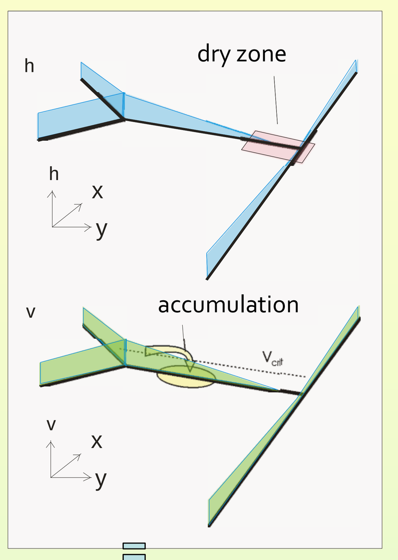
Experiences in water quality simulations of a medium-sized agricultural temporary river basin

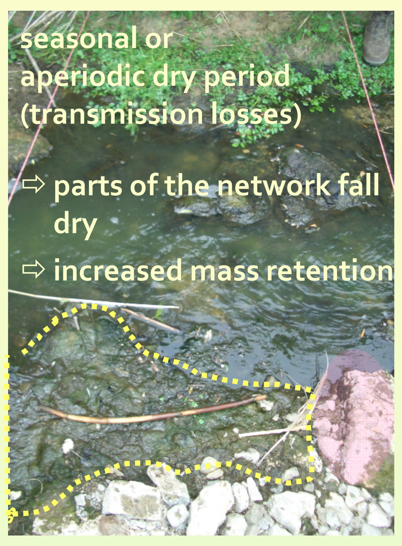
PROBLEM & DATA ANALYSIS

Mediterranean Transportdynamic

SPRING - SUMMER

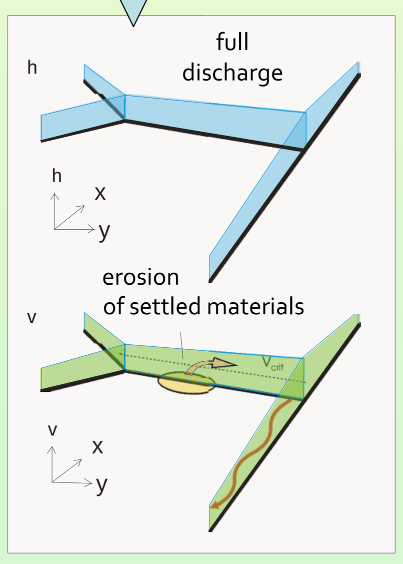


small discharge - increased biomass



FIRST FLUSH = "Rapid changes in water quality after early season rains"

AUTUMN - WINTER

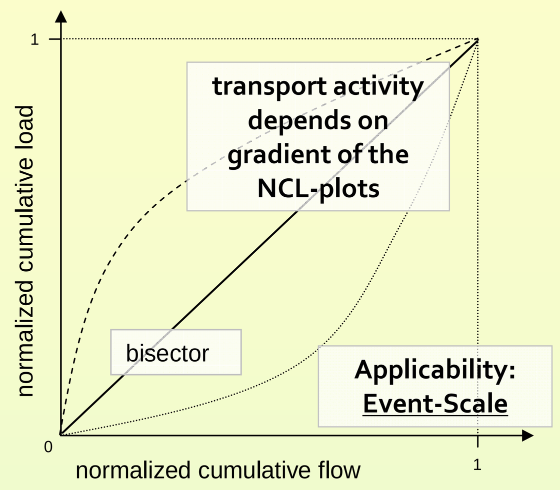


big discharge - less biomass

Normalized cumulative loads - NCL

$$NCF = \frac{\int_{t=t_0}^{t} Q(t)\,dt}{\int_{t=t_0}^{t_e} Q(t)\,dt}$$

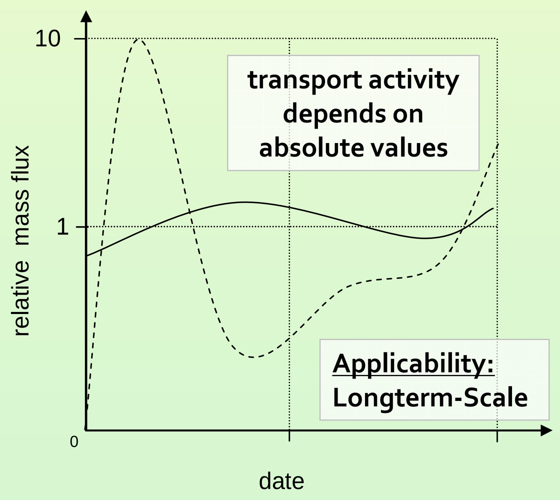
$$NCL = \frac{\int_{t=t_0}^{t} Q(t)\cdot X(t)\,dt}{\int_{t=t_0}^{t_e} Q(t)\cdot X(t)\,dt}$$



Q(t): flow [L³T⁻¹]
X(t): water quality parameter, e.g. concentration [ML⁻³]
t_0, t_e: begin / end of the flood event [T]

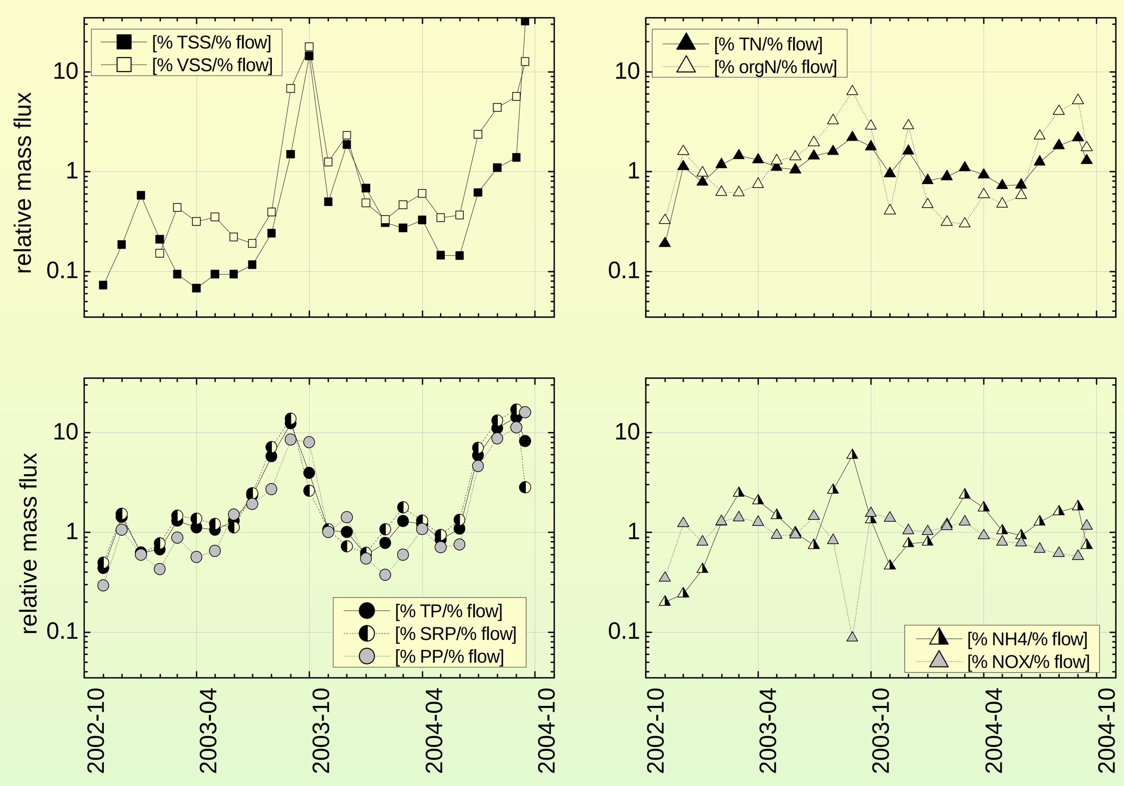
Relative mass fluxes - RMF (Obermann et al., 2007)

$$RMF(X,t) = \frac{NCL(X,\Delta t)}{NCF(\Delta t)} \;\hat{=}\; \frac{percentage\ load}{percentage\ flow}$$



L(X,t): load of parameter X at time t [MT⁻¹]
Q(t): flow at time t [L³T⁻¹]
NCL(X,t): normalized cumulative load of parameter X at time t [-]
NCF(t): normalized cumulative flow at time t [t]

Relative mass fluxes 2002-10 - 2004-09, Vène, France



First Flush Effects:

- most intensive directly downstream of "Hot-Spots"
- most intensive for suspended substances (TSS>TP>TN)
- can cause up to 2/3 of the annual TSS & VSS load (month September)
- ~18% VSS can be transported by only 1% flow (2003-09)
- during FF-events: 72% TSS can be resuspended by the first 25% flow

MODEL DEVELOPMENT & APPLICATION

tempQsim - STREAM Model

Flow Routing

$S_0 - S_f = 0$, $A = \alpha Q^\beta$ — Kinematic Wave

$\frac{\partial y}{\partial x} - (S_0 - S_f) = 0$ — Non inertia Wave

$\frac{1}{A}\left(\frac{\partial Q}{\partial t} + \frac{\partial}{\partial x}\left(\frac{Q^2}{A}\right)\right) + g\frac{\partial y}{\partial x} - g(S_0 - S_f) = 0$ — Dynamic Wave

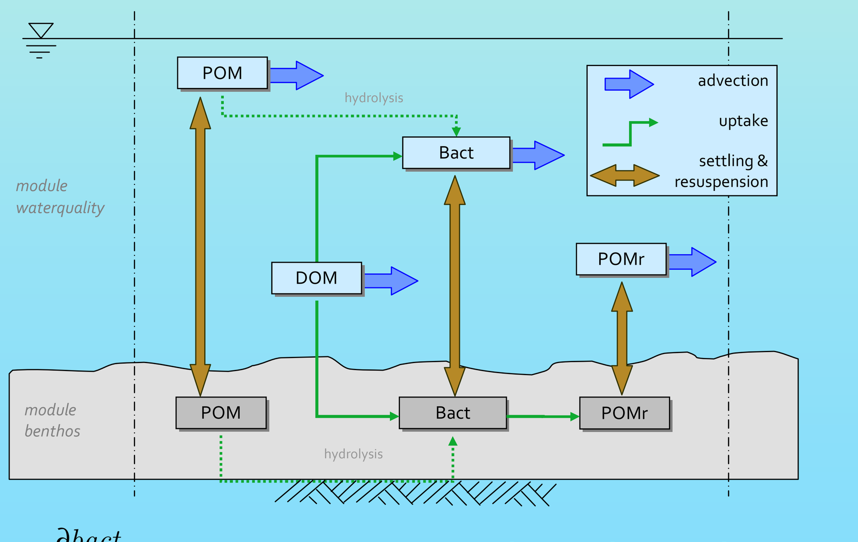
Spatial Discretisation

Finite Volumes, structured static grid (mass conservativ)

Water Quality Calculation

PON, DON_r, DON_{nr}, NH_4, NO_3, NO_2
POP, DOP_r, DOP_{nr}
DO, BOD, temperature, salinity, cohesive sedimente
TSS, VSS, phytoplancton, algae, zoobenthos, het. bacteria

Benthic Reactor incl. Bakteria Growth



$$\frac{\partial bact}{\partial t} = (\mu^{bact} - m^{bact})bact \qquad \mu^{bact} = \mu^{bact}_{DOM} + \mu^{bact}_{POM}$$

$$\mu^{bact}_{POM} = \frac{\psi(T)\cdot \mu^{bact}_{max}\cdot POM_{bottom,r}}{K^{bact}_N + POM_{bottom,r}}$$

Fractioned Sedimenttransport

Adaptive Timestep

VSS and TSS

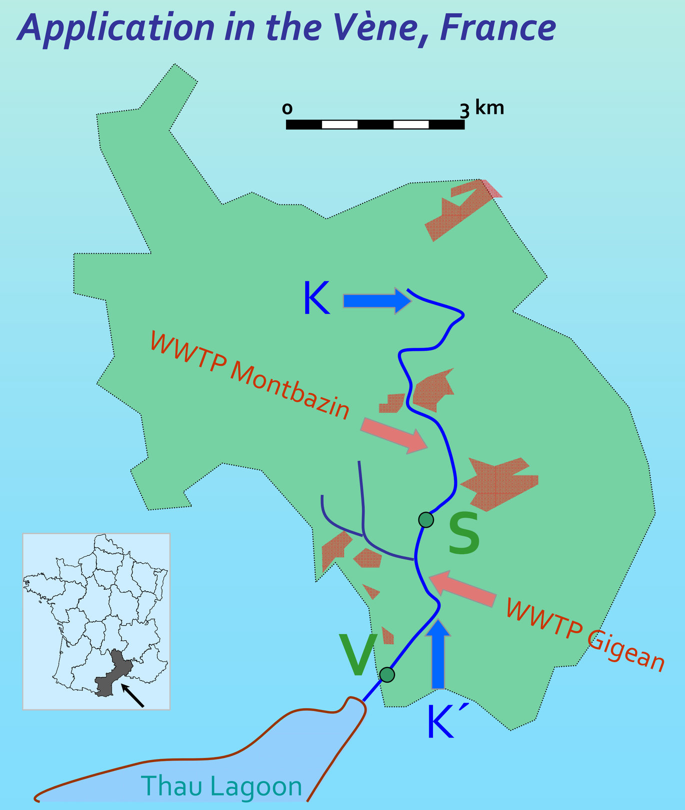
$$VSS = (\alpha^{phy}_{N:C}phyto + \alpha^{dia}_{N:C}diatoms + \alpha^{zoo}_{N:C}zoo + \alpha^{cil}_{N:C}ciliates + \alpha^{phy}_{N:C}bact + POM + POMr)/\alpha_{N:TS}$$

$$TSS = \sum_i cohesive\ sed_i + VSS$$

Enhanced Erosion-ratecalculation based on Parthenіades (1962)

$$E[i] = M_e[i]\left(\frac{\tau_b}{\tau_{crit,e}[i]} - 1\right)\cdot\left(\frac{substance[i]_{bottomconc}}{TSS_{bottomconc}}\right)$$

Application in the Vène, France



Geography

- basin area: 67 km²
- elevation: 2 to 323 m
- river length: 12 km
- mean slope: 0.4%
- mean cross sections: 3 to 5 m
- flows into Thau Lagoon

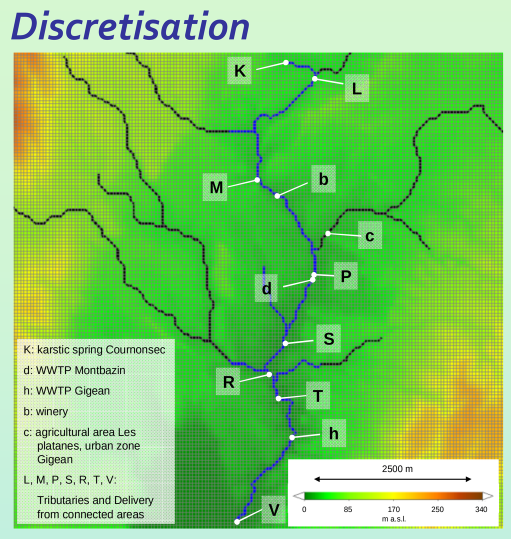
Land Use

- population: 12,400 inhabitants
  3% of total basin area urban
- 63% natural karstic zones
- 34% to agricultural zones

Point Sources

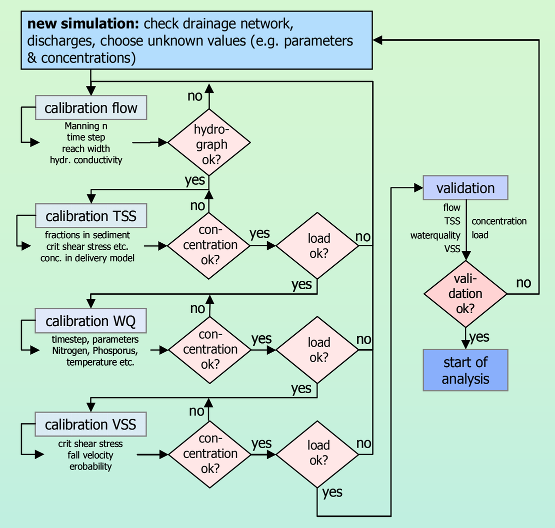
- two karstic springs (K, K')
- wineries
- three WWTPs, 9800 equivalent-inhabitants

Discretisation



- Delineation from 50 x 50m grid
- 360 trapezoid. cross sections 3-6m width
- 12 point source inflows

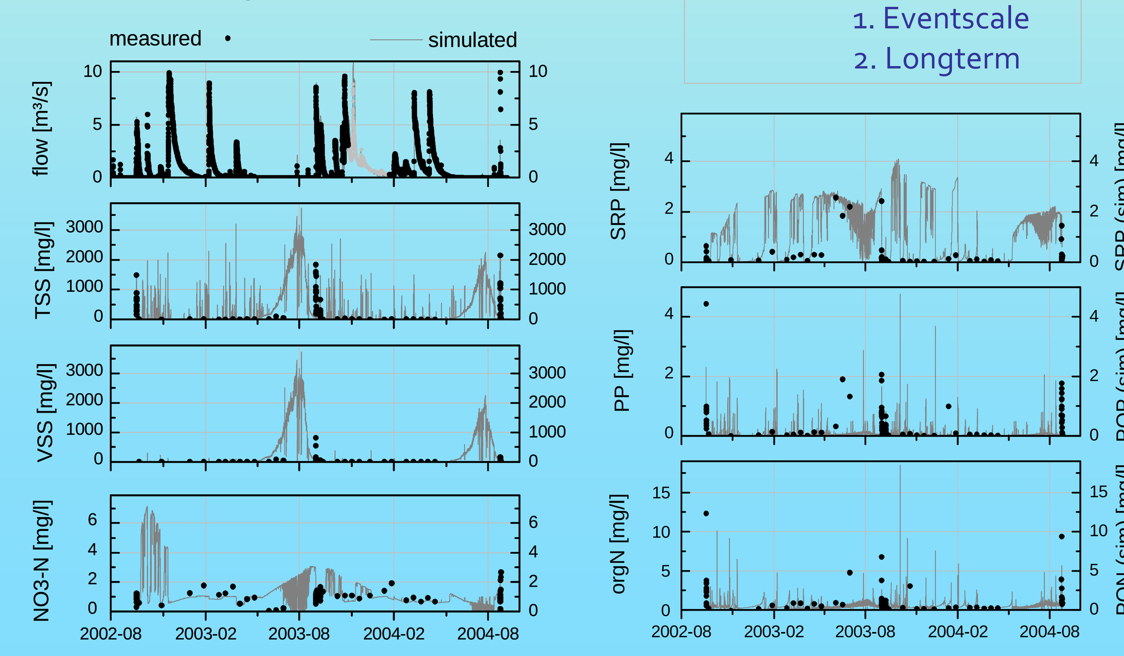
Calibration



- stepwise calibration for 2003
- validation on basis of 2004

Simulation for 2002-2004

Analysis for 2 Scales:
1. Eventscale
2. Longterm

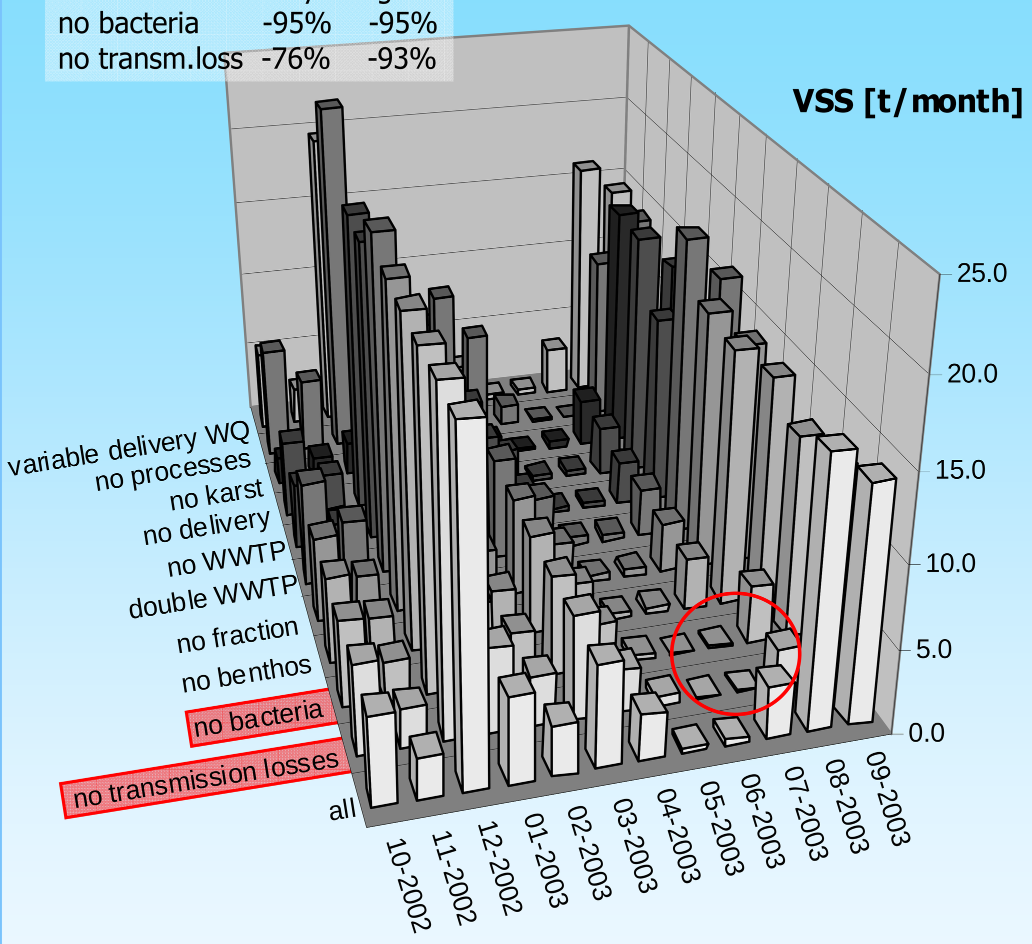


SIMULATIONS & SUMMARY

Scenario Analysis

- 11 Scenarios
- VSS, TSS, NO3, NH4

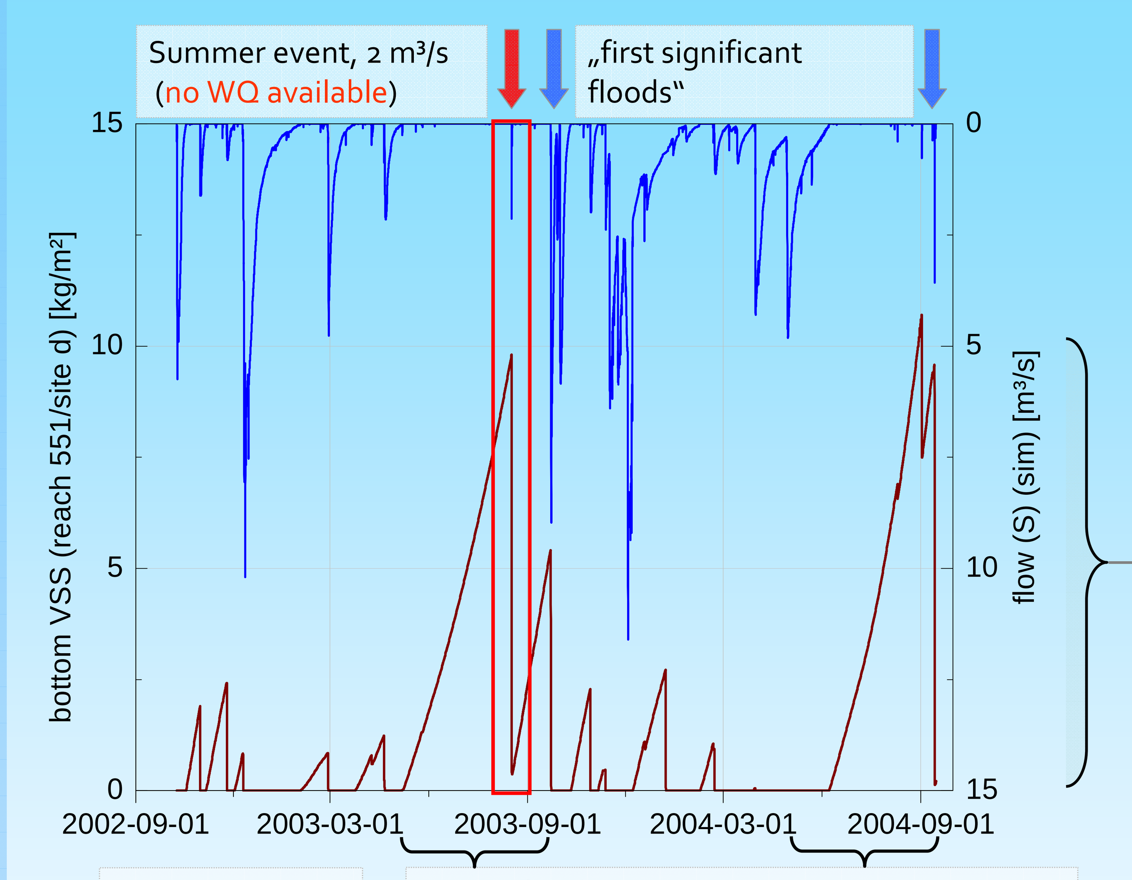
	July	August
no bacteria	-95%	-95%
no transm.loss	-76%	-93%



Relevancy of Processes

⇨ high influence of bacterial growth & transmission lossed especially at the end of the dry period

Resuspension in Summer (simulated)



Accumulation of volatile suspended matter (VSS) at river bed [kg/m²]

Accumulation period (up to 29 kg/m² measured)

flow [m³/s]

small event ⇨ big impact

Resuspension of
95% of the accumulated VSS
≈ 7.8t VSS
≈ 10% of the annual total load

Possible Consequences on Thau Lagoon

"Malaïgue"

- every 5-7 years
- event with high oxygen consumption
- losds of ~1/3 of the oyster population

⇨ € 5 Mio. loss

Summary

Temporary rivers are unique ecosystems. The simulation and analysis of their mass transport regime requires special knowledge, which cannot necessarily be derived from the experiences which were already gained in perennial rivers.

With regard to the requirements of the European Water Framework Directive for a good water quality in surface waters until 2015, there is a need to define quality characteristics for temporary waters and to provide suitable methods and models for the investigation.

The extrem amplitude in flow conditions leads to highly concentrated nutrient and pollutant waves -mostly transported with the first flood events in late summer or early autumn. These first flushes impose a great financial and ecological risk to downstream water bodies as e.g. lagoons and lakes, especially with regard to water supply and other ecosensitive uses as fishing or recreation.

The herein presented methods incl. the developed tempQsim - STREAM Model proved to be able to correctly analyse and reproduce the main features of temporary rivers. This means a fundamental contribution to the preparation of „best management strategies" in mediterranean river basins.

Especially during the dry period, there is a need to move towards an adopted, integrated limitation of emmissions following the principle of reducing ambient pollution.

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