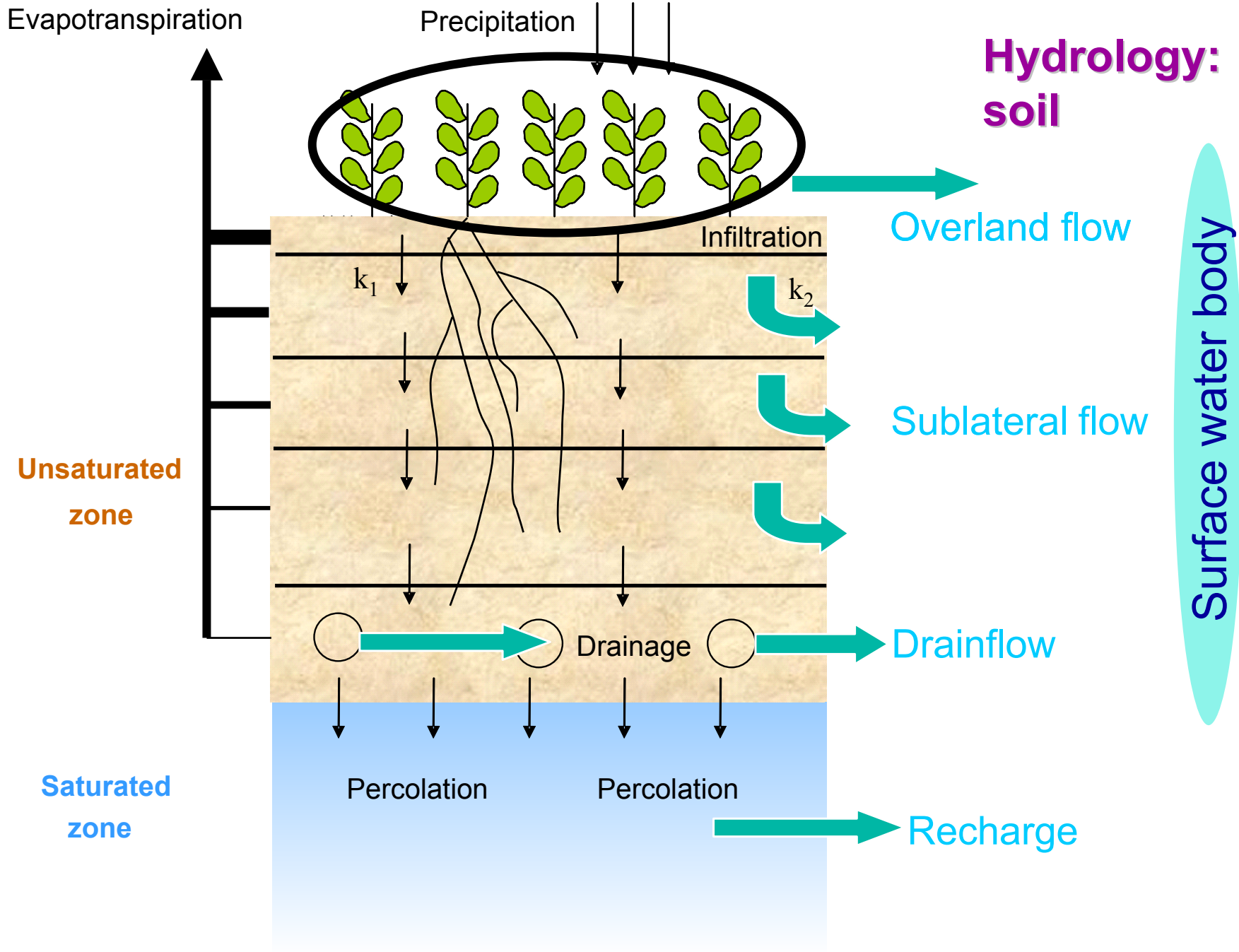


Surface water

Groundwater

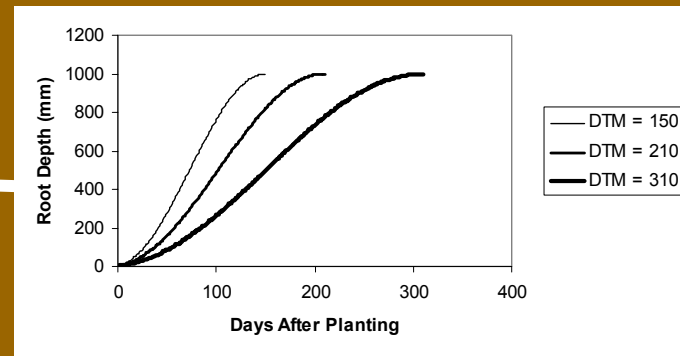
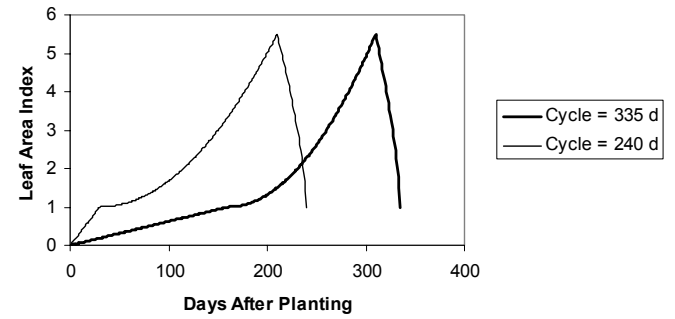
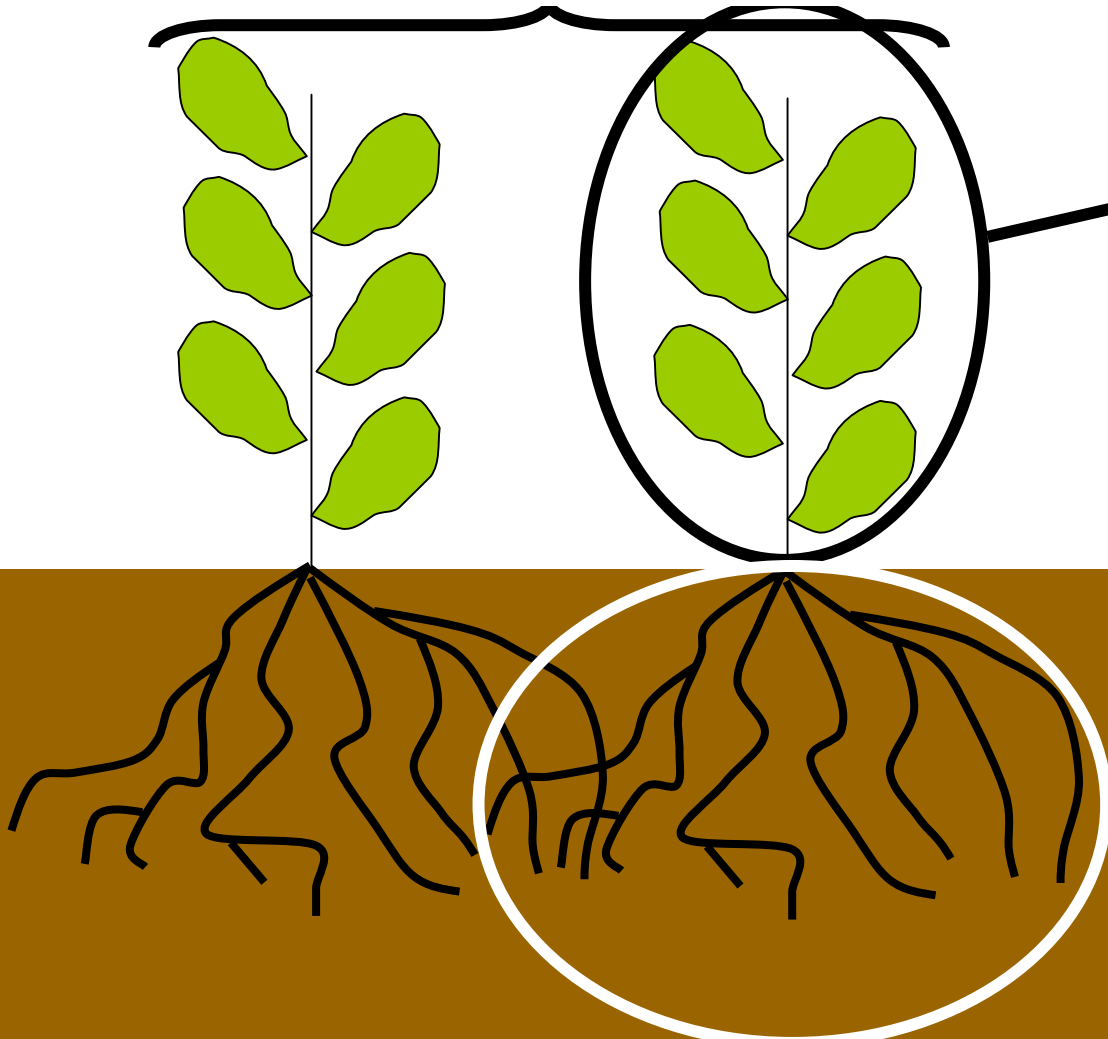
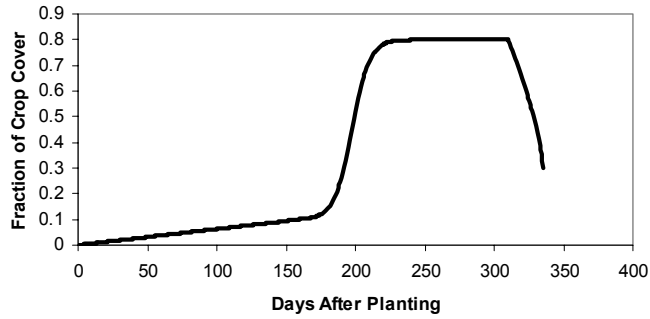
Baseflow







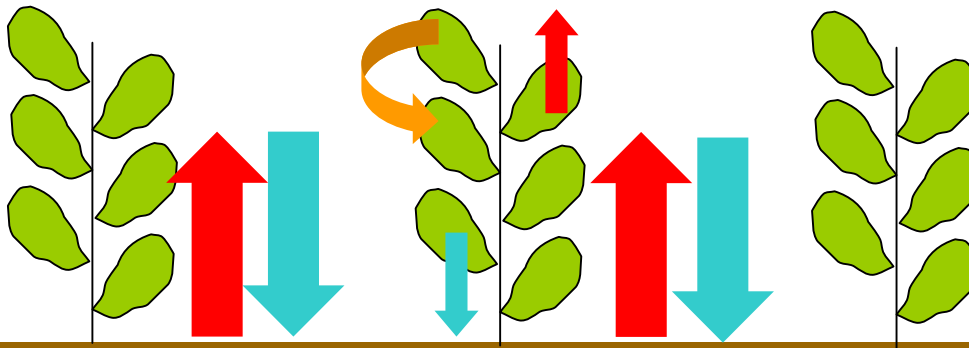
# Crop physiology





## Hydrology: canopy processes

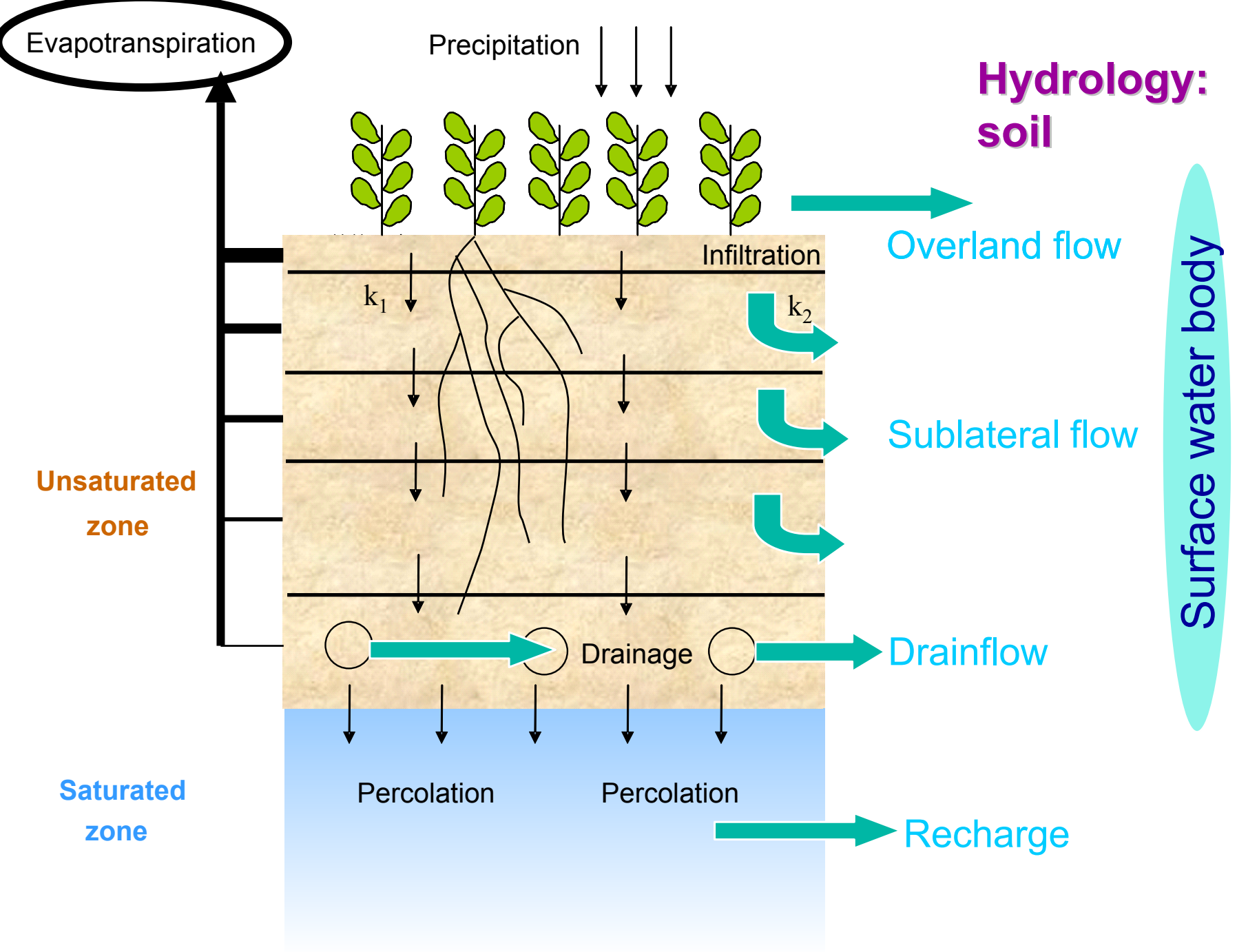
- Storage
- Evaporation
- Net rain to soil



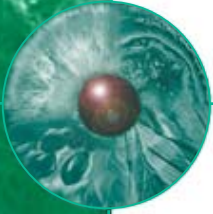
Storage =  $f$ (leaf area index)

Net  $Et_r$  to soil =  $f$ (Rain, Storage, % Cover,  $ET_r$ )

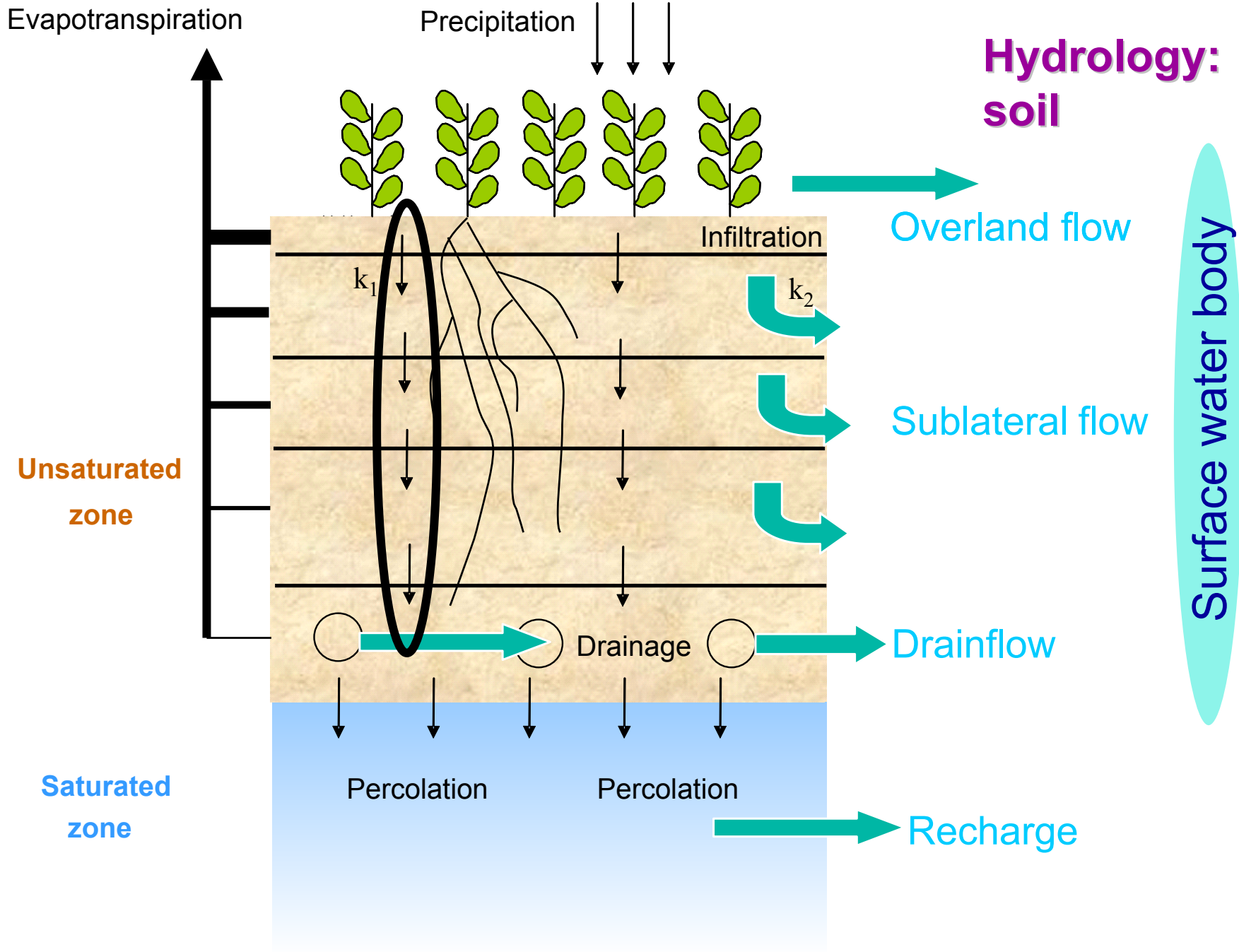
Net rain to soil =  $f$ (Rain, Storage, % Cover,  $ET_r$ )



# Evapotranspiration



- Penman-Monteith equation as applied in FAO 56 (Allen *et al.*, 1998)
- Water removed from:
  - A-horizon if crop root length < A-horizon boundary
  - Soil profile depending on crop root length
- Actual ET accounts for:
  - crop growth stage
  - water stress



## Vertical water movement

- Capacitance model (tipping bucket):
  - Water in excess of field capacity moved to next layer
  - Transmission rate determined with hydraulic conductivity
- Hydraulic conductivity:
  - Van-Genuchten equation
  - Parameters are input from modeller or derived from pedotransfer functions using Cl, Si, Sa, OC, BD (John Hollis, NSRI and SWBCM model)

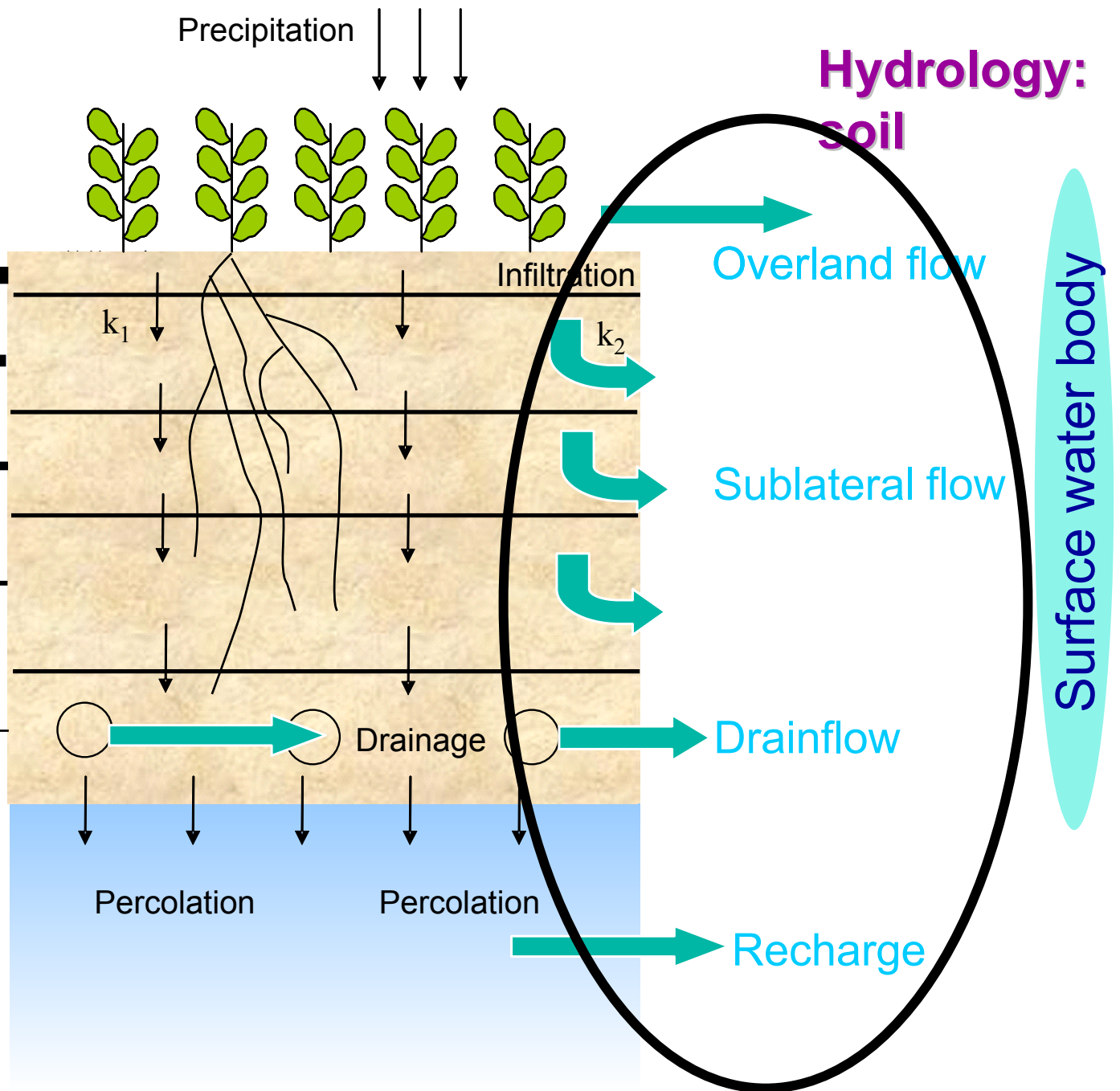
Evapotranspiration

Precipitation

Hydrology:  
soil

Unsaturated  
zone

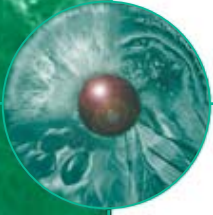
Saturated  
zone



## Water input to ditches/stream

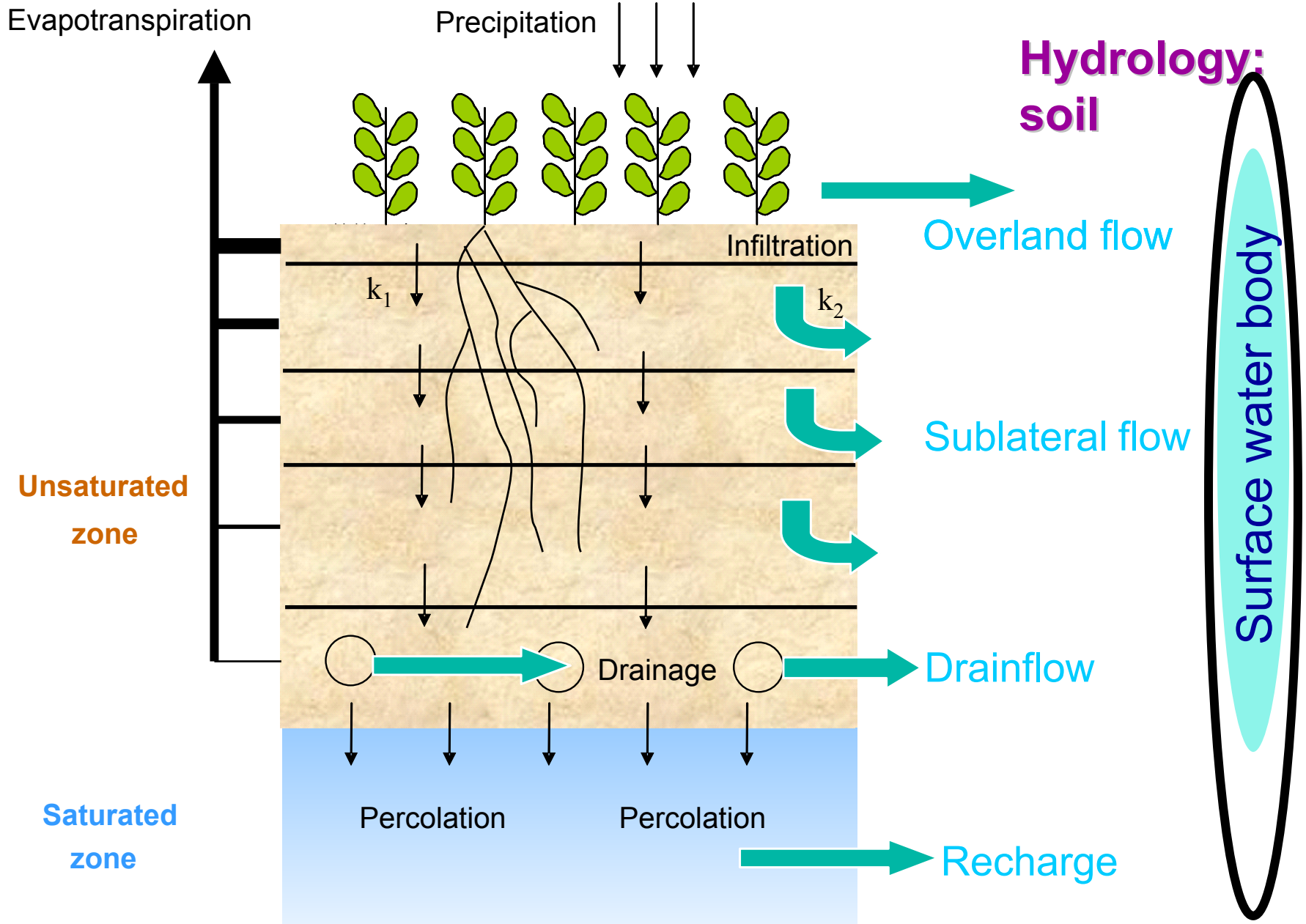
- Surface runoff:
  - if rain intensity  $>$   $K_{sat}$  of layer
  - if profile becomes saturated
- Interlayer flow:
  - removes water in excess of field capacity after percolation
  - kinematic wave approximation (Sloan and Moore, 1984)
  - Pedotransfer functions for lateral hydraulic conductivity





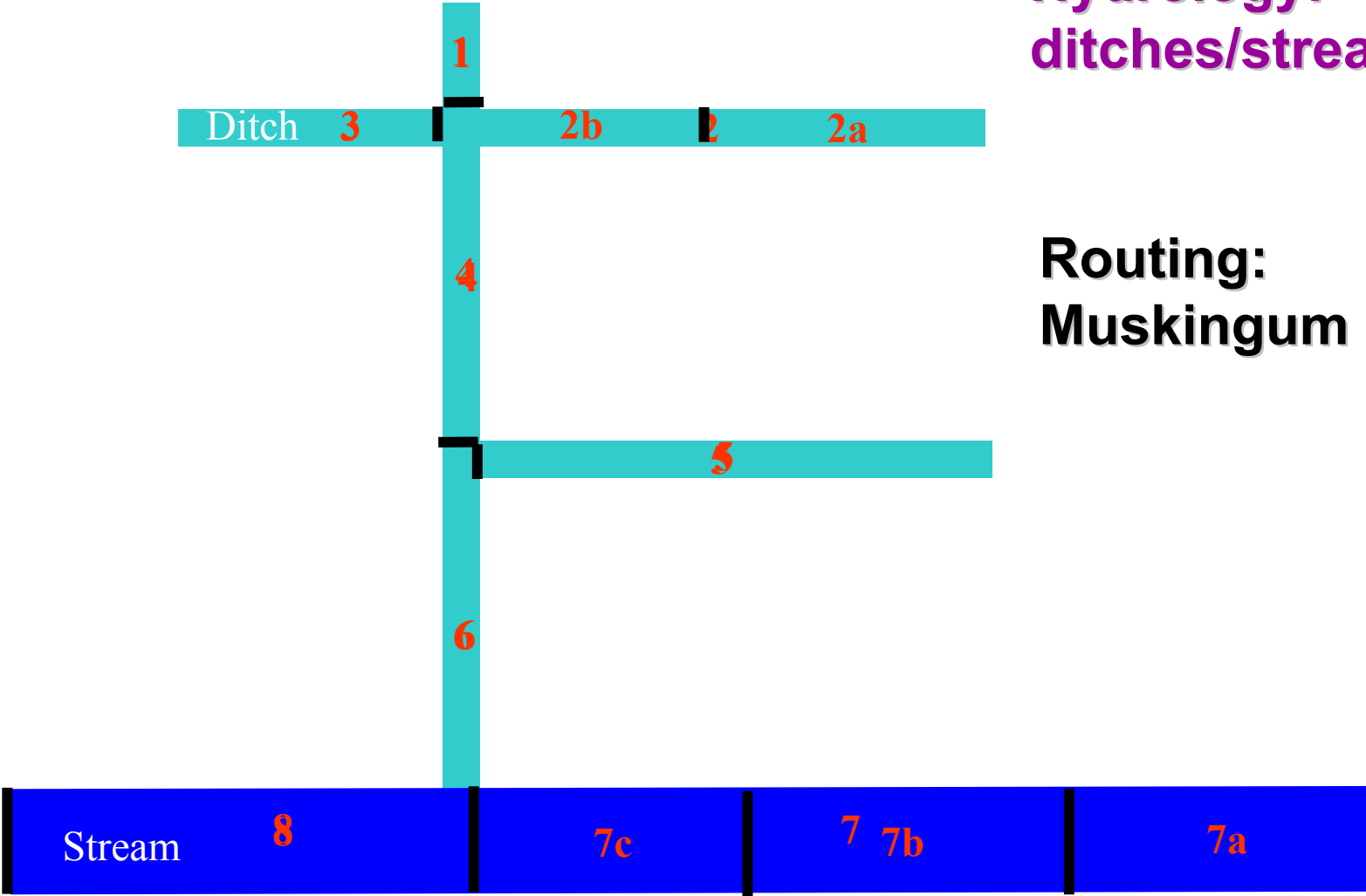
## Water input to ditches/stream (cont'd)

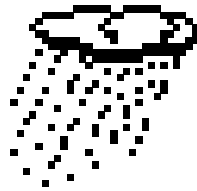
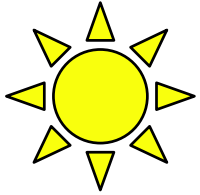
- Drainflow:
  - Water in excess of field capacity in thin (*ca* 10 cm) but adjustable layer removed within one hourly time step
- Groundwater recharge:
  - recharge from base of soil profile
  - initial water table height (BGS data)
  - storage coefficient (BGS data)



Hydrology:  
ditches/stream

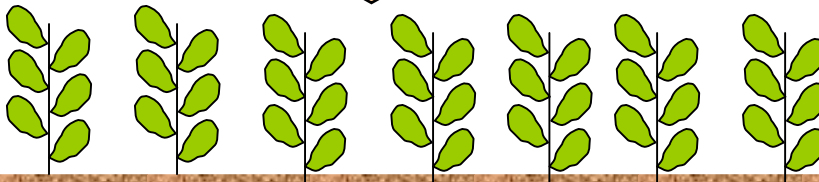
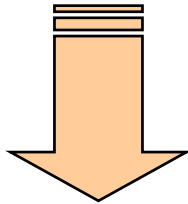
Routing:  
Muskingum



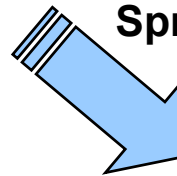


# Pesticide entry

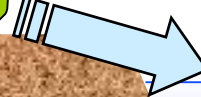
Pesticide application



Spray drift



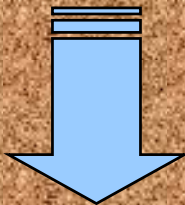
(Runoff)



Edge of field

Soil

Leaching



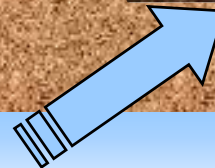
Lateral flow



Drain discharge



Surface water

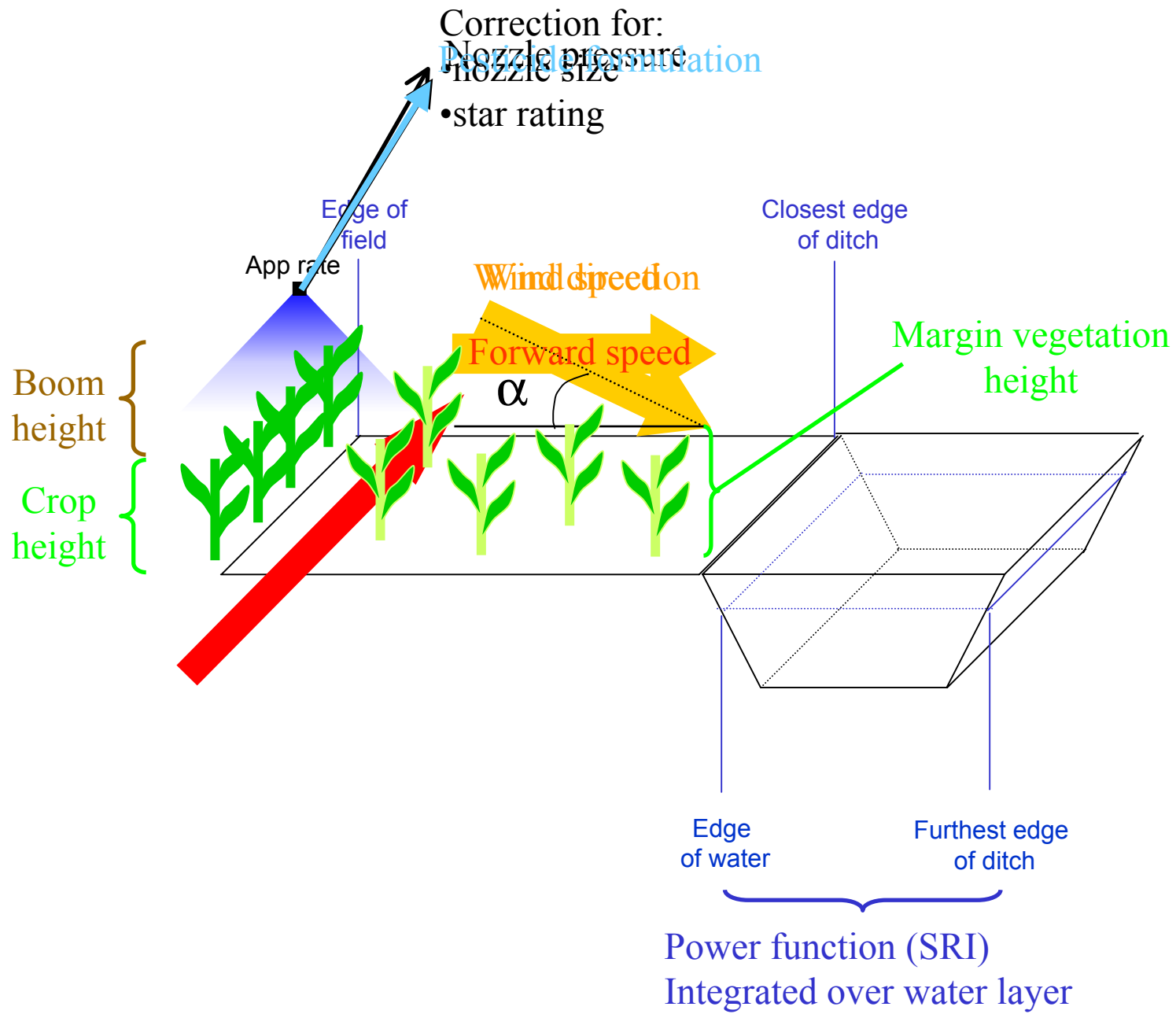


Baseflow

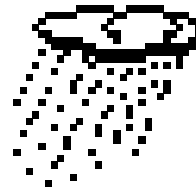
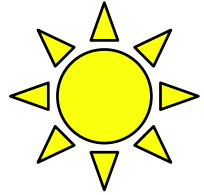
Groundwater

## Spray drift

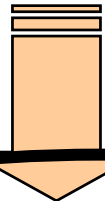
- For each application:
  - ID ditches associated with field
  - Compares angle of incidence of wind with ditches
  - Determines if ditch is up/down wind
- Spray drift calculated (equations provided by SRI):
  - Basic drift is power function of distance to nozzle
  - Additional factors taken into account



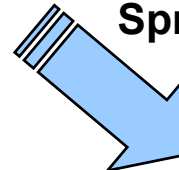
# Pesticide entry



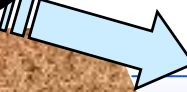
Pesticide application



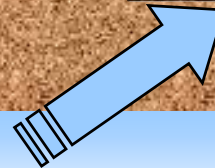
Spray drift



(Runoff)



Surface water



Baseflow

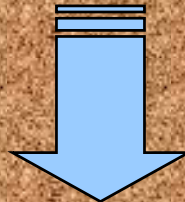
Lateral flow



Drain discharge



Leaching



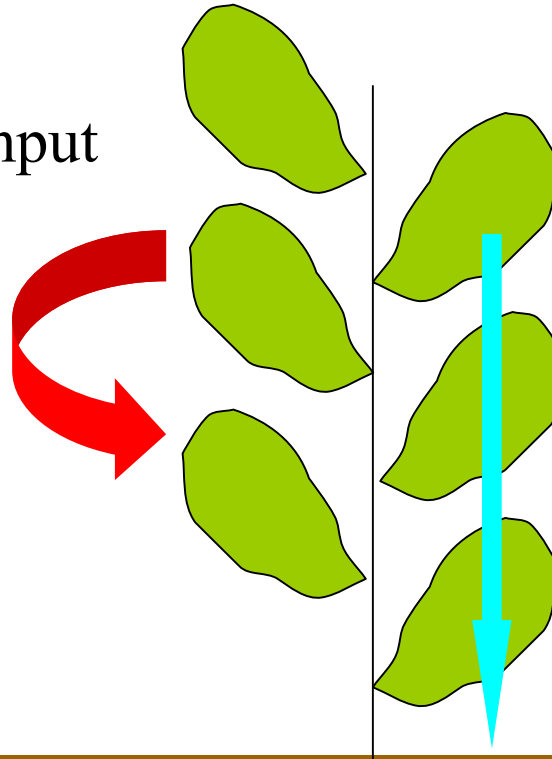
Edge of field

Soil

Groundwater

## Degradation

- First order decay
- $DT_{50} = 10$  d or user input

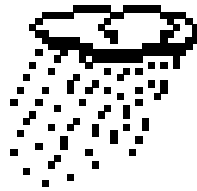
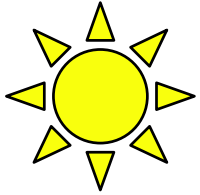


## Pesticide: canopy processes

### Wash-Off

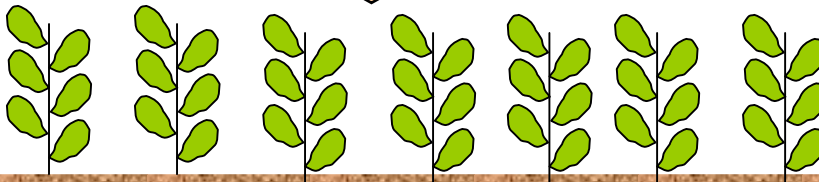
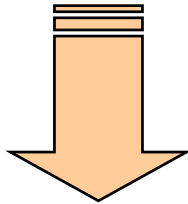
- FOCUS method
- Only if  $Rain > Storage$



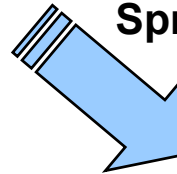


# Pesticide entry

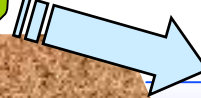
Pesticide application



Spray drift



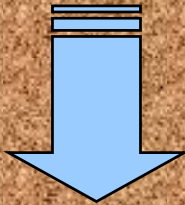
(Runoff)



Edge of field

Soil

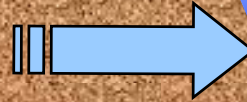
Leaching



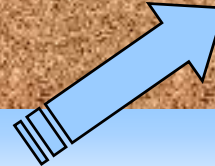
Lateral flow



Drain discharge



Surface water

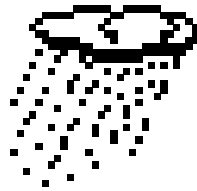
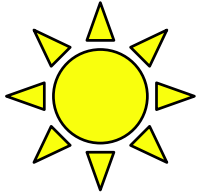


Baseflow

Groundwater

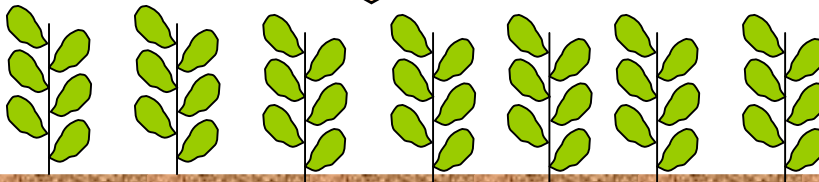
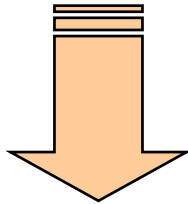
## Pesticide movement in soil

- Assumed to be completely mixed in the soil layer
- Moves with water
- Freundlich isotherm:
  - corrected for organic carbon
- First order kinetic degradation:
  - corrected for temperature
  - corrected for water content
- Soil temperature:
  - double sinusoidal function (daily & annual temp waves)
  - thermal properties vary with soil constituents
  - average calculated for each soil layers

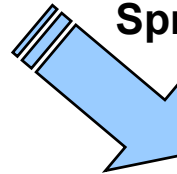


# Pesticide entry

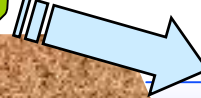
Pesticide application



Spray drift



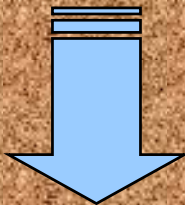
(Runoff)



Edge of field

Soil

Leaching



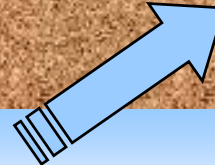
Lateral flow



Drain discharge

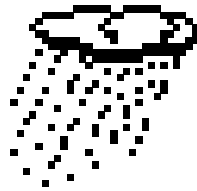
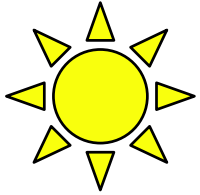


Surface water



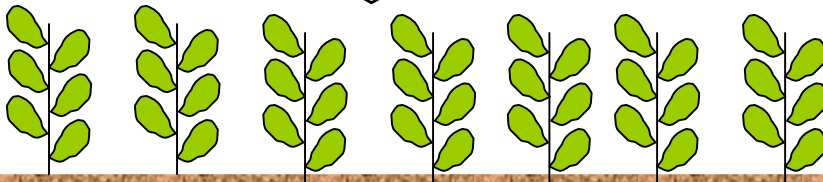
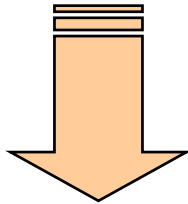
Baseflow

Groundwater

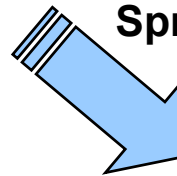


# Pesticide entry

Pesticide application



Spray drift



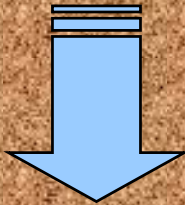
(Runoff)



Edge of field

Soil

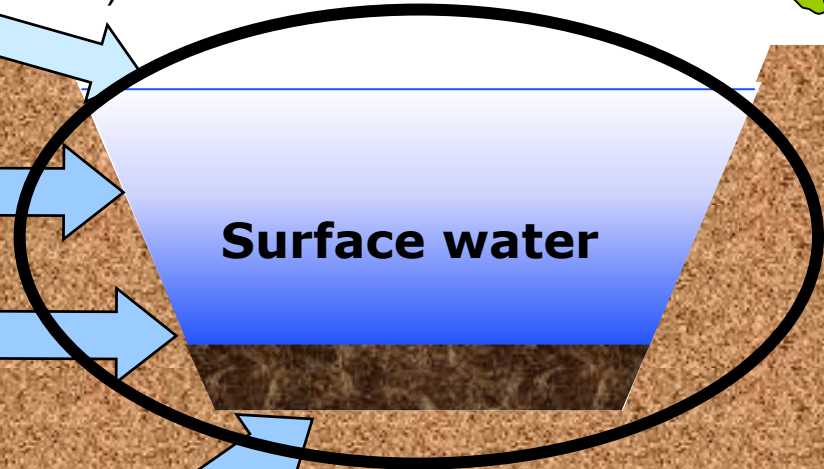
Leaching



Lateral flow

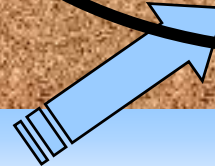


Drain discharge



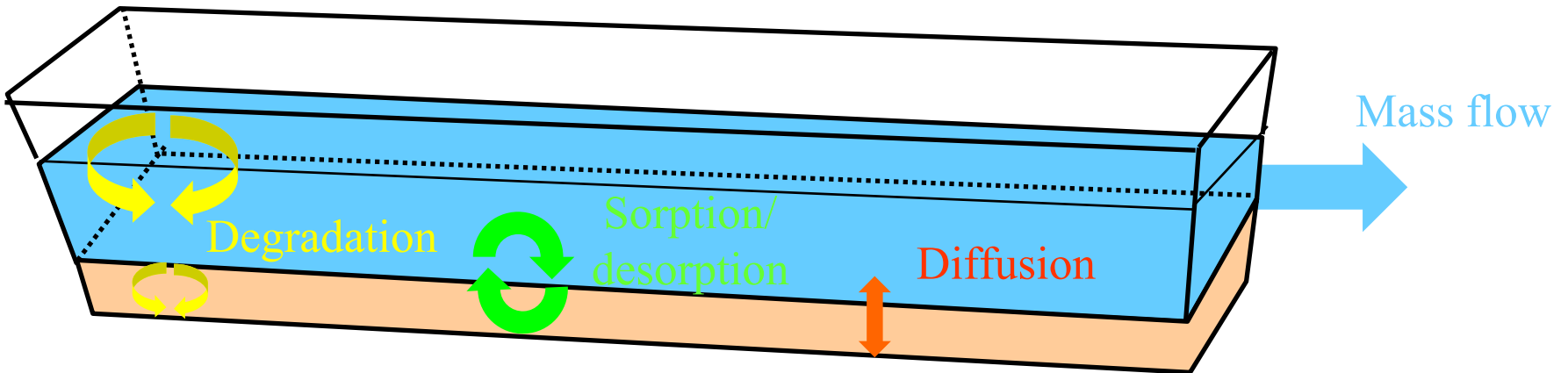
Surface water

Baseflow



Groundwater

## Pesticide: ditch & stream



- Degradation and sorption  $\Rightarrow$  FOCUS
- Diffusion added for near static flow systems

## Conclusions

- Model developed directly at scale of application
- Several routes of pesticide entry in ditches and streams accounted for within one model
- Despite hourly time step, input requirements reasonable (rainfall and stream hydrograph required at hourly time step)
- Parameterisation relatively simple as data requirement kept to a minimum
- Modeller can simulate realistic pesticide applications in the landscape and can determine the impact of mitigation measures on pesticide concentration in ditches and streams

## Next steps

- Evaluate model:
  - drainflow predictions
  - water flow in ditches and stream
  - pesticide concentrations in ditches and streams
- Data for model evaluation:
  - existing field/small catchment studies in the UK
  - full monitoring of a small catchment (2004/2005)