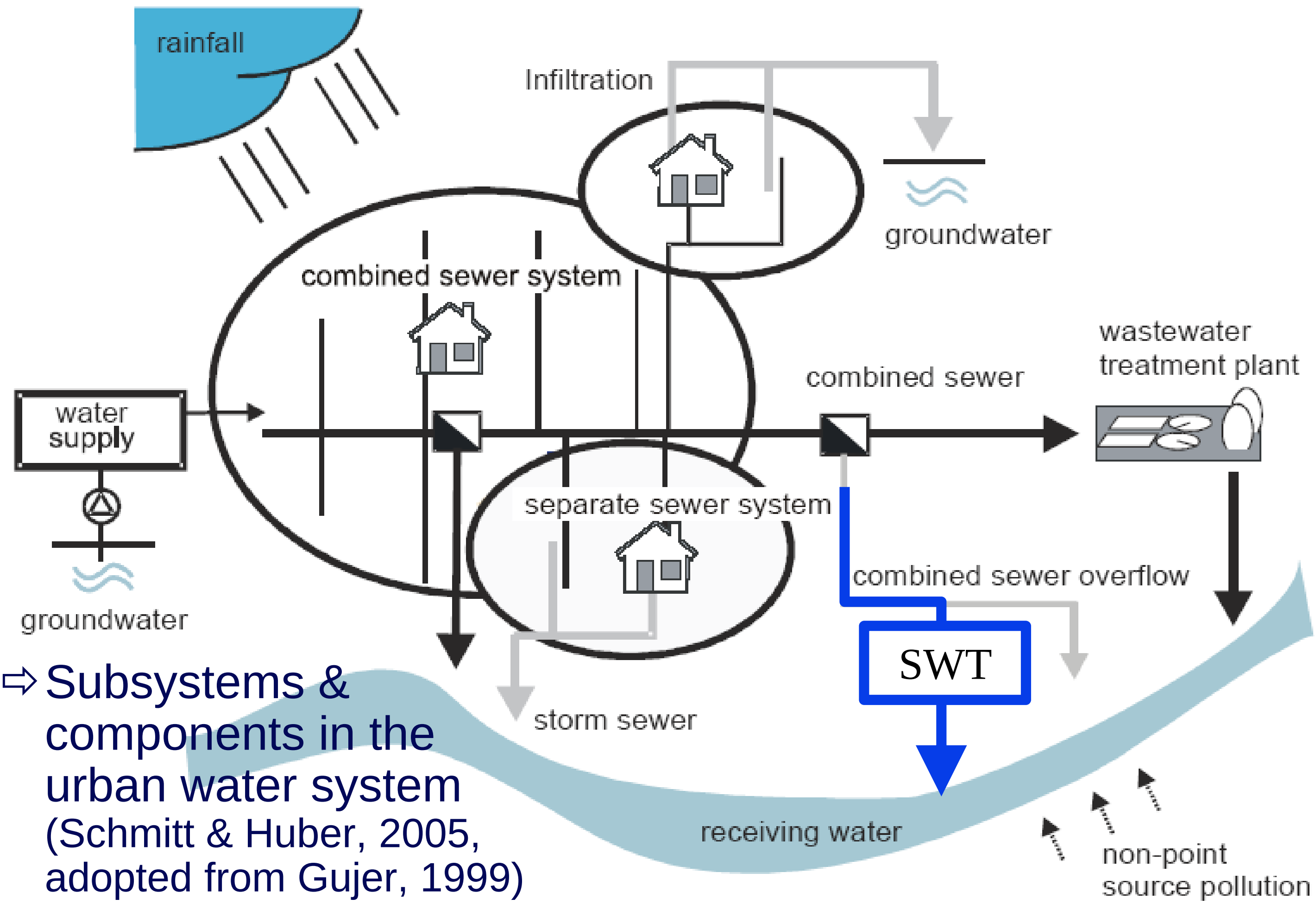
Modelling of Sewer + WWTP + Receiving waters - An Introduction -

Thomas Ertl

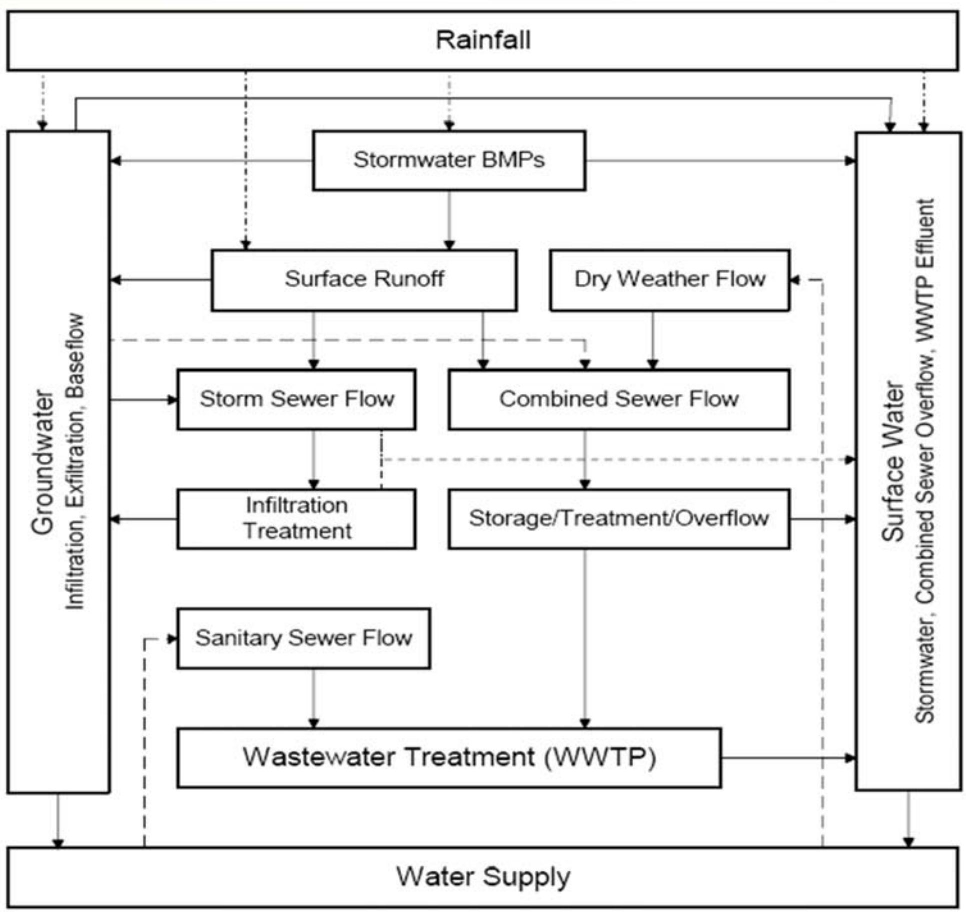
Institute of Sanitary Engineering and Water Pollution Control



⇨ Subsystems & components in the urban water system (Schmitt & Huber, 2005, adopted from Gujer, 1999)

Introduction

- Sewerage + WWTP + receiving waters as 1 Unity
- Emission / Immission
- Conditions of receiving waters:
  hydraulic, substances, physical // time course!
- Although the various coherences between the elements are well known for a long time, until today a separate view on the processes has remained.
- The application of models for simulation of sewerage, treatment plant and receiving water enables the integrated view on the ecologic exposure to the watercourses by urban drainage. (RAUCH, 1996)

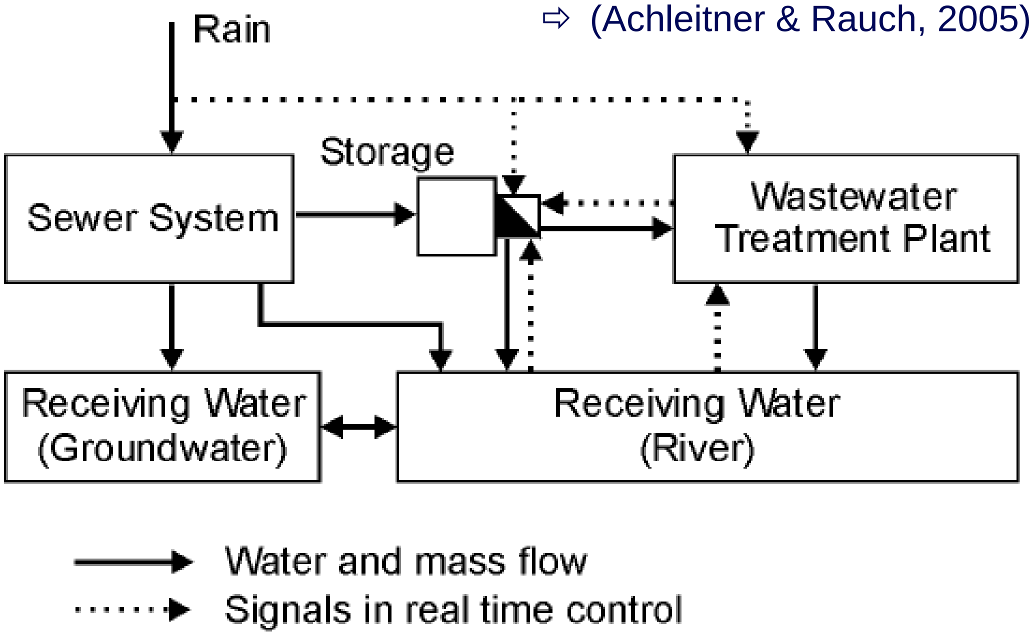


Schmitt & Huber (2005)

2. Sub-systems, components and interactions in the urban water system

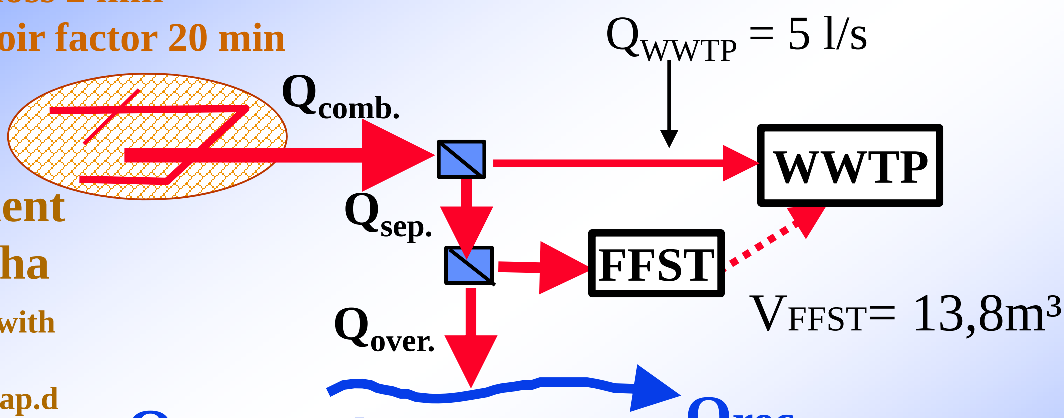
Schematic overview on the main elements and information flow in an integrated model

⇨ (Achleitner & Rauch, 2005)



Example: Combined Sewer Overflow

Rain = 8 mm (40min)
Initial loss 2 mm
Reservoir factor 20 min



Catchment
A_{red} = 3 ha
345 Capita with 250l/Cap.d
10g NH4/Cap.d

Q_{347} = 10 l/s

Question: Which flow and concentrations result in the receiving water during rainfall event?

Example:
Calculation of flow in the receiving water

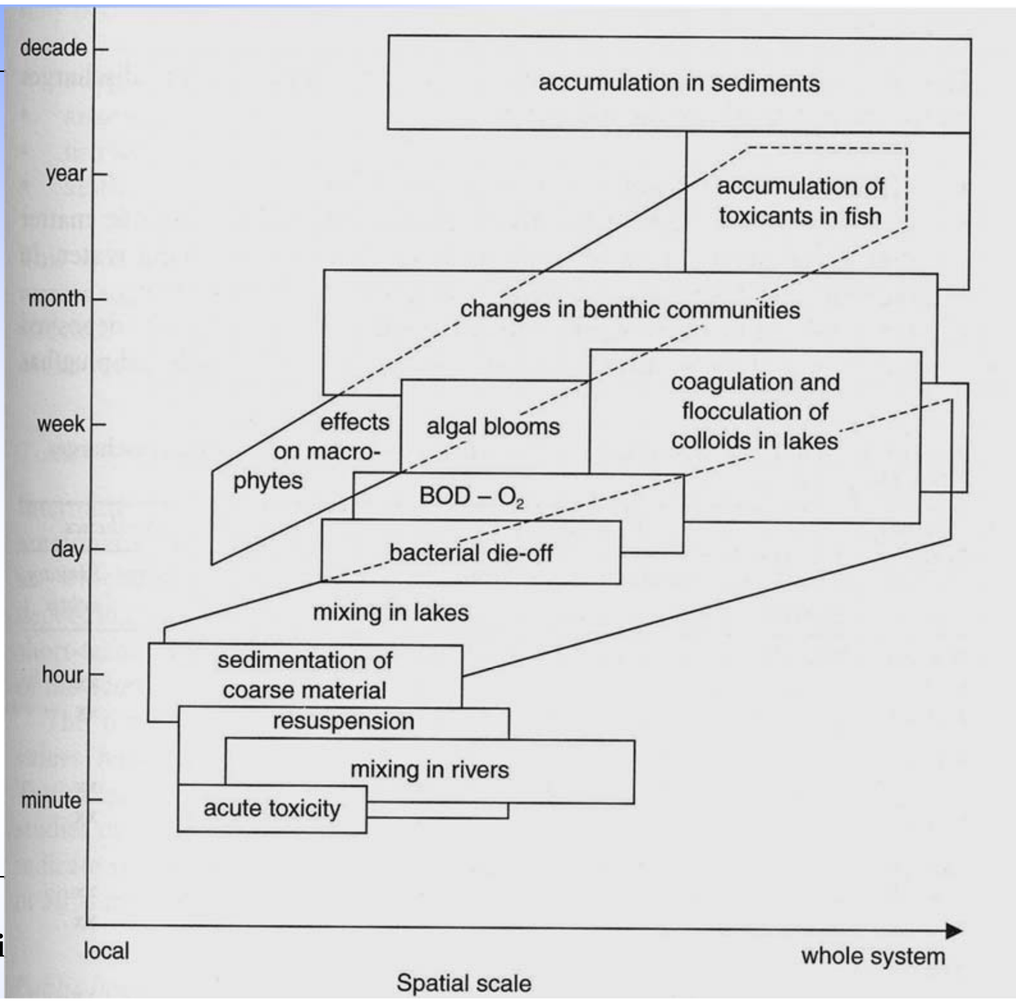
See EXCEL file: ex_rec08indicat.xls

Excursus: water ecology

- influencing factors:
  flow, streaming conditions, water temperature and oxygen concentration
- disturbance through CSO depends on type of water:
- running / stagnant water: high / low transport capacity vs. small / big volume
- temporary impact with acute toxic pollutant as f(intensity, duration) leads to shift or elimination of the biocoenosis

Receiving Water Impacts

⇨ Time and spatial scales for receiving water impacts (Butler & Davies, 2000)



Excursus: water chemistry

- ⇨ Types of Nitrogen
- ⇨ Ammonia / Ammonium
- ⇨ pH - buffer system
- ⇨ Alkalinity, ABC (acid binding capacity), water hardness

The different forms of Nitrogen

Oxidation #	pH high	pH low
Reduced: O_2 demand		
-3	NH_3 (Ammonia)	NH_4^+ (Ammonium)
0	N_2 (elementary Nitrogen)	
+3	NO_2^- (Nitrite)	
+5	NO_3^- (Nitrate)	
Oxidized: ‘O_2 surplus’		
-3	Organic bound Nitrogen	

Alkalinity

Capacity (Sum of substances)

The Alkalinity (or Acid Binding Capacity, **ABC**)
is the measure for the pH buffer capacity of water.
It says, how much acid is necessary to reduce the pH of water till 4.3
As a first approximation in waste water it is:

Alkalinity = Bicarbonate (HCO_3^-)

$$HCO_3^- + H^+ \leftrightarrow H_2CO_3 \leftrightarrow H_2O + CO_2$$

Alkalinity + Acid

The Alkalinity is dependent of the local drinking water,
typical concentrations are in the range of 5 - 8 mole m^{-3}.

pH value: pH = - $\log_{10}(H^+)$

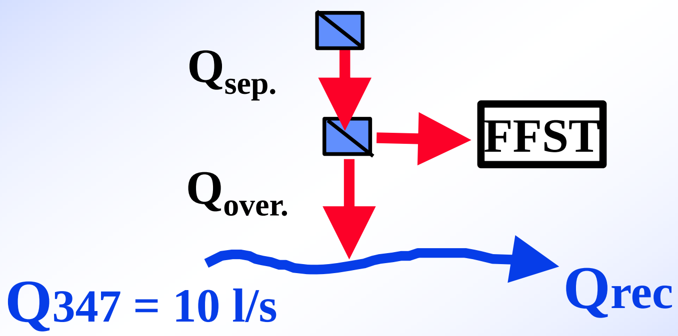
Substance, Activity

The pH value is a measure for the activity (concentration) of protons (H^+) in water. The pH-value has influence on the solubility of salts, the activity of microorganisms, the distribution of acids and bases, etc.

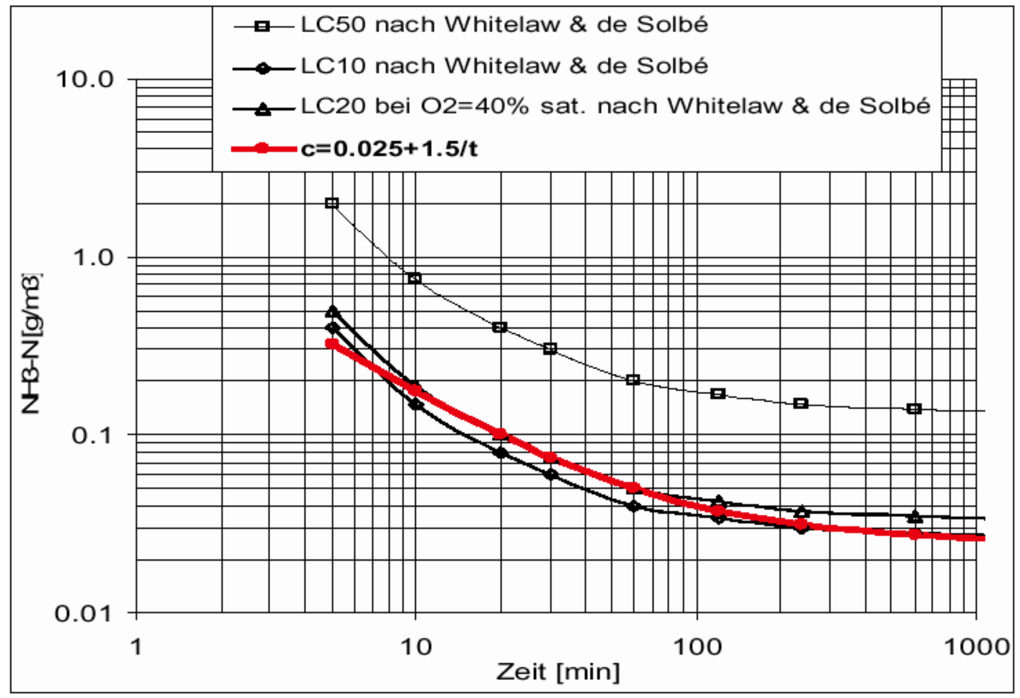
Typical pH values in wastewater are in the range of 6.7 - 7.5
In waters often higher values are observed. Especially in times of summer sunshine till values of 9.0!

Example: Calculation of NH4-N concentration in combined wastewater and in the receiving water

See EXCEL file: ex_rec08indicat.xls

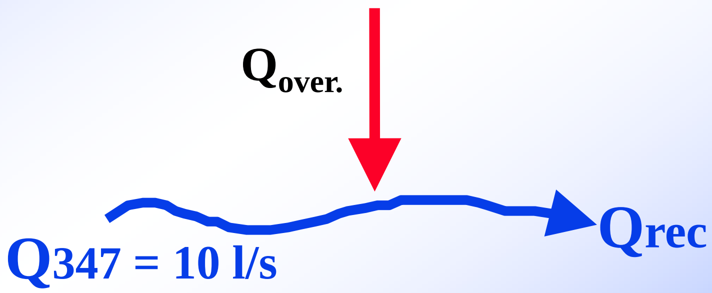


Ex.: Calculation of NH3 dose in the receiving water



Ex.: Calculation of mixing waters with different pH-values

See EXCEL file: ex_rec08indicat.xls



Integrated Model - Basic Principle

⇨ Building up a mathematical relation between cause (rain) and impact (on water quality)

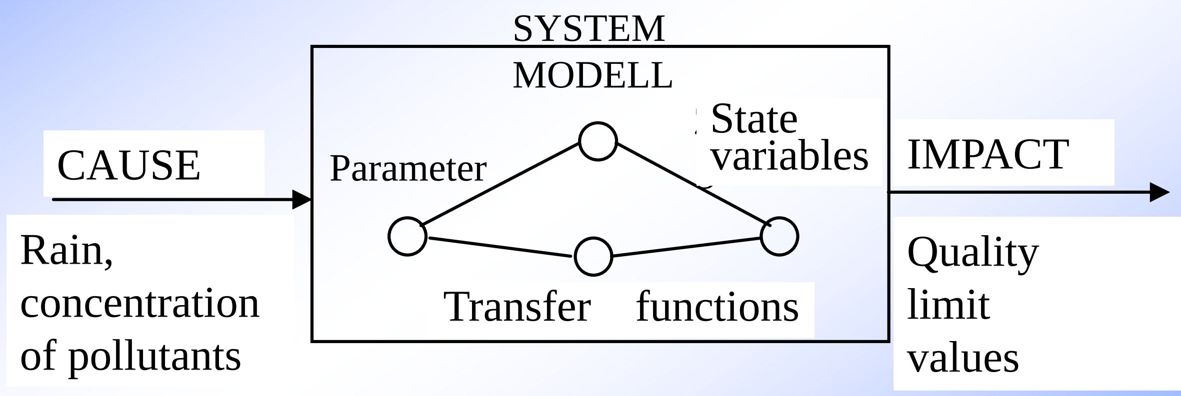


Figure 4: system analysis and model (acc. to Rauch, 1995)

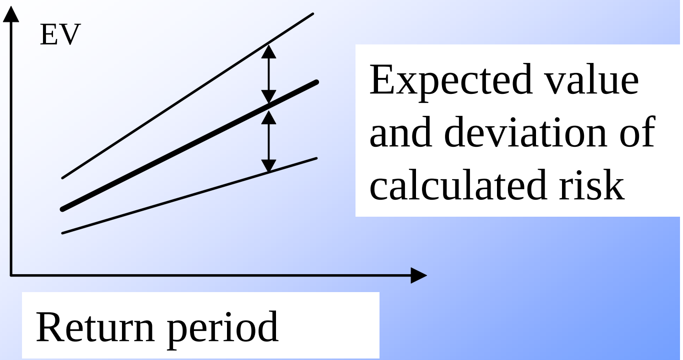
Model -Classification

⇨ According to structure and parameter of transfer functions

- Phenomenologic M. (Black Box): pure description of cause / impact relation (e.g. Monod)

⇨ further classification:

- **deterministic** M.: no chance! Equal data --> equal results
- **stochastic** M.: statistical distribution of potential results, by far more information



Criteria for Proof

- ⇨ Proof: emission limit values resp. cases of „immission“
  - differentiation of critical cases (see FENZ, 2001)
    - **Ammonia, Oxygen, hydraulic stress, pollutant load**
  - Adopted measures: increase throttle flow, constructed wetland, increase shadowing, avoidance of breakdowns (e.g. pumping stations)!!!
- ⇨ Simulation: continuous vs. many single events
  - continuous: effects of delayed processes, but additional implementation of dry weather periods -> more elaborate models
  - In case of evaluation of the accumulative load of waters the higher effort of the continuous simulation is absolutely necessary.

Model Interfaces

- ⇨ Interfaces:
  - Sewer / WWTP, Sewer / Rec. Waters, WWTP <-> Rec. W.
- ⇨ Needs:
  - time steps, parameters (validation!), ...
- ⇨ Reality:
  - Development of different Disciplines --> separated models with different
    - parameters: WWTP different fractions of COD / river model: BOD
    - time steps: sec / hours
- ⇨ Future: Accordance!
  - see papers by Seggelke, Erbe

Example: Calculation of bed load drive

Tabelle 4: Angaben zur typischen Korngrössen verschiedener Gewässertypen.

Gewässertyp	d_m (m)	d_{90} (m)
Wiesenbach im Flachland mit sandiger Sohle	0.002	0.01
Bach im hügligen Gelände mit sandiger bis feinkiesiger Sohle	0.01	0.025
Bach in den Voralpen mit fein- bis grobkiesiger Sohle	0.03	0.07
Bach in den Voralpen/Alpen mit grobkiesiger bis steiniger Sohle	0.06	0.11
Steiler Bach mit steiniger bis felsiger Sohle; Blockwurf	0.1	0.3

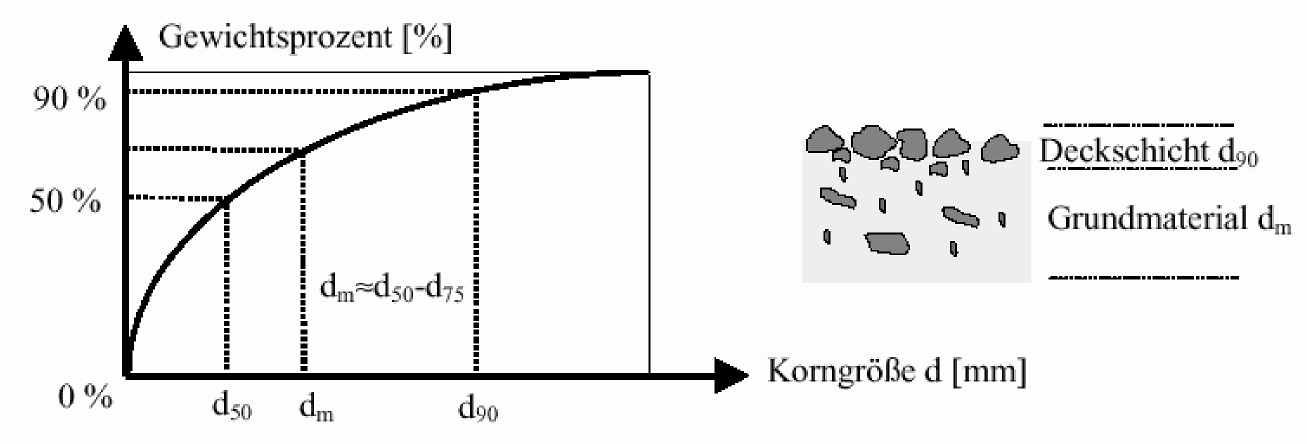


Abbildung 13: Siebkurve einer Geschiebprobe.

River water models

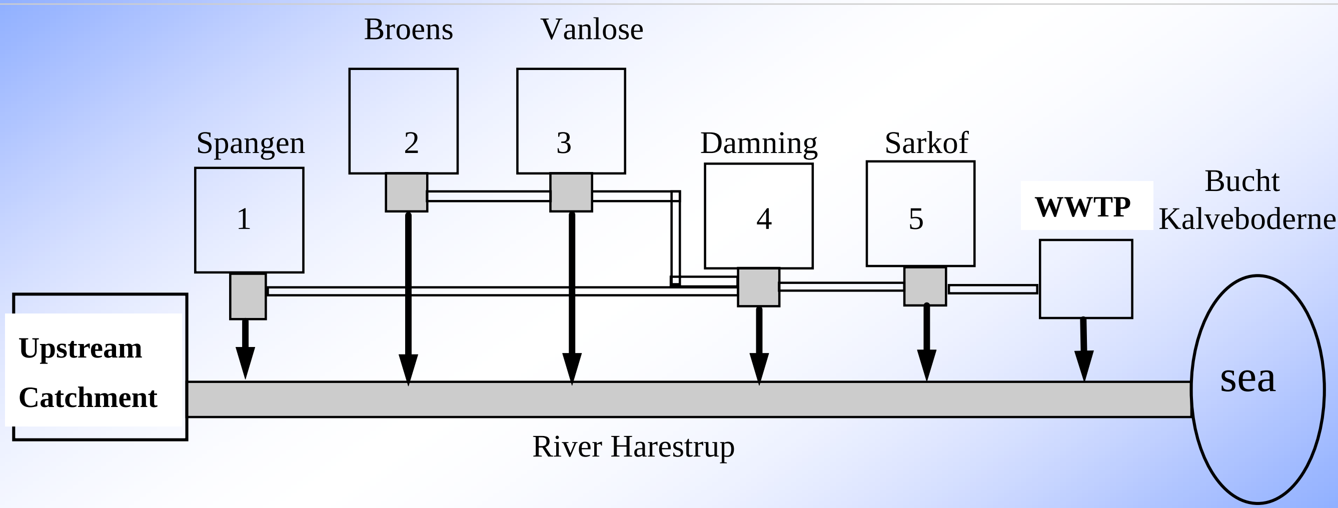
⇨ Methods and application of catchment and immission oriented models for urban drainage

	Method	Calibration		Advantages	Disadvantages	Application
		hydraulic	physical			
Analytical	Calculation of mixtures, Flowtime methods, analytical calculation of pollutant concentrations	-	-	Fast available	Non dynamic Loading case related extreme simplification	Pre-examination Sensitivity analysis approximate comparison of alternatives
dynamic	Linking detailed models for relevant parts of the system to an integrated model (Catchment-Sewer-WWTP-Receiver)	+	-	Dynamic Long term examination possible in principle	Partly generalisation necessary	Problem identification and optimisation of the whole system, Cost-Efficiency analysis, Evaluation of control strategies in system parts
	Detailed River Quality Modelling with measured or calibrated pollutant loads	+	+	Dynamic Precise Results	Loading case related	As above & detailed evaluation of riverside measures possible (section, slope etc.)

Niemann, A. (2002) Die Gewässergütesimulation als Planungsinstrument für die Entwässerung an kleinen Fliesgewässern. *ATV- Bundestagung*

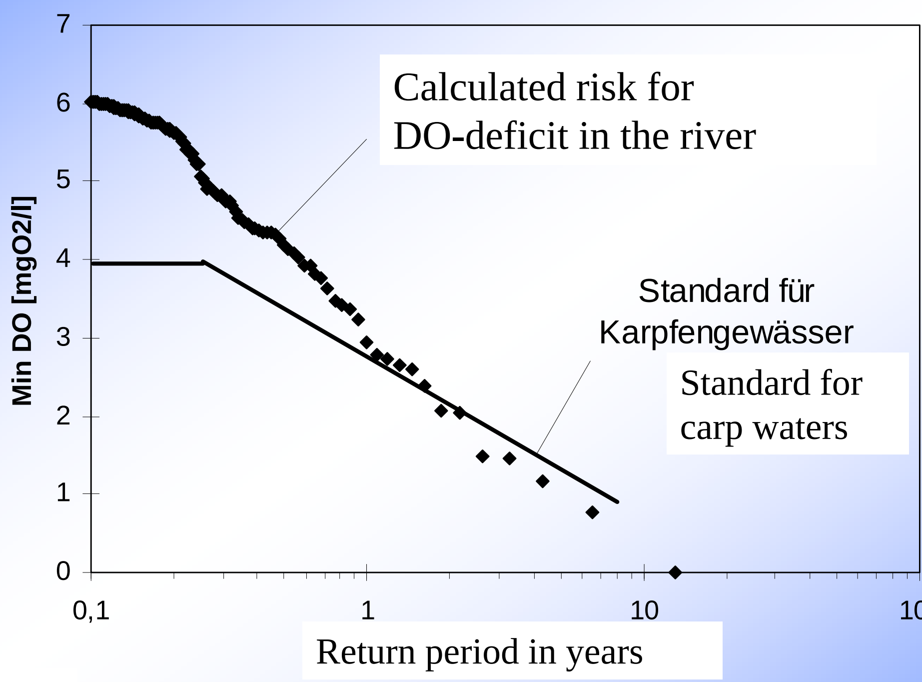
Integrated Model – Example #1

⇨ Scheme of the total drainage system (Rauch, 1996)



Integrated Model – Example #1

⇨ Comparison of the statistical analysis of the global DO-deficit in the river with the danish standard (Rauch, 1996)



Integrated Model – Example #2

- ⇨ Erbe et al. (2002)

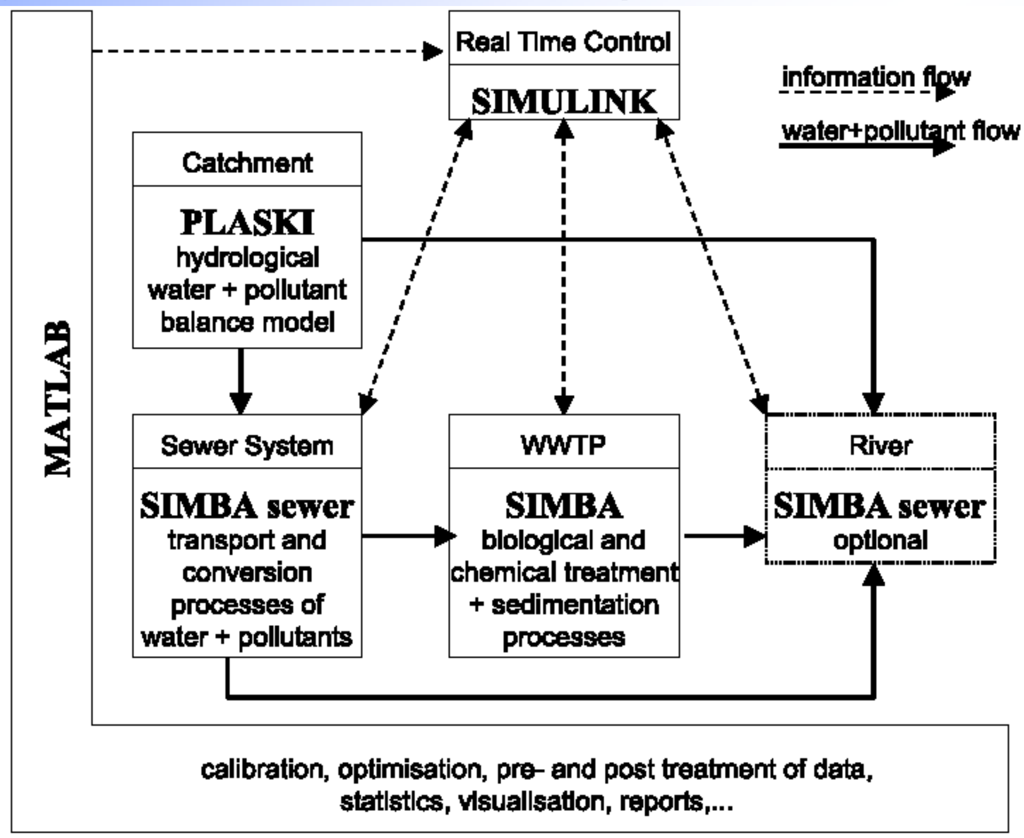
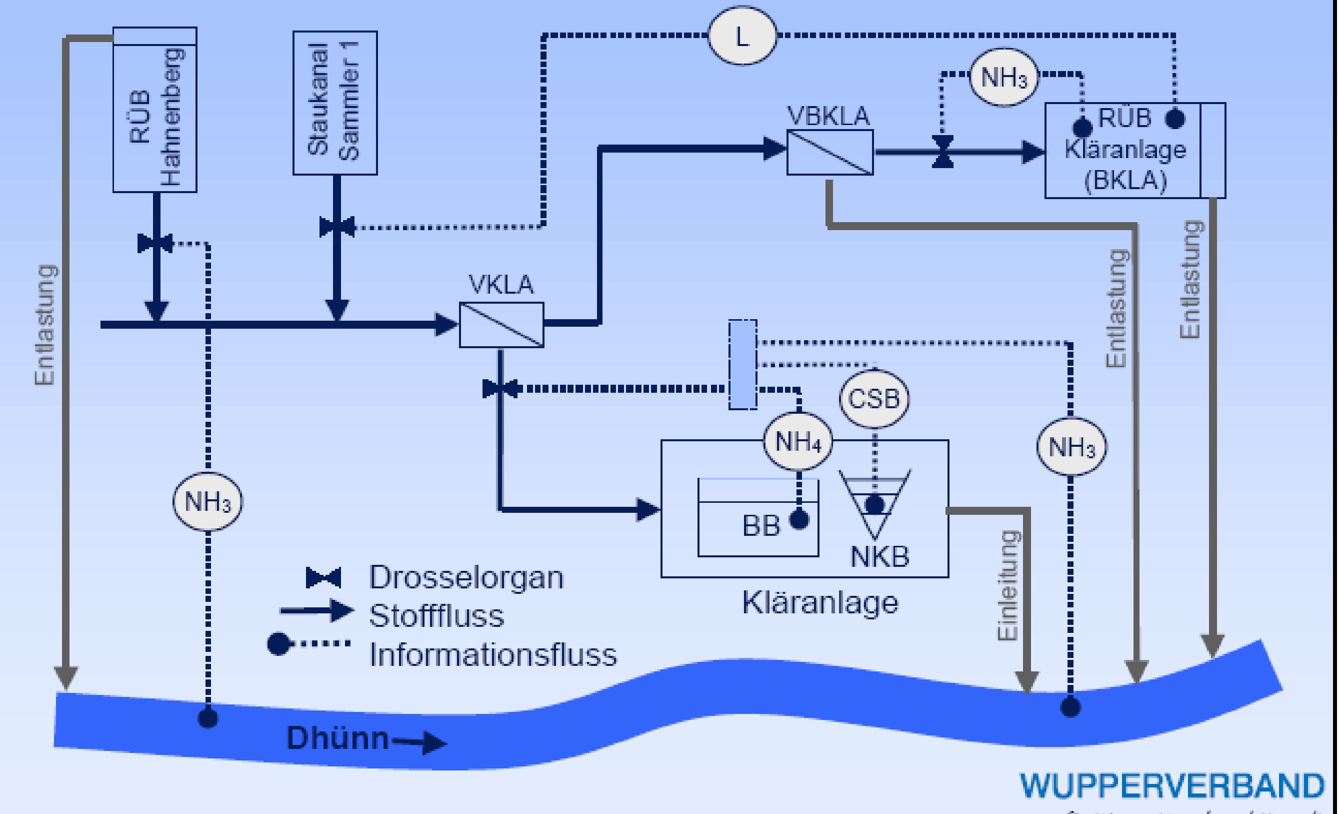


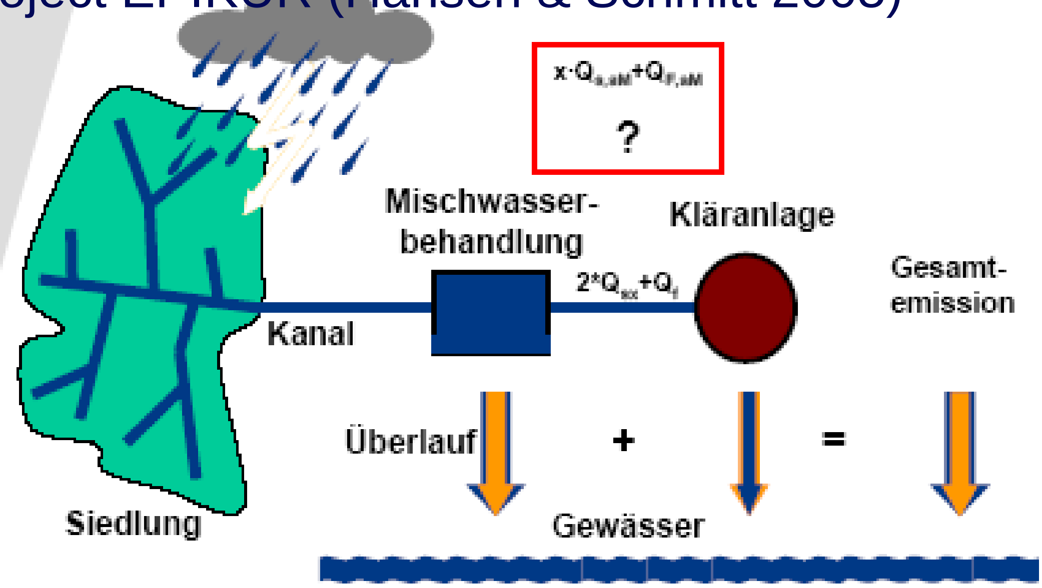
Fig. 1. Components of the integrated simulation system.

Integr. Model Ex. #2: Control of Sewerage and WWTP (Erbe, 2004)



Integrated Model – Example #3

⇨ Project EPIKUR (Hansen & Schmitt 2005)



J. Hansen, T.G. Schmitt

Zentrum für Innovative AbWassertechnologien
an der Technischen Universität Kaiserslautern

Integrated Model – Example #4

⇨ Enhanced Treatment of CSO with Secondary Clarifiers (Nikolavcic et al., 2006)

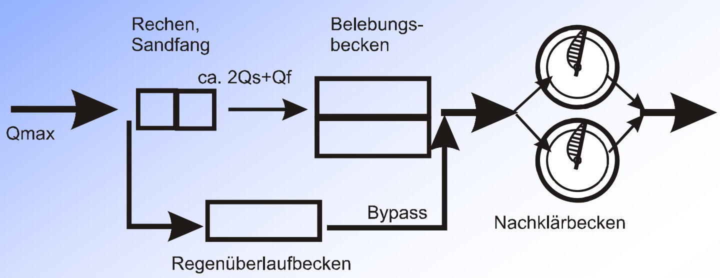
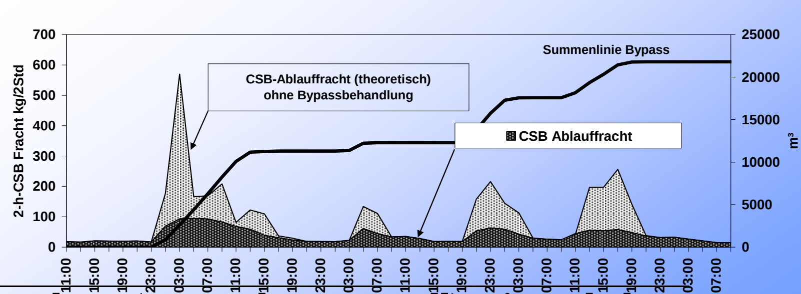
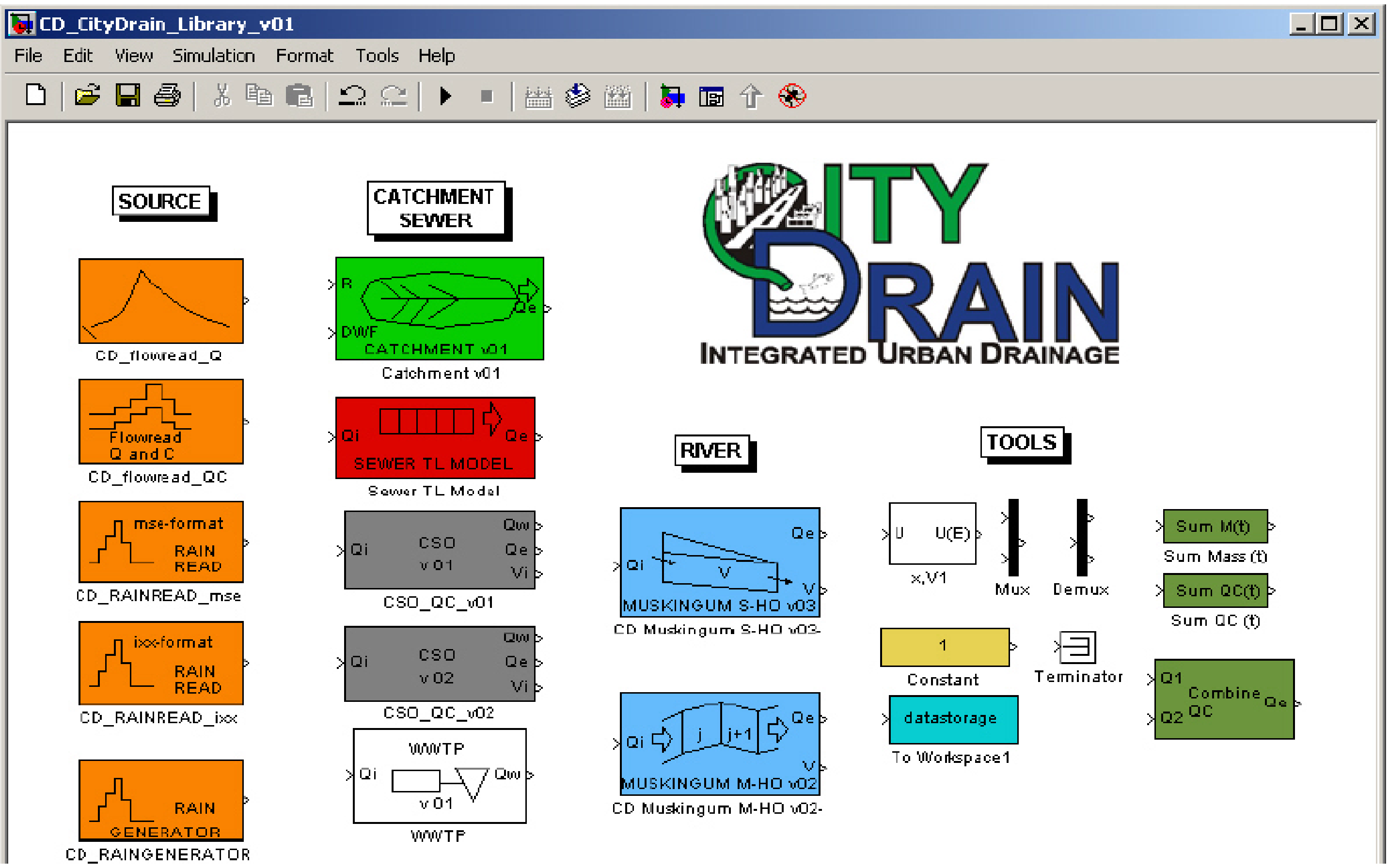


Abbildung 2: Verfahrensführung bei Einbindung eines Regenüberlaufbeckens



CSB-Frachten (2-Stunden Intervall) mit und ohne Bypass.



⇨ Achleitner Stefan and W. Rauch (2005) **CITY DRAIN © - A simulation software for integrated modelling of urban drainage systems.** stefan.achleitner@uibk.ac.at

References

⇨ Achleitner Stefan and W. Rauch (2005) **CITY DRAIN © - A simulation software for integrated modeling of urban drainage systems.** Proceedings of the 10th ICUD. Copenhagen. *stefan.achleitner@uibk.ac.at*

⇨ Alex,J.,Risholt,L.P.,Schilling,W.(1999).**Integrated modelling system for simulation and optimization of wastewater systems**. *In Proceedings of 8th international conference on urban storm drainage, Sydney (Vol.3,pp.1553 – 1561).30 August –3 September 1999.*

⇨ Erbe V. (2004) **Integrierte Modellierung.** *Presentation (in german) at the "Hochschulgruppe" Meeting in Luxemburg.*

⇨ Erbe V., L. P. Risholt, W. Schilling and J. Londong (2002) **Integrated modelling for analysis and optimisation of wastewater systems – the Odenthal case,** *Urban Water, Volume 4, Issue 1, March 2002, pp 63-71*

⇨ Fenz, R. (2001) **Gewässerschutz bei Mischwasserentlastungen Emissions- und Immissionsanforderungen.** *Wiener Mitteilungen Band 168, S. M1-32*

⇨ Hansen J. & Schmitt Th. (2005) Präsentation Project EPIKUR.

⇨ Nikolavcic, B., G. Wandl, K. Svardal, G. Spatzierer, V. Kuehn and N. Günther (2006) **Enhanced treatment of CSO with secondary clarifiers**. Presentation @ UDM & WSUD Conference, Melbourne

References

- Rauch, W. (1996) **Modellierung von Kanalnetz - Kläranlage – Vorfluter.** *Wiener Mitteilungen Bd. 131. S. 277-298*
- Rauch Wolfgang, Hans Aalderink, Peter Krebs, Wolfgang Schilling and Peter Vanrolleghem **Requirements for integrated wastewater models - driven by receiving water objectives,** *Water Science and Technology, Volume 38, Issue 11, 4 December 1998, Pages 97-104*
- Rauch, W., M. Henze, L. Koncsos, P. Reichert, P. Shanahan, L. Somlyódy and P. Vanrolleghem **River water quality modelling: I. State of the art,** *Water Science and Technology, Volume 38, Issue 11, 4 December 1998, Pages 237-244*
- Schmitt, Theo and W. C. Huber (2005) **The scope of integrated modeling - system boundaries, sub-systems, scales and disciplines.** Proceedings of the 10th ICUD. Copenhagen
- Schütze, M.R.(1998). **Integrated simulation and optimum control of the urban wastewater system.** *Dissertation. Department of Civil Engineering, Imperial College of Science, London.*

List of Abbreviations

- BMP — Best Management Practise
- CSO — Combined Sewer Overflow
- FFST — First Flush Stormwater Tank
- Q_{347} — Flow which occurs on 347 days per year
- Q_{DWF} — Dry Weather Flow
- $Q_{I/I}$ — Infiltration/Inflow (Parasite Flow)
- Q_{rec} — Flow in the receiving water
- Q_{sep} — Separated Flow to the CSO (Combined Flow minus Q_{WWTP})
- Q_{WWTP} — Throttled flow to the WWTP
- SWT — StormWater Tank
- V_{FFST} — Volume of FFST
- WWTP — WasteWater Treatment Plant