weftec the water quality event™ Technical Sessions

Cost-effective solutions for river water quality improvement in Eindhoven supported by sewer-WWTP-river integrated modeling

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[6] Waterschap De Dommel, 5280 Boxtel, Netherlands

– The Kallisto project
– System definition
– Project approach
– Selection of measures
– Scenario analysis
– Conclusions

Waterschap De Dommel

gemeente Eindhoven

WATERSCHAP Vallei & Eem

Waterschap Brabantse Delta

stowa

WAGENINGEN UNIVERSITEIT
WAGENINGEN UR

UNIVERSITEIT GENT

WATERWAYS

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Agentschap NL
Ministerie van Infrastructuur en Milieu

kallisto
samen slim schoon

Together | Smart | Clean

Clean: Improving the receiving surface water quality to **comply** with the national legislation and the **EU Water Framework Directive**

Smart: Controlling storm water and wastewater flows by **cost-effective** control, buffering and treatment measures in the **Integrated** Urban Water System

Together: Involving different **stakeholders** in the water chain across the boundaries of responsibilities including municipalities, the waterboard, knowledge institutes and STOWA (dissemination)

The Eindhoven system

Complex combined wastewater system

Large area with severe impact on vulnerable surface water

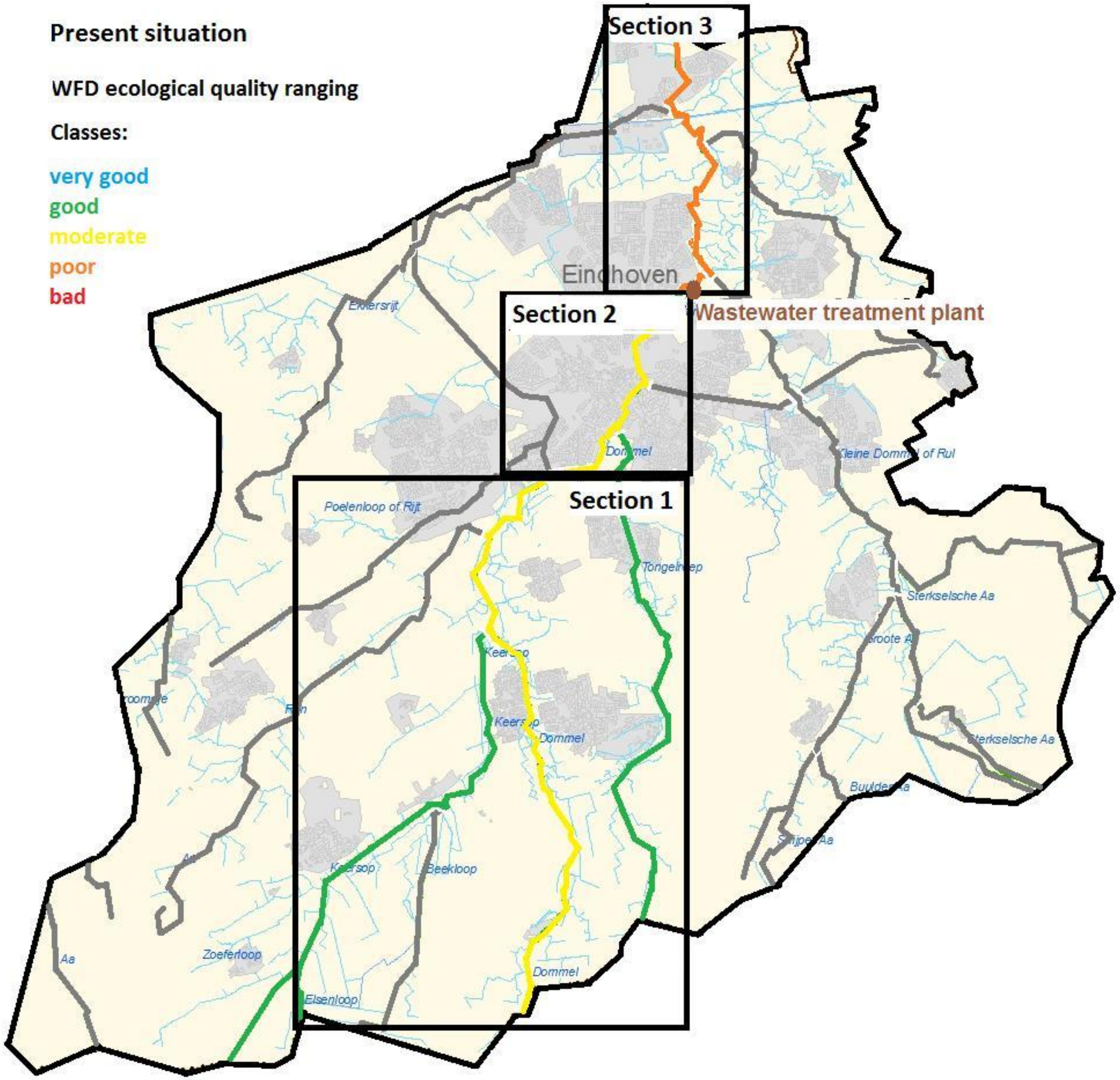
10 municipalities

750,000 PE WWTP

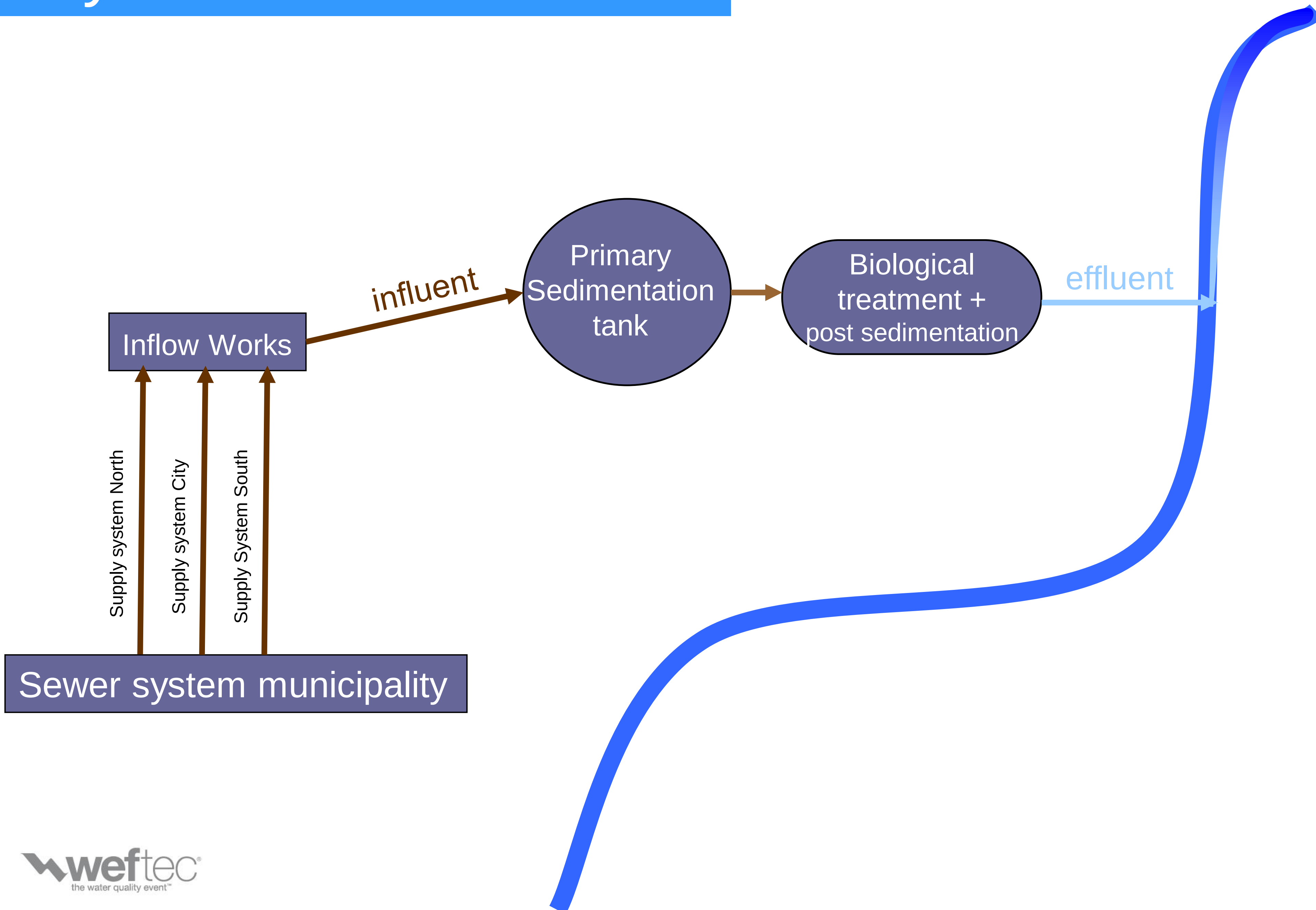
>200 CSOs

The Eindhoven WWTP

The Dommel River: ecological quality



Dry weather



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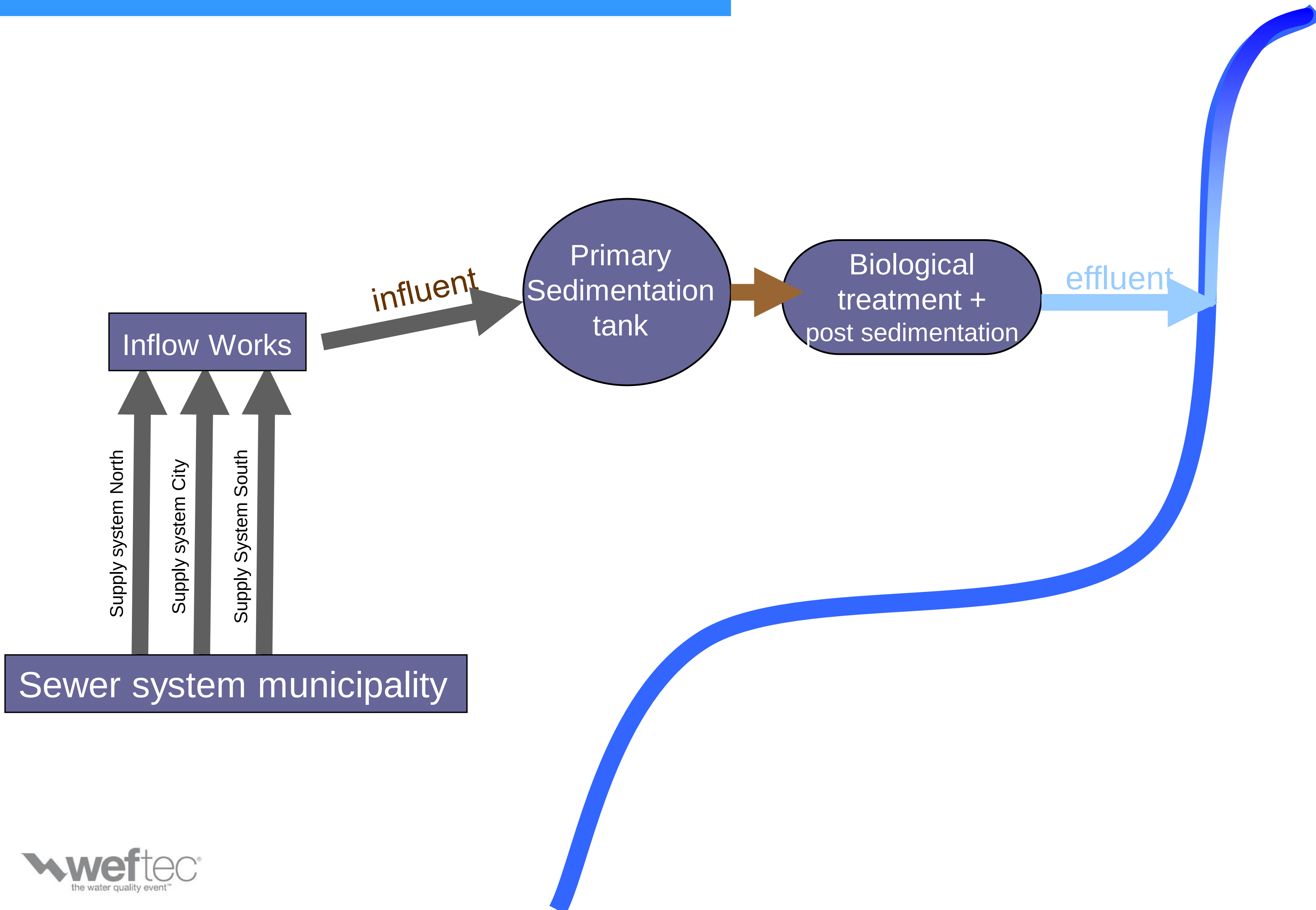
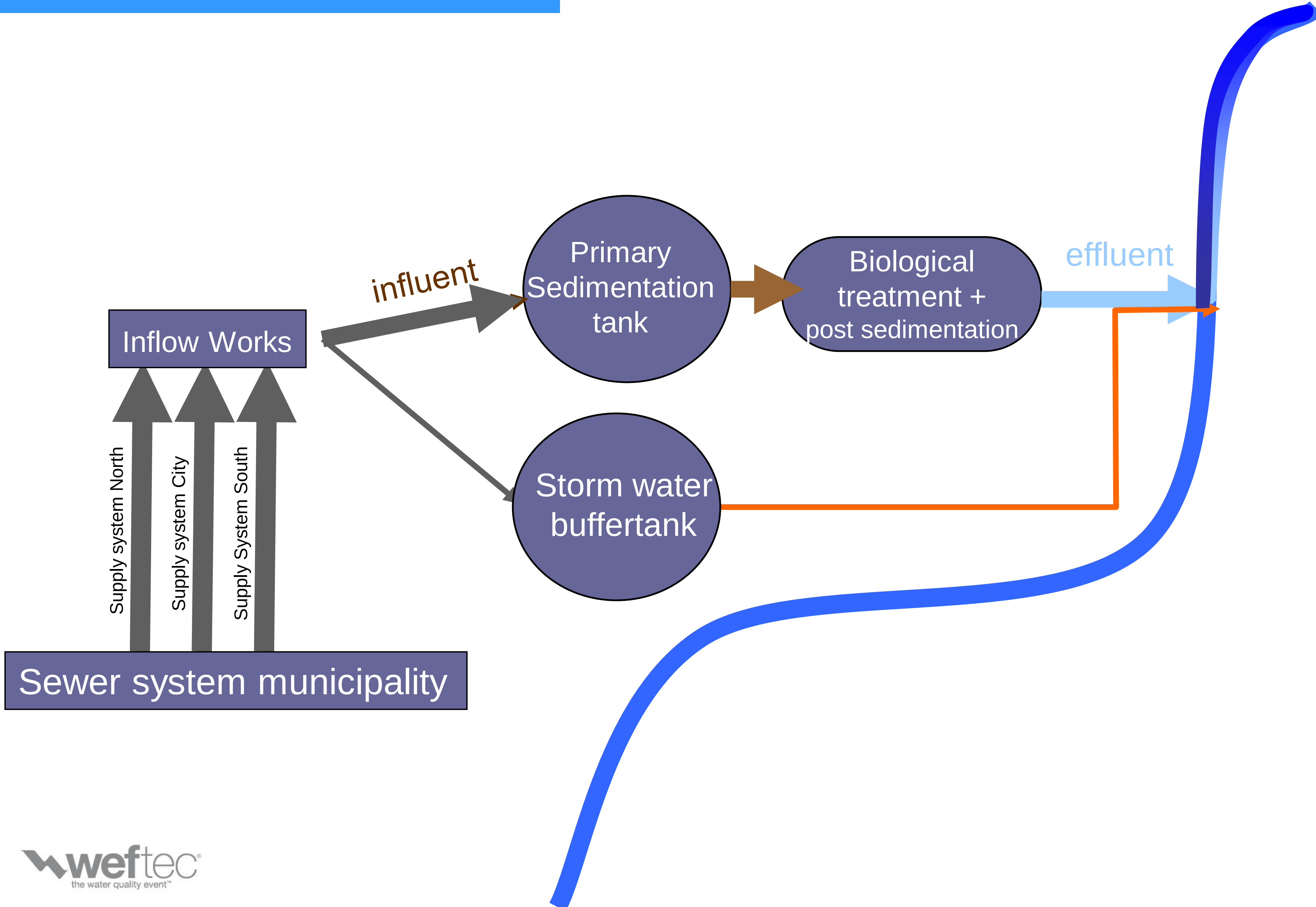
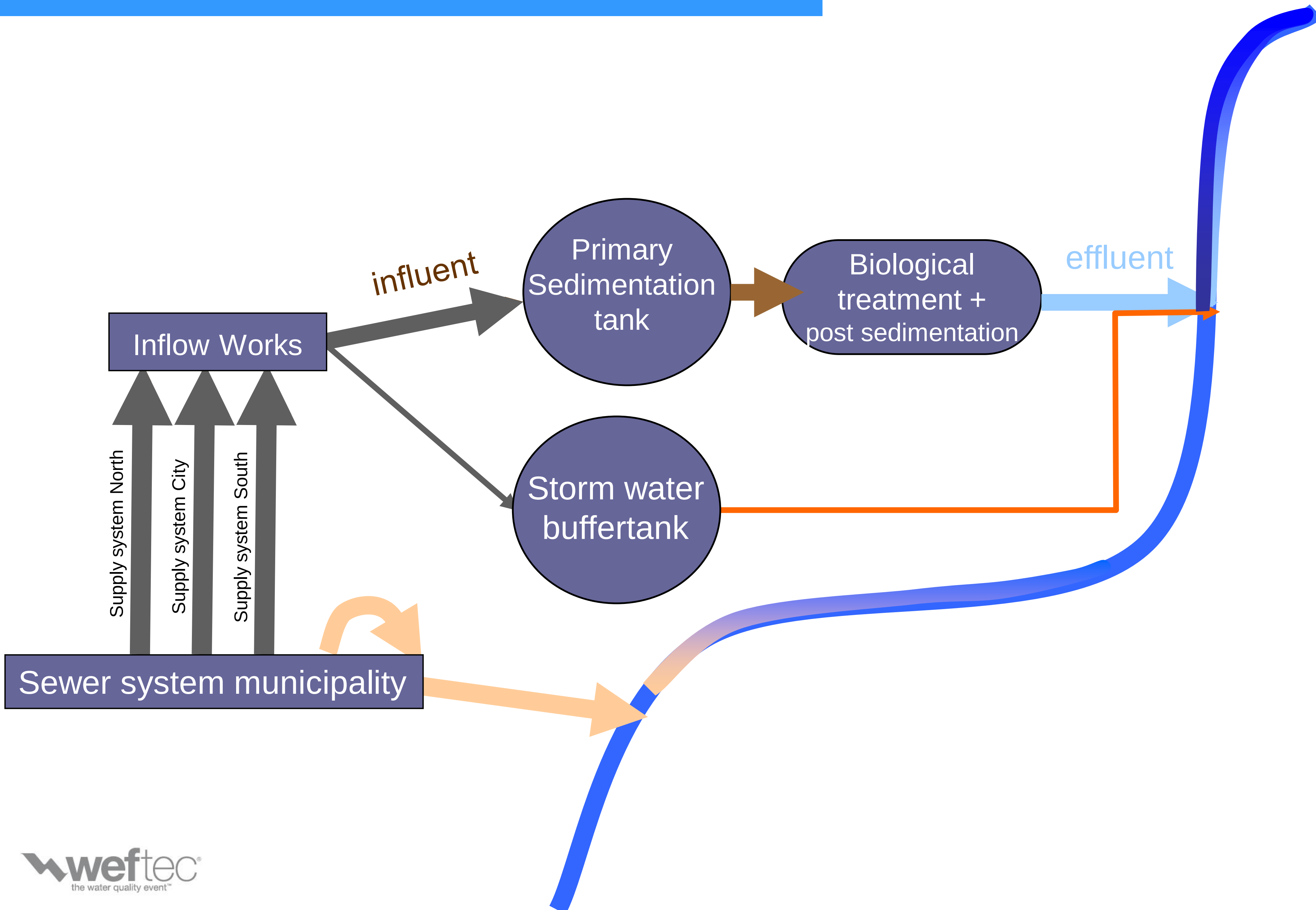
Rain weather



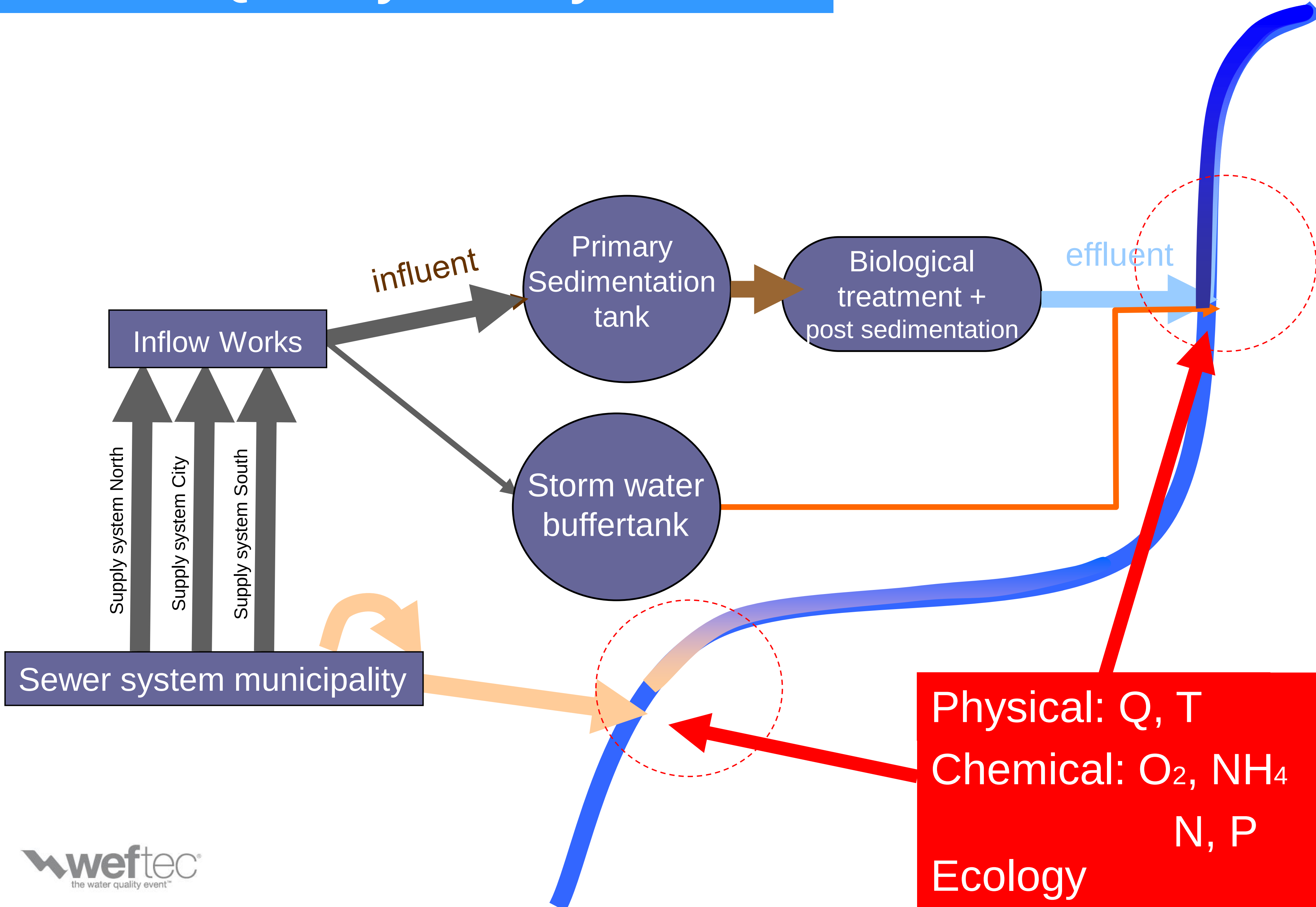
Storm weather



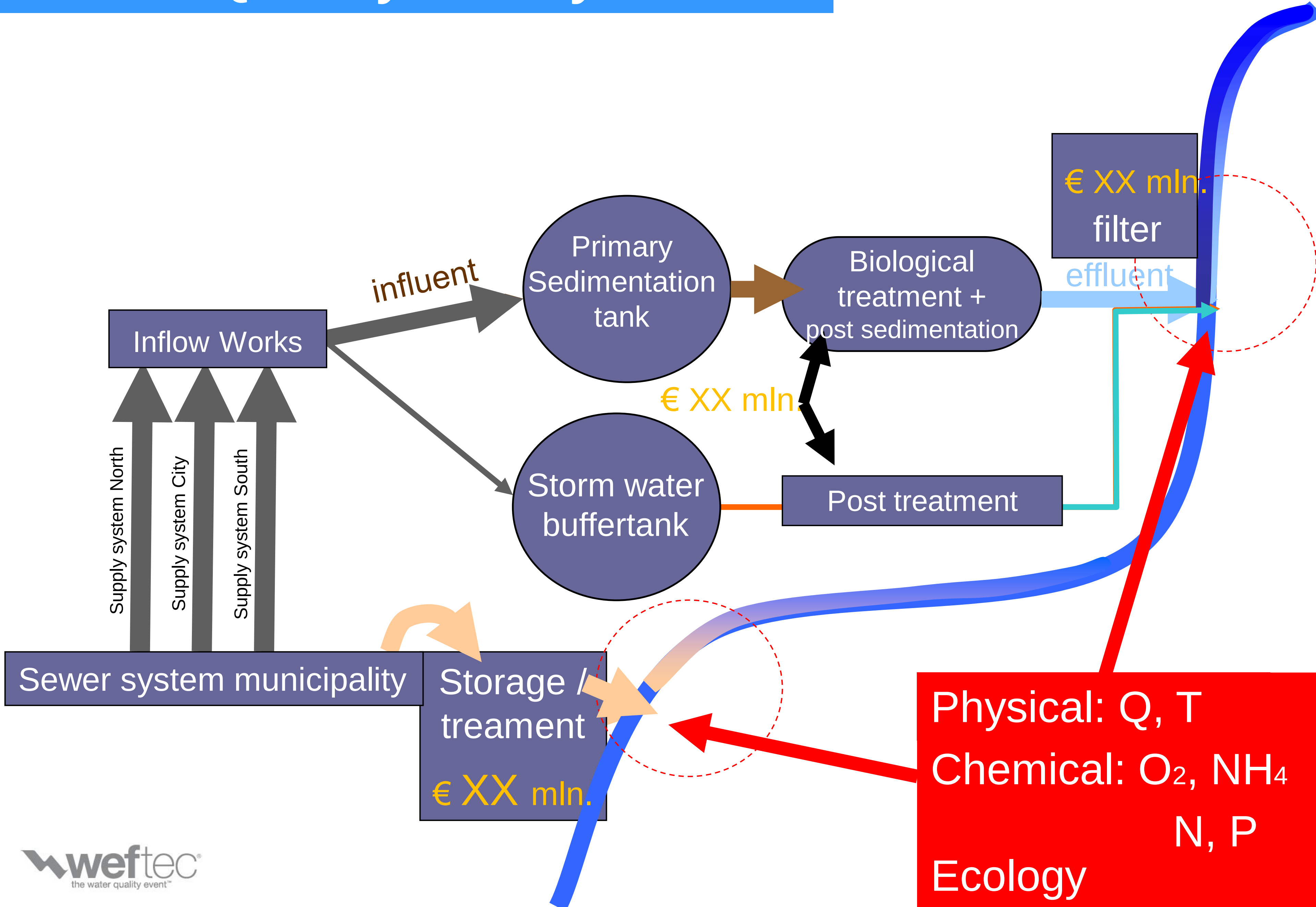
Storm weather + overflow



Water Quality Policy / WFD

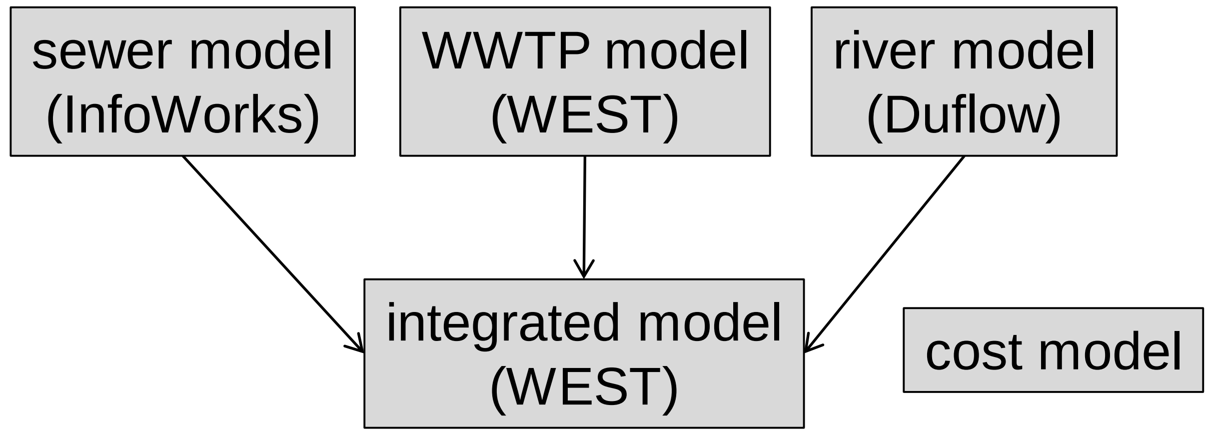


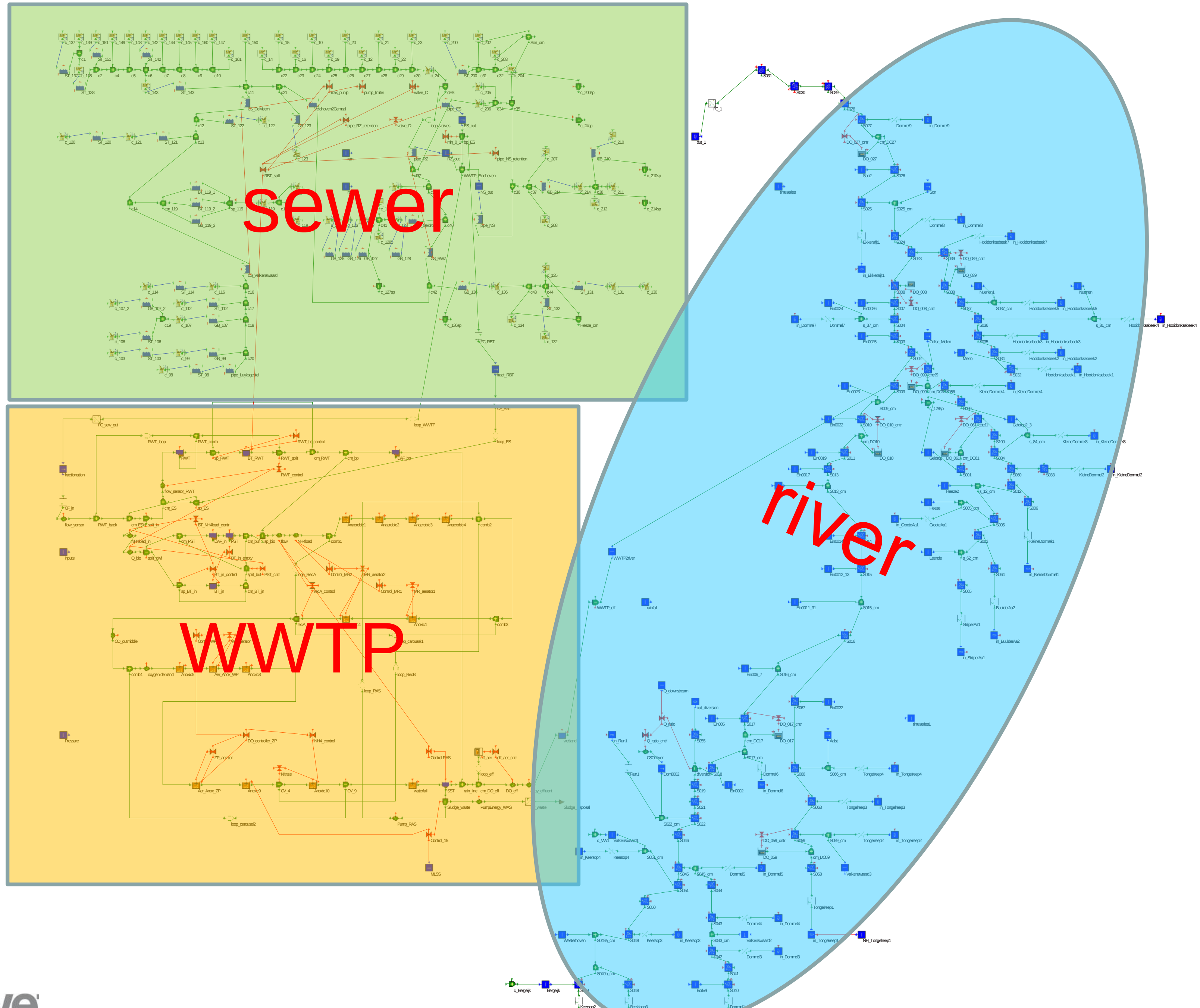
Water Quality Policy / WFD



Modeling (after monitoring)

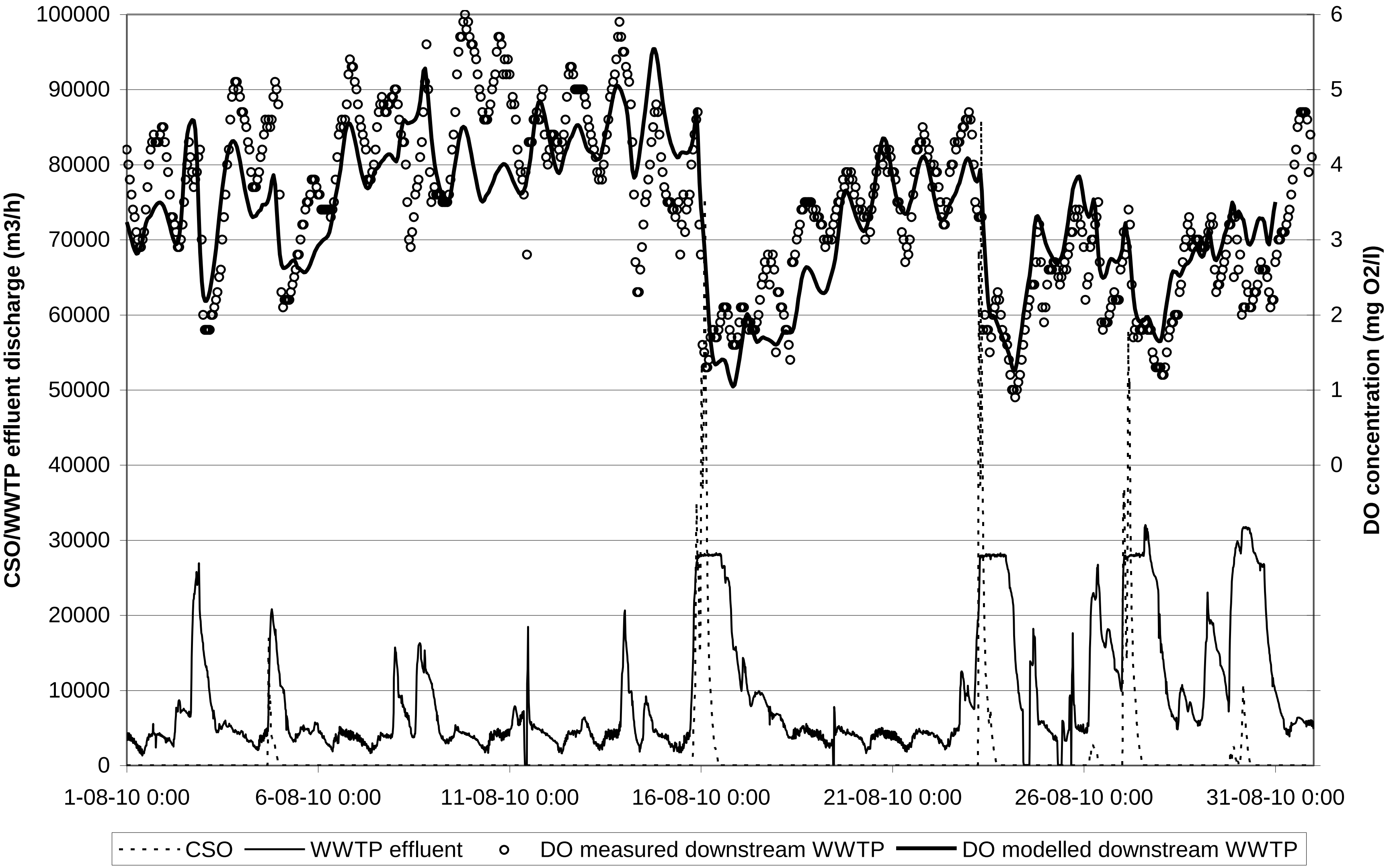
1. model development



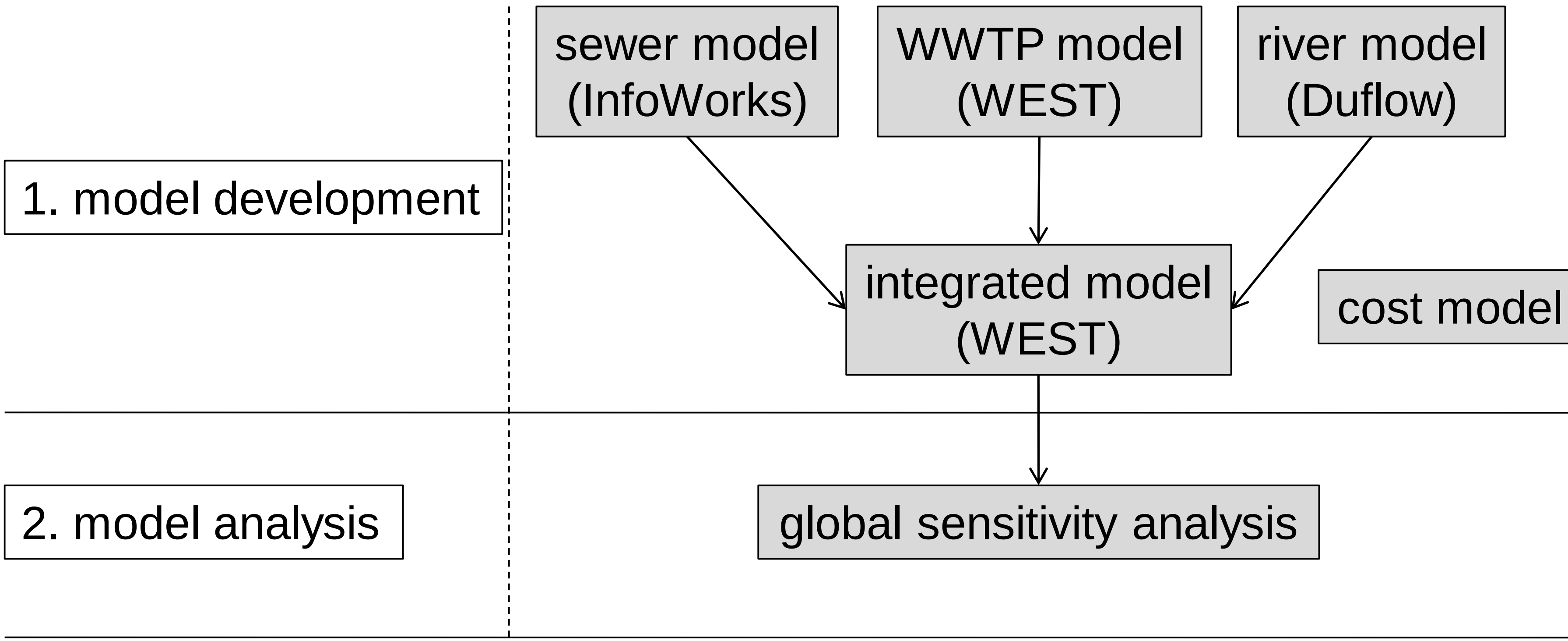

sewer
WWTP
river

- One single model:
  - Mass and information flows (impact on receiving water, RTC)
- Speed:
  - Many scenarios
  - Long-term simulation (10y in 2h)
  - Monte Carlo for UA/SA

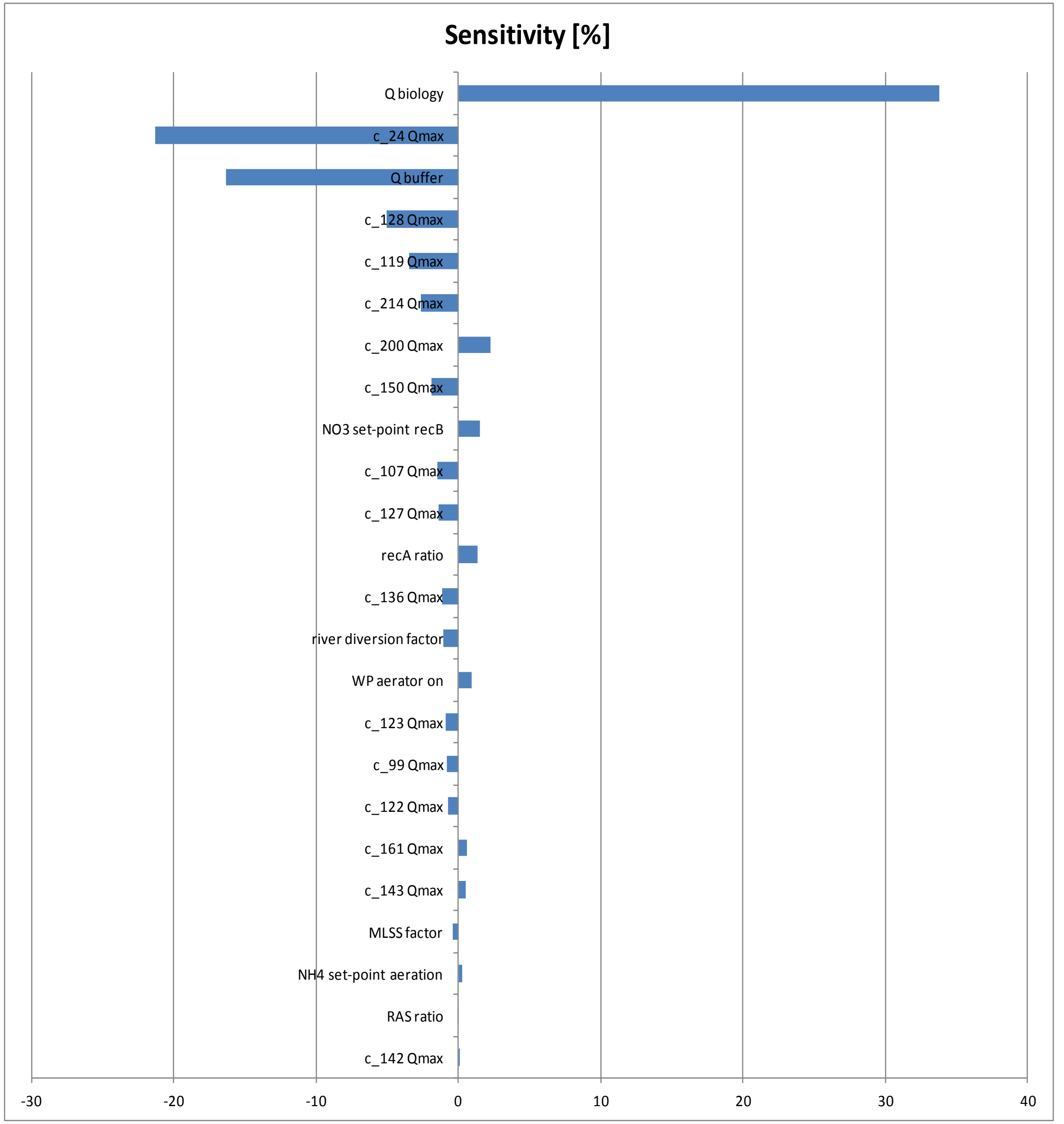
Integrated model results: DO at river section DS of WWTP



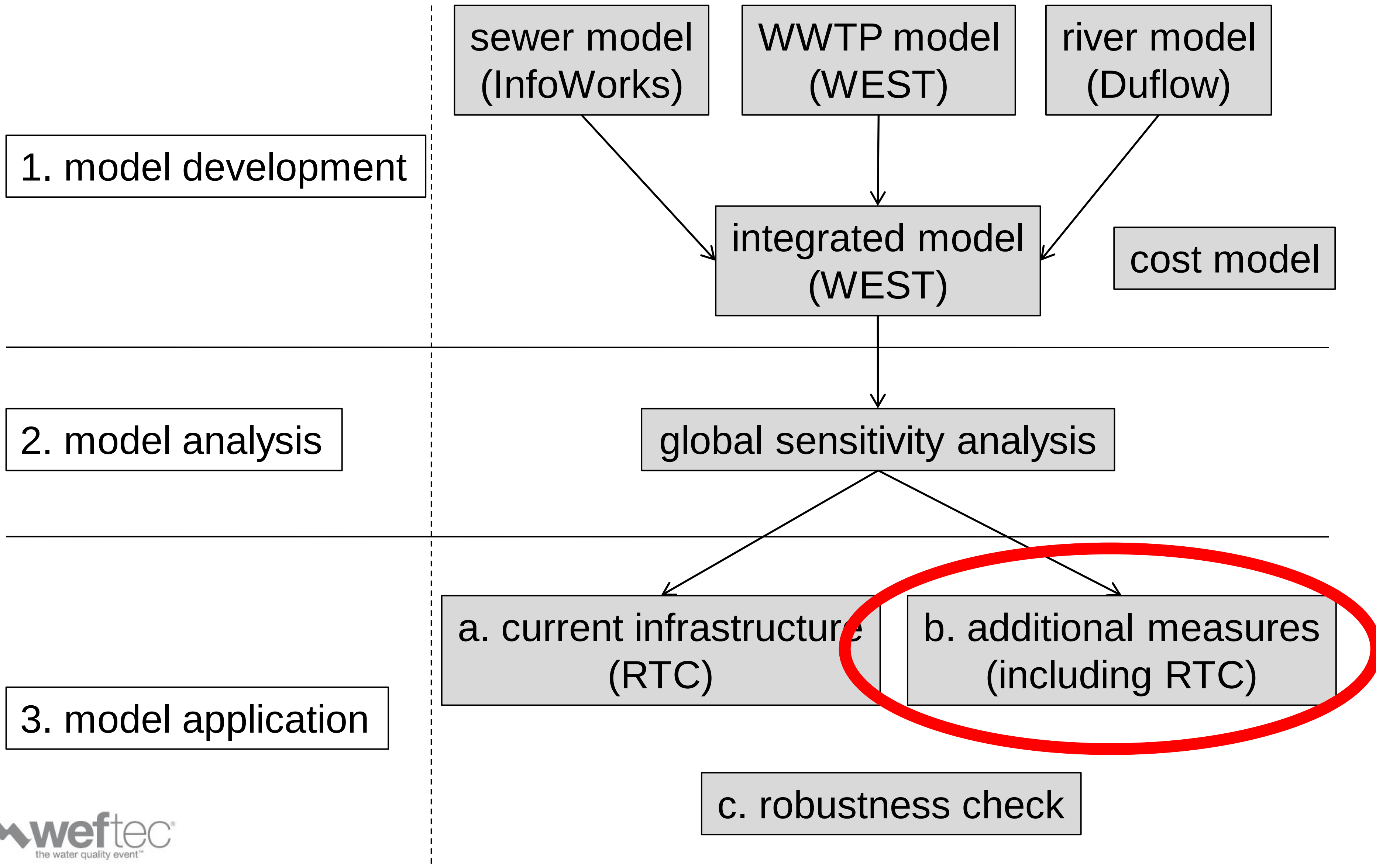
Modeling


sewer model (InfoWorks)
WWTP model (WEST)
river model (Duflow)
1. model development
integrated model (WEST)
cost model
2. model analysis
global sensitivity analysis

GSA: operational parameters ranking



Modeling


sewer model (InfoWorks)
WWTP model (WEST)
river model (Duflow)
1. model development
integrated model (WEST)
cost model
2. model analysis
global sensitivity analysis
a. current infrastructure (RTC)
b. additional measures (including RTC)
3. model application
c. robustness check

Measure	Field of application/objective
RTC in the sewer system	Minimisation of DO dips and/or NH_4 peaks in river with available system capacity
DAF, fine screens, lamella settler, fuzzy filter	Pre-treatment of wastewater during DWF Treatment of WWF
CSO storage	Reduction of CSO emissions
Dry buffers at WWTP inlet	Peak load shaving to reduce NH_4 concentration peaks in effluent
River aeration	Reduce DO dips in river
Effluent aeration	Reduce DO dips in river due to WWTP effluent
WWTP: additional aeration capacity, increase of MLSS and of aeration volume	Enhance nitrification process to reduce NH_4 peak concentrations in river
Equalisation pond/wetland	Equalisation of WWTP effluent to reduce NH_4 peak concentrations to the river
Increase interceptor/pumping capacities	Reduce DO dips in river
Increase hydraulic capacity of biological treatment at WWTP	reduce NH_4 peak concentrations and DO dips in river
Sand filter for treatment of WWTP effluent	Reduce N_{total} and P_{total} in effluent

Scenario analysis

– **10-year dynamic** simulations
– Approx. **40** different scenarios tested
– Evaluation
    - Ecological framework based on **concentration-duration-frequency** curves for sensitive species
    - Focus on **DO** and **NH_4**
    - Costs (**CAPEX** and **OPEX**)

Scenario analysis: costs

Costs of measures to reduce **DO** depletion and achieve basic DO levels

Measure	Investment	CAPEX	OPEX
Additional storage	€ 79,800,000	€ 3,830,000	€ 79,500
River aeration	€ 1,040,000	€ 96,700	€ 117,000

Scenario analysis: costs

Reference scenario:

- conventional methods of solving water quality issues (**uncoupling** of paved area, building sewer **storage** facilities at CSOs)
- yearly cost (CAPEX+OPEX) approximately **€ 15 million**

Scenario analysis: costs

Scenario	A	B	C
Measure in all scenarios	River aeration + effluent aeration Sand filter for effluent filtration RTC aiming at reducing NH_4 concentration peaks Additional aeration capacity at WWTP		
Measures	dry storage	wetland	DAF pre-treatment
Investment	€ 160,140.000	€ 90,410.000	€ 36,780.000
CAPEX	€ 11,295,000/year	€ 8,328,000/year	€ 3,052,000/year
OPEX	€ 3,670,00/year	€ 3,194,000/year	€ 4,641,000/year
Total annual costs (CAPEX + OPEX)	*€ 14,965,000/year*	*€ 11,522,000/year*	***€ 7,693,000/year***

Scenario analysis: water quality

current situation

WWTP

NH_4	*Duration of the event*				S066						S000						S017						S010						S008						S031					
		1 - 5 h	**6 - 24 h**	**> 24 h**																																				
Tolerated	**12**	1.5	0.7	0.3	1	2	1	0.6	6.1	2.8	1	1	1	0.3	1.6	0.2	1	4	2	0.6	18.7	6.5	1	2	2	1.4	8.1	9.5	4	5	5	22.6	77.4	38.6	2	5	5	11.7	60.2	45.6
frequency	**4**	2	1.2	0.5	1	1	1	0.0	1.6	0.9	1	1	1	0.0	0.1	0.1	1	2	3	0.0	2.4	4.3	1	1	2	0.8	1.7	3.3	5	5	5	31.0	65.1	40.1	5	5	5	12.9	54.4	36.8
per year	**1**	2.5	1.5	0.7	1	2	2	0.0	0.7	0.6	1	1	1	0.0	0.0	0.1	1	2	4	0.0	0.7	1.8	1	2	4	0.0	1.0	1.5	5	5	5	32.5	51.0	16.9	5	5	5	11.1	41.3	18.9
	0.2	4.5	3	1.5	1	1	1	0.0	0.0	0.1	1	1	1	0.0	0.0	0.1	1	1	4	0.0	0.0	0.4	1	1	1	0.0	0.0	0.1	5	5	5	4.3	2.2	0.6	1	5	4	0.0	0.7	0.3

DO critical	*Duration of the event*				S066						S000						S017						S010						S008						S031					
		1 - 5 h	**6 - 24 h**	**> 24 h**																																				
Tolerated	**12**	5.5	6	7	1	1	1	0.6	4.8	4.0	1	4	4	2.0	16.2	22.0	1	3	3	4.8	13.4	12.6	1	2	2	2.2	9.0	11.8	2	5	5	6.2	35.3	28.3	1	5	5	4.1	38.6	30.7
frequency	**4**	4	5.5	6	1	2	1	0.2	2.2	0.7	1	5	4	0.2	8.7	6.0	2	5	4	2.3	9.5	5.7	1	3	3	0.9	4.8	4.1	3	5	5	4.2	36.0	26.3	1	5	5	1.0	23.9	18.8
per year	**1**	3	4.5	5.5	1	2	2	0.1	0.9	0.6	1	5	5	0.0	2.1	2.6	2	5	5	0.7	5.0	3.6	1	4	5	0.2	1.3	2.5	4	5	5	1.5	20.5	19.7	1	5	5	0.3	9.0	11.6
	0.2	1.5	2	3	1	1	1	0.0	0.0	0.1	1	1	1	0.0	0.0	0.0	1	1	1	0.0	0.0	0.1	1	5	5	0.0	0.5	0.9	1	5	5	0.0	0.7	2.2	1	4	5	0.1	0.4	1.5

DO basic	*Duration of the event*				S066						S000						S017						S010						S008						S031					
		1 - 5 h	**6 - 24 h**	**> 24 h**																																				
Tolerated	**12**	3	3.5	4	1	1	1	0.1	0.2	0.1	1	1	1	0.0	0.3	0.2	1	1	1	0.7	1.5	0.6	1	1	1	0.2	0.5	1.6	1	2	2	1.5	6.7	6.3	1	1	1	0.3	1.6	2.2
frequency	**4**	2.5	3	3.5	1	1	1	0.0	0.0	0.1	1	1	1	0.0	0.0	0.1	1	1	1	0.0	0.3	0.2	1	1	1	0.2	1.1	1.5	1	2	2	0.3	2.4	3.5	1	1	1	0.2	0.8	1.7
per year	**1**	2	2.5	3	1	1	1	0.0	0.0	0.1	1	1	1	0.0	0.0	0.0	1	1	1	0.1	0.2	0.1	1	2	2	0.1	1.0	0.9	1	4	5	0.3	1.4	2.2	1	3	4	0.0	1.1	1.5
	0.2	1	1.5	2	1	1	1	0.0	0.0	0.0	1	1	1	0.0	0.0	0.0	1	1	1	0.0	0.0	0.1	1	4	5	0.1	0.4	0.5	1	5	5	0.1	0.6	1.1	1	4	4	0.0	0.3	0.3

Scenario analysis: water quality

scenario C
(RTC + riv.aer. + DAF)

WWTP ↓

NH_4	Duration of the event				S066						S000						S017						S010						S008						S031					
		1 - 5 h	6 - 24 h	> 24 h																																				
Tolerated	12	1.5	0.7	0.3	1	2	1	0.6	6.1	2.8	1	1	1	0.3	1.6	0.2	1	4	2	0.4	14.8	6.8	1	2	2	1.9	7.2	9.4	1	2	2	3.2	8.0	8.1	1	1	2	0.7	6.0	6.8
frequency	4	2	1.2	0.5	1	1	1	0.0	1.6	0.9	1	1	1	0.0	0.1	0.1	1	1	3	0.0	1.4	4.6	1	1	2	0.9	1.8	3.4	1	2	1	0.4	2.1	0.7	1	1	1	0.0	1.3	0.7
per year	1	2.5	1.5	0.7	1	2	2	0.0	0.7	0.6	1	1	1	0.0	0.0	0.1	1	1	4	0.0	0.5	1.9	1	2	4	0.0	0.9	1.4	1	1	1	0.0	0.3	0.2	1	1	1	0.0	0.2	0.1
	0.2	4.5	3	1.5	1	1	1	0.0	0.0	0.1	1	1	1	0.0	0.0	0.1	1	1	4	0.0	0.0	0.3	1	1	1	0.0	0.0	0.1	1	1	1	0.0	0.0	0.1	1	1	1	0.0	0.0	0.1

DO critical	Duration of the event																																							
		1 - 5 h	6 - 24 h	> 24 h																																				
Tolerated	12	5.5	6	7	1	1	1	0.3	4.2	3.9	1	1	2	0.0	0.0	9.8	1	2	2	0.0	8.0	8.4	1	1	2	0.0	0.0	10.5	1	1	1	0.0	0.0	0.9	1	1	2	0.0	0.1	8.0
frequency	4	4	5.5	6	1	1	1	0.1	2.0	0.7	1	1	1	0.0	0.0	0.0	1	1	1	0.0	0.0	1.4	1	1	1	0.0	0.0	0.0	1	1	1	0.0	0.0	0.0	1	1	1	0.0	0.0	0.1
per year	1	3	4.5	5.5	1	1	1	0.0	0.3	0.2	1	1	1	0.0	0.0	0.0	1	1	1	0.0	0.0	0.0	1	1	1	0.0	0.0	0.0	1	1	1	0.0	0.0	0.0	1	1	1	0.0	0.0	0.0
	0.2	1.5	2	3	1	1	1	0.0	0.0	0.0	1	1	1	0.0	0.0	0.0	1	1	1	0.0	0.0	0.0	1	1	1	0.0	0.0	0.0	1	1	1	0.0	0.0	0.0	1	1	1	0.0	0.0	0.0

DO basic	Duration of the event																																							
		1 - 5 h	6 - 24 h	> 24 h																																				
Tolerated	12	3	3.5	4	1	1	1	0.0	0.0	0.1	1	1	1	0.0	0.0	0.0	1	1	1	0.0	0.0	0.0	1	1	1	0.0	0.0	0.0	1	1	1	0.0	0.0	0.0	1	1	1	0.0	0.0	0.0
frequency	4	2.5	3	3.5	1	1	1	0.0	0.0	0.0	1	1	1	0.0	0.0	0.0	1	1	1	0.0	0.0	0.0	1	1	1	0.0	0.0	0.0	1	1	1	0.0	0.0	0.0	1	1	1	0.0	0.0	0.0
per year	1	2	2.5	3	1	1	1	0.0	0.0	0.0	1	1	1	0.0	0.0	0.0	1	1	1	0.0	0.0	0.0	1	1	1	0.0	0.0	0.0	1	1	1	0.0	0.0	0.0	1	1	1	0.0	0.0	0.0
	0.2	1	1.5	2	1	1	1	0.0	0.0	0.0	1	1	1	0.0	0.0	0.0	1	1	1	0.0	0.0	0.0	1	1	1	0.0	0.0	0.0	1	1	1	0.0	0.0	0.0	1	1	1	0.0	0.0	0.0

Conclusions

Integrated model used to describe the **dynamics** of the whole urban wastewater system and evaluate **cost-effective** upgrade scenarios to comply with specific **water quality regulation**

Several upgrade options are available to achieve the desired water quality in terms of **DO** and **NH_4**

There are **substantial cost differences** between scenarios, with clear advantages in using **in-stream aeration** for DO depletion and WWTP **DAF** pre-treatment for NH_4 peaks

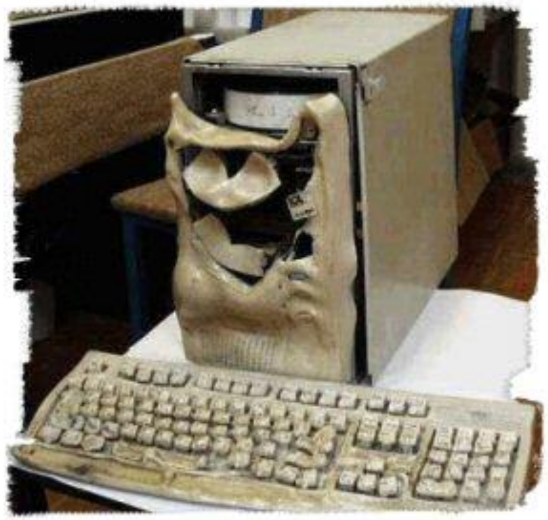
The integrated model proved to be a very powerful tool to quickly investigate **interactions**, **synergies** and **conflicts** in the system

Perspectives

Next 2 years implementation:

- Sewer RTC
- WWTP higher inflow + RTC upgrade
- DAF demo 1500 m^3/h
- River aeration one station upstream WWTP

THANK YOU !!!



more details on RTC Wed 10:30 session **87**

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