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BIOMATH

Department of Applied Mathematics, Biometrics and Process Control

An integrated model for the Bleesbruck catchment, Luxembourg

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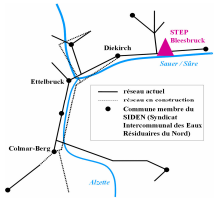
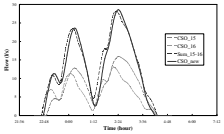
Presentation Outline

- Introduction
- The case study
- The integrated model
- Scenarios and Results
- Outlook





Introduction: Objectives

- Water Framework Directive
  - Holistic approach
  - « good » chemical and ecological status of natural waters: **Immission crititeria (combined to emission)**

River water quality evaluates the performance of the urban wastewater system

- CD4WC

Cost-effective optimisation of the integrated operation of the sewer and the WWTP for better river water quality

Introduction: Approach

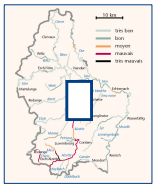
Objectives

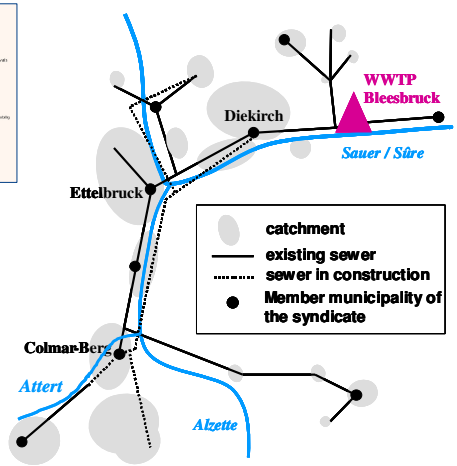
Case Study

Toolbox / Data | **Analysis**

Results

Case Study: Luxembourg





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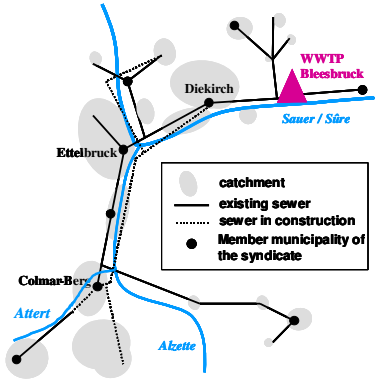
Case Study: Catchment



catchment

Area: ~ 10 km^2

~ 20 semi-rural subcatchments

Domestic discharges: ~ 25000 PE

Industrial discharges: ~ 30000 PE

sewer network

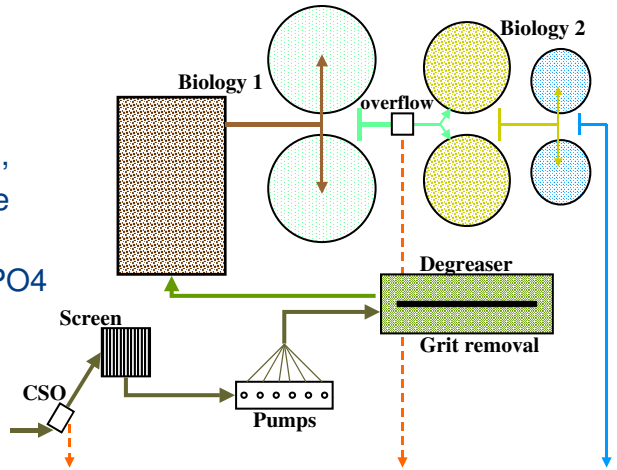
Length: ~ 60 km

+ new collector + new basins

Case Study: WWTP

Hydraulic capacity:
100000 PE

2 bio-units in series,
chemical phosphate precipitation,
online NH3, NO3, PO4 measurements



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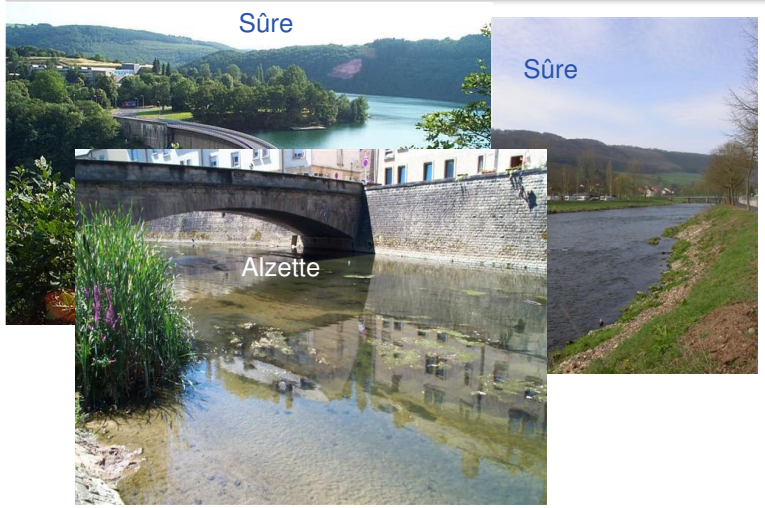
CENTRE DE RECHERCHE PUBLIC HENRI TUDOR
www.tudor.lu

Case Study: Receiving rivers

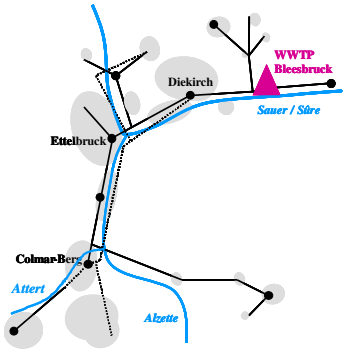


Case Study: Receiving rivers

3 river stretches

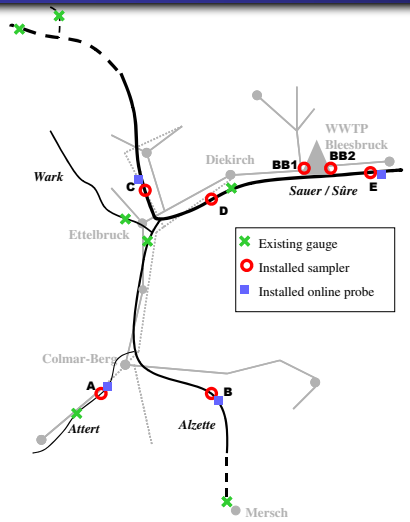
Length: ± 20 km

Base Flows: 3-15 m3/s



Case Study: Measurement Campaign

Water Quality



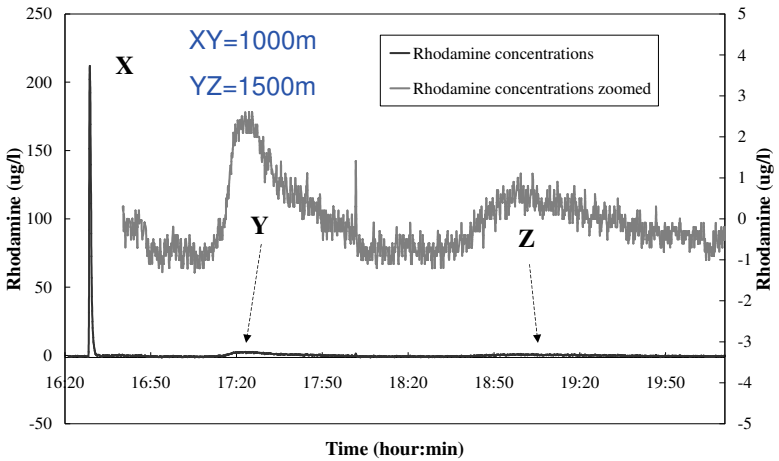
- DO, Temp
- BOD, COD particulate, COD soluble
- NH_3, NO_3, PO_4
- ChlA
- Suspended Solids

Case Study: Measurement Campaign

Water transport

Case Study: Measurement Campaign

Water transport

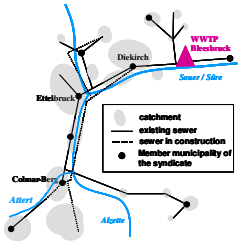


Case Study: Deficit Analysis (1)

Receiving Rivers

Immissions:

during summer low **DO**: < 5 mg/l
high ammonium: **NH4-N**: > 3 mg/l
high phosphate: **PO4-P**: ~ 0.5 mg/l
Localised high **algae** concentration



Pressures:

Alzette carrying wastewater from populated and industrial South of Luxembourg, agriculture,…

How much pressure is this catchment/WWTP exerting?

Case Study: Deficit Analysis (2)

WWTP

Emissions: (EU Urban Wastewater Directive, 1991)

Total nitrogen **TN**: > 15 mg/l
Total phosphorus: **TP**: > 2 mg/l (peaks)
No **denitrification**

Pressures:

Hydraulic overloading during wet weather flow conditions, bad nitrification and phosphate control due to on/off actuators, random sludge input from other WWTPs,…

Case Study: Deficit Analysis (3)

Sewer network

Emissions:

Localised CSO events (simulated and witnessed by operator, no measurements)

Pressures:

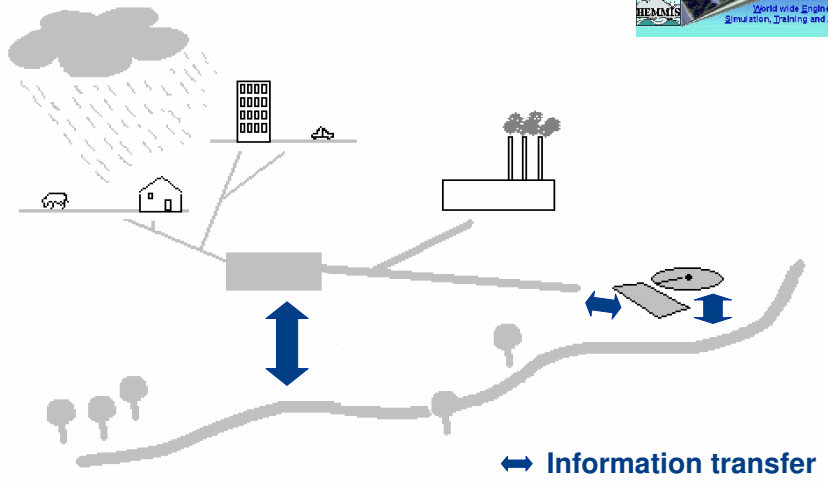
No storage volume until now, infiltration, river water intrusion during high flows in winter, not much control potential so far,…

Case Study: Objectives

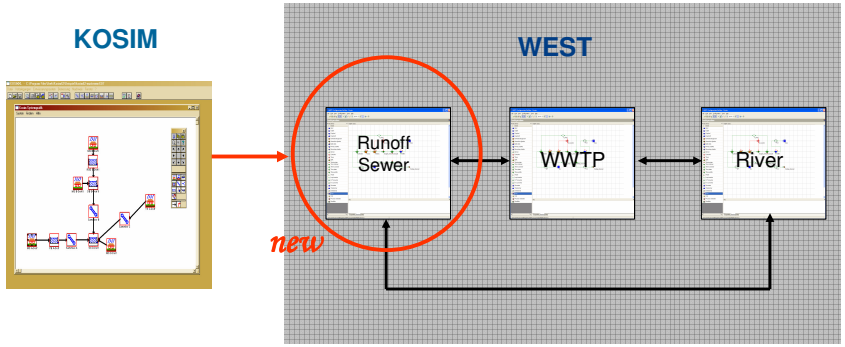
- **Measurement campaign** on the river and the WWTP (CD4WC).
- **Data collection** and deficit analysis
- **Model** building and calibration

1. **Develop scenarios** to improve quality of the eutrophied river and test them using simulatons of the integrated system.
2. Find **control strategies** for the ‘new’ system

Modelling & Simulation: Software

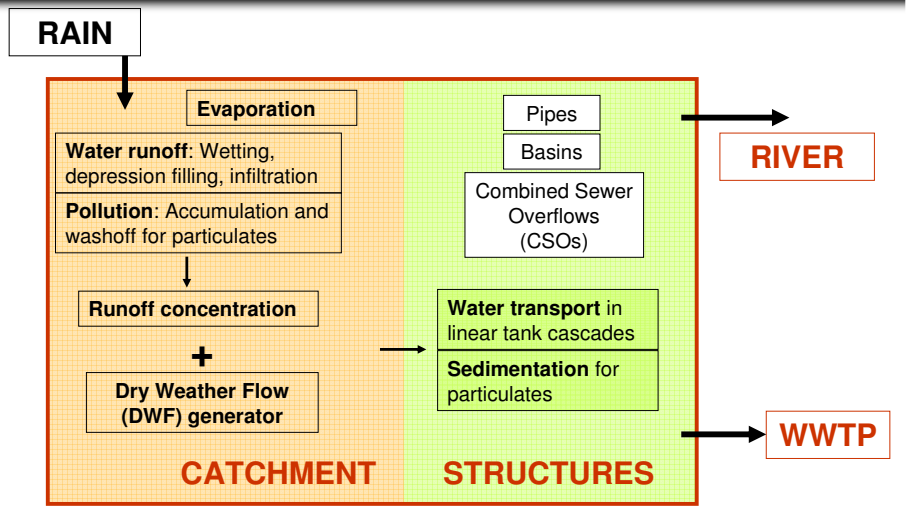


Modelling & Simulation: KOSIM-WEST

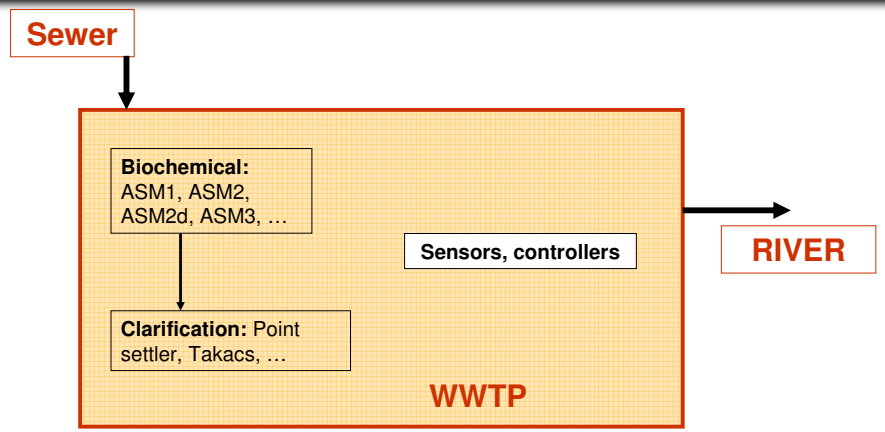


Jurgen Meirlaen, PhD Thesis (2002)

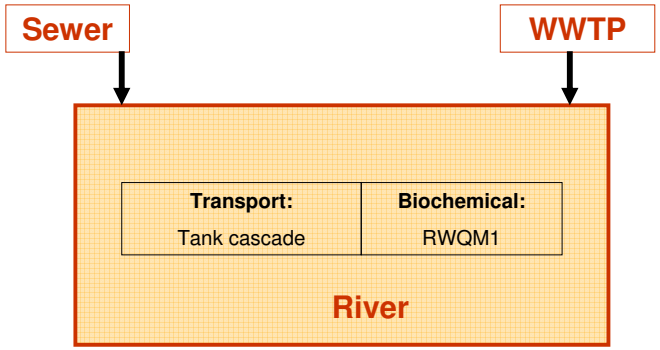
Modelling & Simulation: Catchment & Sewer



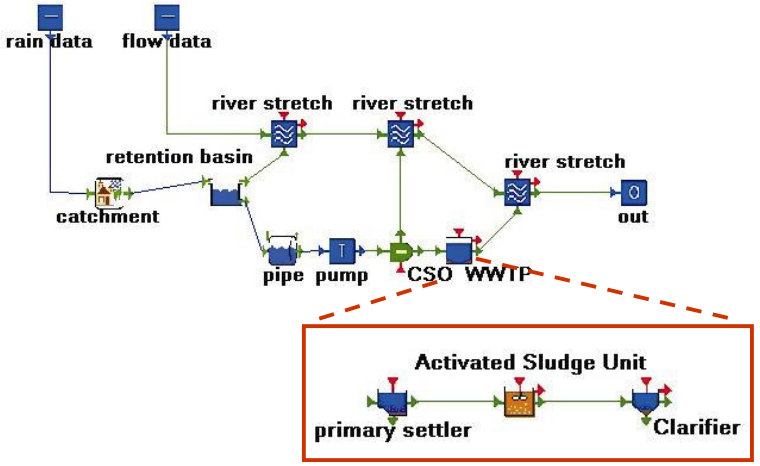
Modelling & Simulation: WWTP



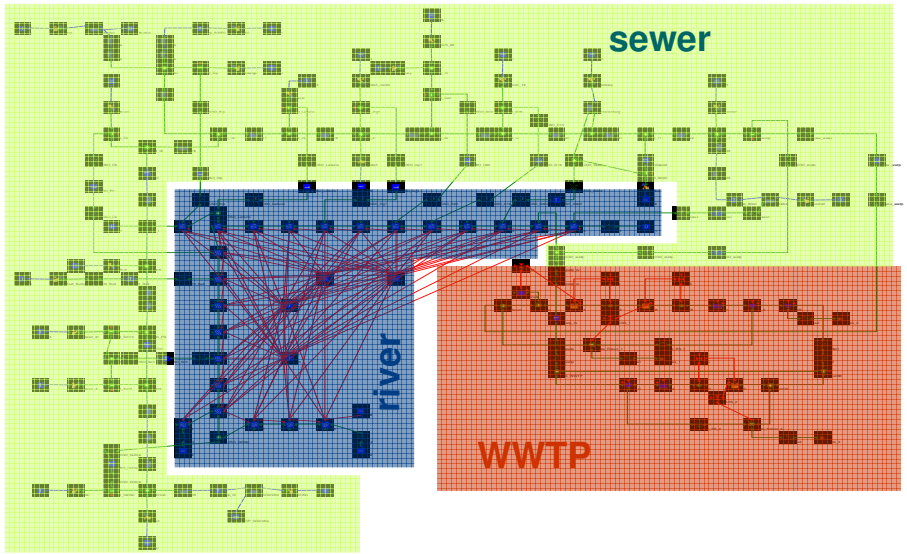
Modelling & Simulation: River



Modelling & Simulation: Modelling Approach (1)

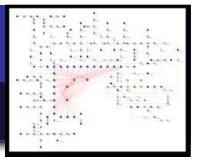


Modelling & Simulation: The Integrated Model



Bleesbruck Model

Catchment & Sewer Network (1)



- 20 catchments
- 4 basins / storage pipes
- 6 pumps
- 16 km main collector
- Reduction of CSOs down to 16

DATA USED:

Population and industry

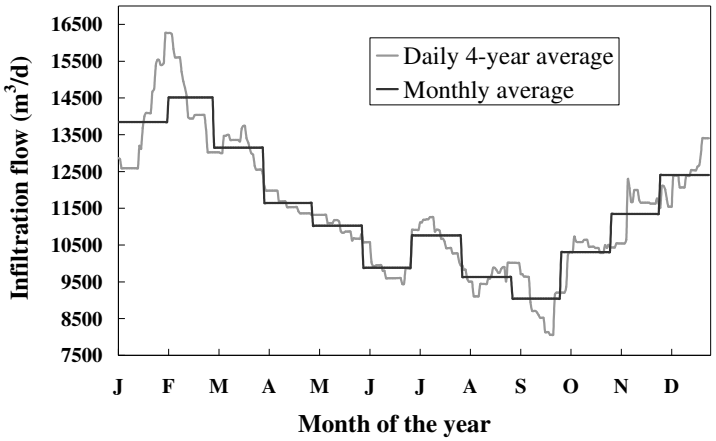
Surface characterisation

Geometric data for sewer

evaporation & infiltration

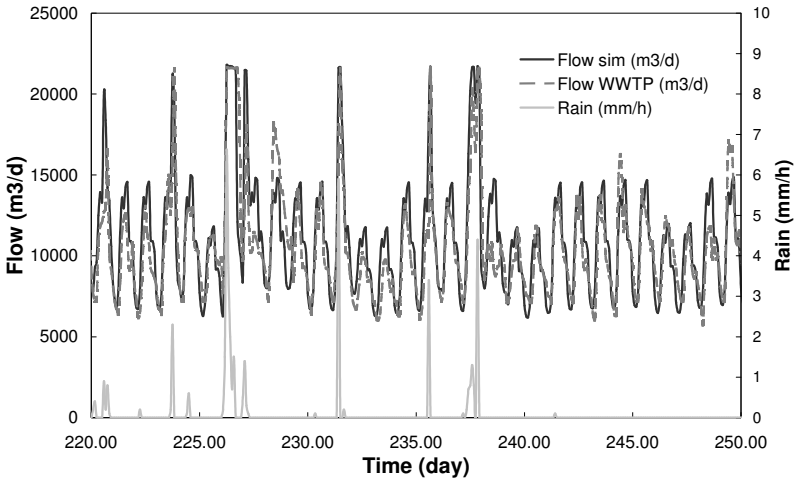
Bleesbruck Model

Catchment & Sewer Network (2): Infiltration



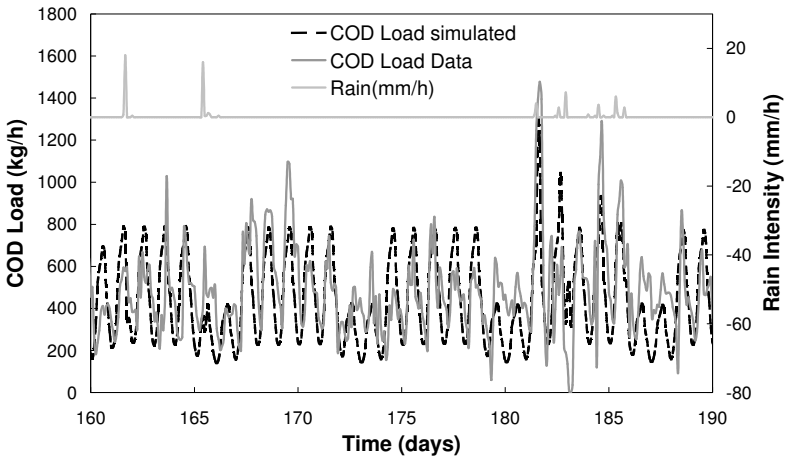
Bleesbruck Model

Catchment & Sewer Network (2): Yearly Calibration Results, 2005



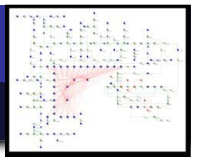
Bleesbruck Model

Catchment & Sewer Network (3): Yearly Calibration Results, 2005



Bleesbruck Model

WWTP (1)



- 2 activated sludge units in series (removal of COD, nitrification): ASM2d model
- Chemical phosporous removal by precipitation
- Clarification with ideal settlers

DATA USED:

WWTP dimensions

Water quality measurements

Influent characteristics

Operation schemes

Existing model

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Bleesbruck Model

WWTP (2): Weekly Calibrations

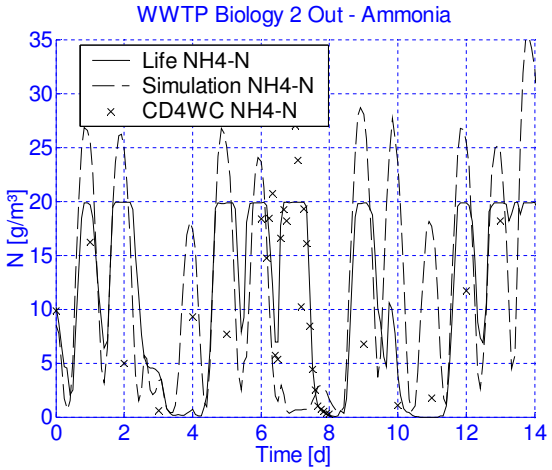
1st Biology parameter changes

		NEW	
μ_H	6.0	3.0	d^{-1}
b_H	0.6	1.2	d^{-1}
μ_{AUT}	1.0	1.5	d^{-1}
η_{NO3}	0.8	1.0	-

- Life project (from Simba to WEST)
- CD4WC project (influent from sewer simulations & measurement campaign)

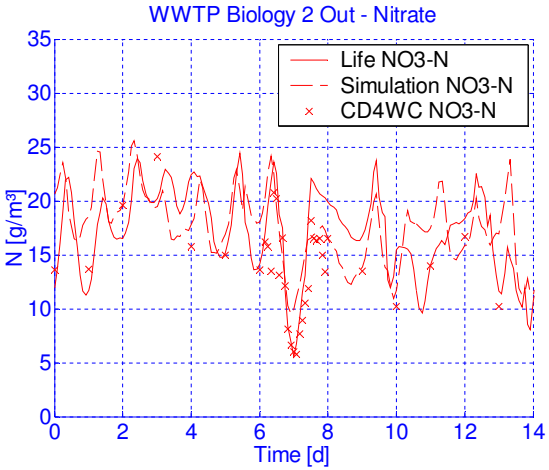
Bleesbruck Model

WWTP (3): Weekly CD4WC Calibration



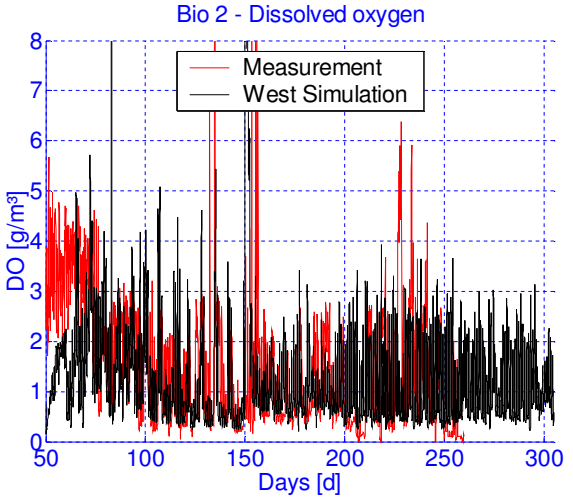
Bleesbruck Model

WWTP (3): Weekly CD4WC Calibration



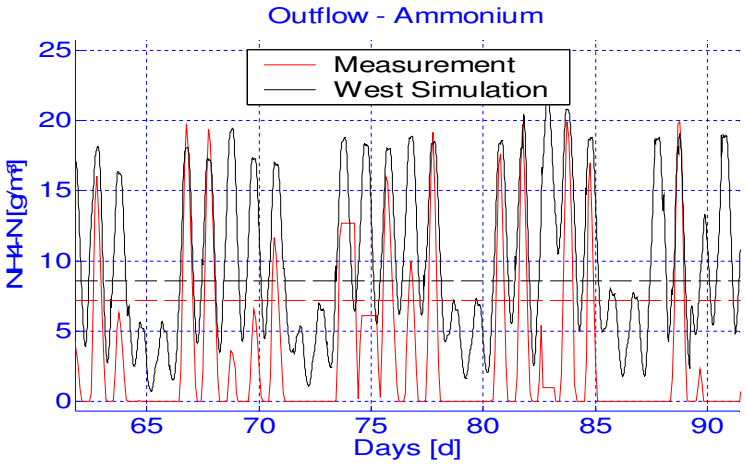
Bleesbruck Model

WWTP (4): Yearly Calibration, 2005



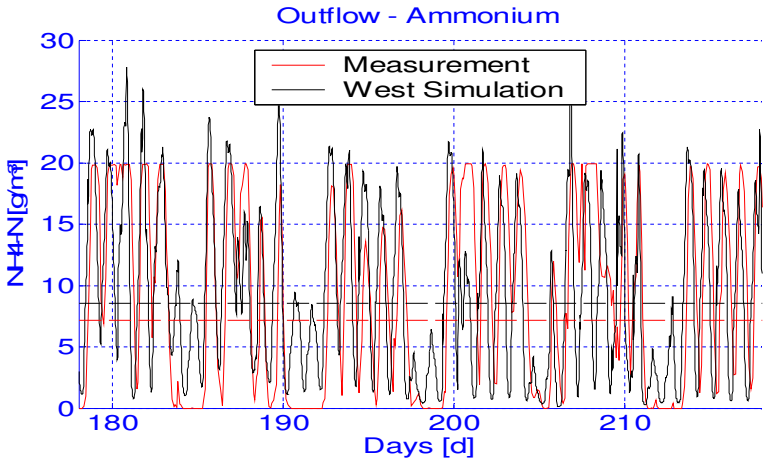
Bleesbruck Model

WWTP (5): Yearly Calibration, 2005



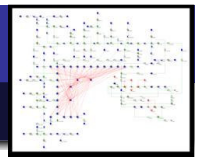
Bleesbruck Model

WWTP (5): Yearly Calibration, 2005



Bleesbruck Model

Receiving rivers (1)



- River: Tanks-in-series (transport)
  Simplified RWQM1
  - No pH
  - No macrophytes
  - Reaeration
  - Autotrophic growth and decay
  - Heterotrophic growth and decay
  - Algae growth
  - Hydrolysis

DATA USED:

Flow & Dispersion

Base pollutant concentrations

- Connectors:
  - Vanrolleghem et al. (2005)

Bleesbruck Model

Receiving rivers (2): Calibration

River parameter	Calibrated
Groundwater quantity (fraction of flow)	0.03
Groundwater temperature (°C)	12.5
Reaeration coefficient ($days^{-1}$)	2
Growth of algae ($days^{-1}$)	15
Radiation intensity saturation coefficient (W/m^{-1})	500
Saturation coefficient for algae (g/m^3)	5
Retention constant ($days^{-1}$)	0.015
Incoming biomass concentration (mg/l)	X_H = 6
	X_N1 = X_N2 = 0.3
Incoming algae concentration (mg/l)	dynamic

Scenario Analysis

Scenarios tested

- **Source control:**
  - Ammonia decoupling — FlatNH3
  - DWF flattening through basins at housing level — FlatDWF
  - Impervious surface reduction — RedImp
- **System rehabilitation**
  - Sewer infiltration reduction — RedInf
  - Retention basins — RetBas
  - Buffer tank for incoming sludges — Buffer
  - Nitrification volume increase — NitVol
- **Operation strategies**
  - Increase in WWTP loading — OvLo
  - Improved nitrogen control — ImprN
  - Improved phosphorus control — ImprP
- **River measures**
  - Shading — Sha
  - Reaeration — Reae

Scenario Analysis

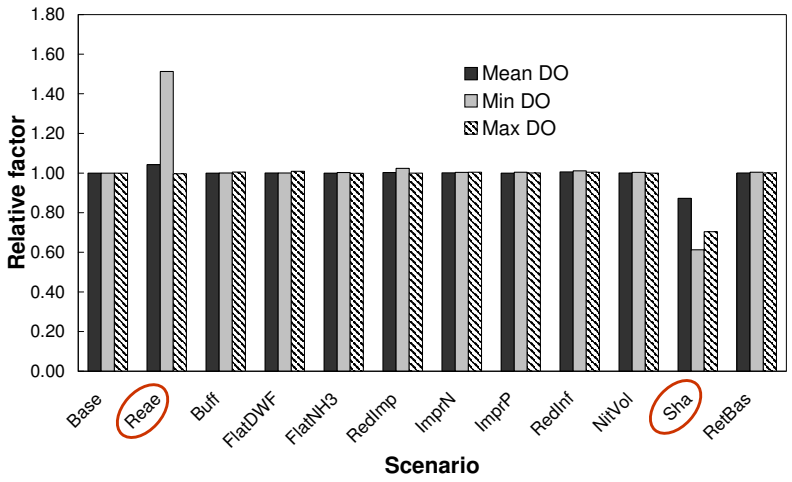
Evaluation criteria

Immission and Emission

- Exceedance lengths
- Number of exceedances
- Means
- Maxima
- Minima
- Total loads

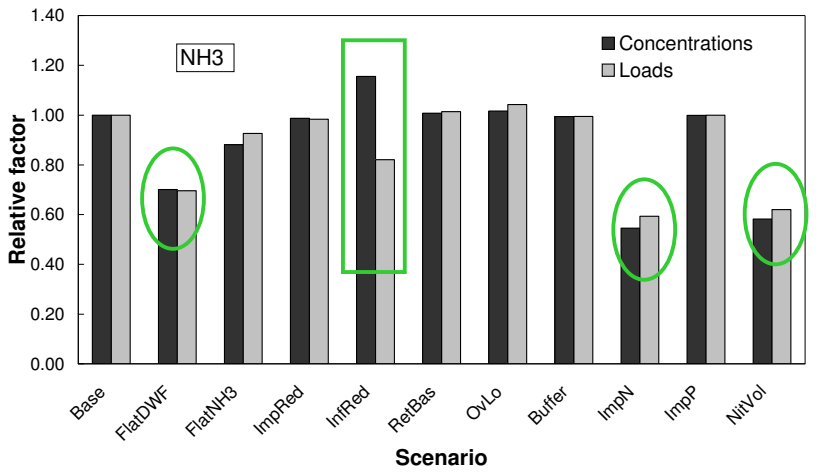
Scenario Analysis

Immission: Dissolved Oxygen



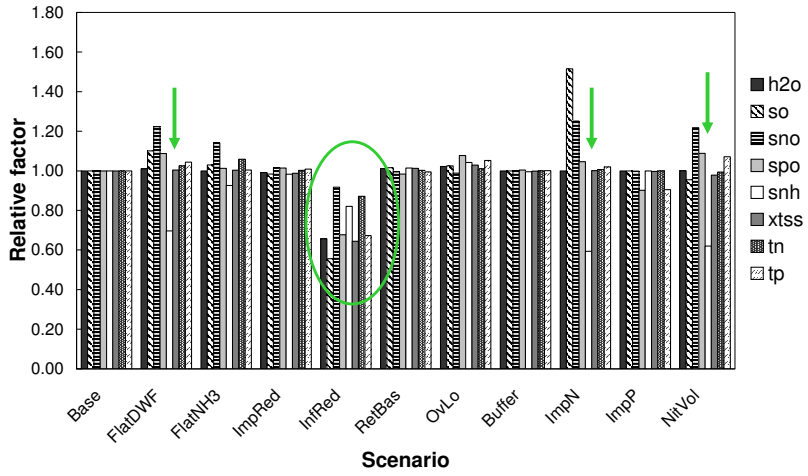
Scenario Analysis

Emissions: WWTP: NH3



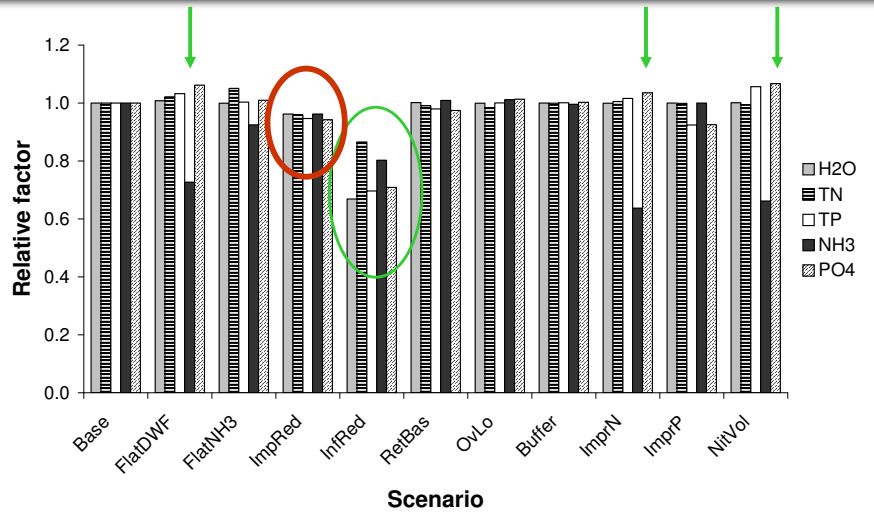
Scenario Analysis

Emission Loads from WWTP



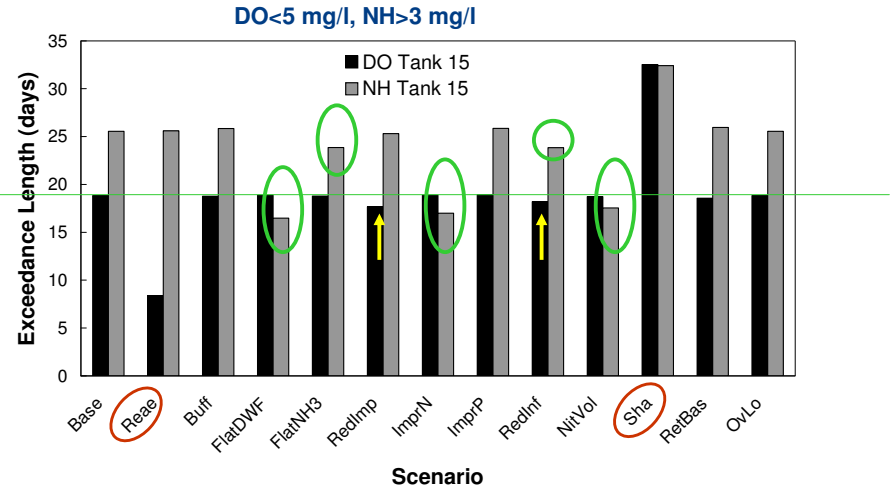
Scenario Analysis

Total Emission Loads from CSOs and WWTP



Scenario Analysis

Immission: Exceedances



Costs

Measure	Investments (€)	Operation (€)
FlatDWF	++++	
ImpRed	+++	
InfRed	?	
RetBas	+++	+
NitVol	++	
Buffer	+	
ImprN	+	
ImprP	0	0
OvLo	0	0
Reae	++	++

Conclusions (1)

- **Shading** not an option here
- **Reaeration** helps to improve DO concentrations, but is expensive
- **Background pollution** large compared to impact of catchment, therefore measures within the catchment seem to have little impact

Conclusions (2)

- Measures are often expensive, **ImprN** and **ImprP** cheap to implement bringing about good changes
- **InfRed** reduces loads significantly
- **ImpRed** shows beneficial impact (keep impervious surface to a minimum during planning processes

Perspectives

- **Event-based** analysis
- Scenario with **denitrification** at WWTP could be interesting
- Immision evaluation of scenarios in case of **low base flow** pollution in river

Improvements

- **River model**: more data will become available through another project: FluxAlzette
- **Sewer model**: further calibration of catchment runoff using on/off pumping data
- **Sewer model**: include parallel collector in a new updated model and test scenarios

Outlook

- Usefulness of integrated modelling
- Complexity of analysis of scenarios:
  - Immission and emission
  - Interactions between subsystems
  - Evaluation criteria
  - Combination of measures
- Test scenarios: before and after the construction of new retention basins; propose **operation strategies** for the operators of sewer and WWTP.

Thank you for your attention.

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The presented results have been elaborated in the framework of the European Project CD4WC of the CityNet cluster (FP5).

UGent-Biomath, Coupure Links 653, 9000 Gent, BE