Integrated modeling of urban water systems

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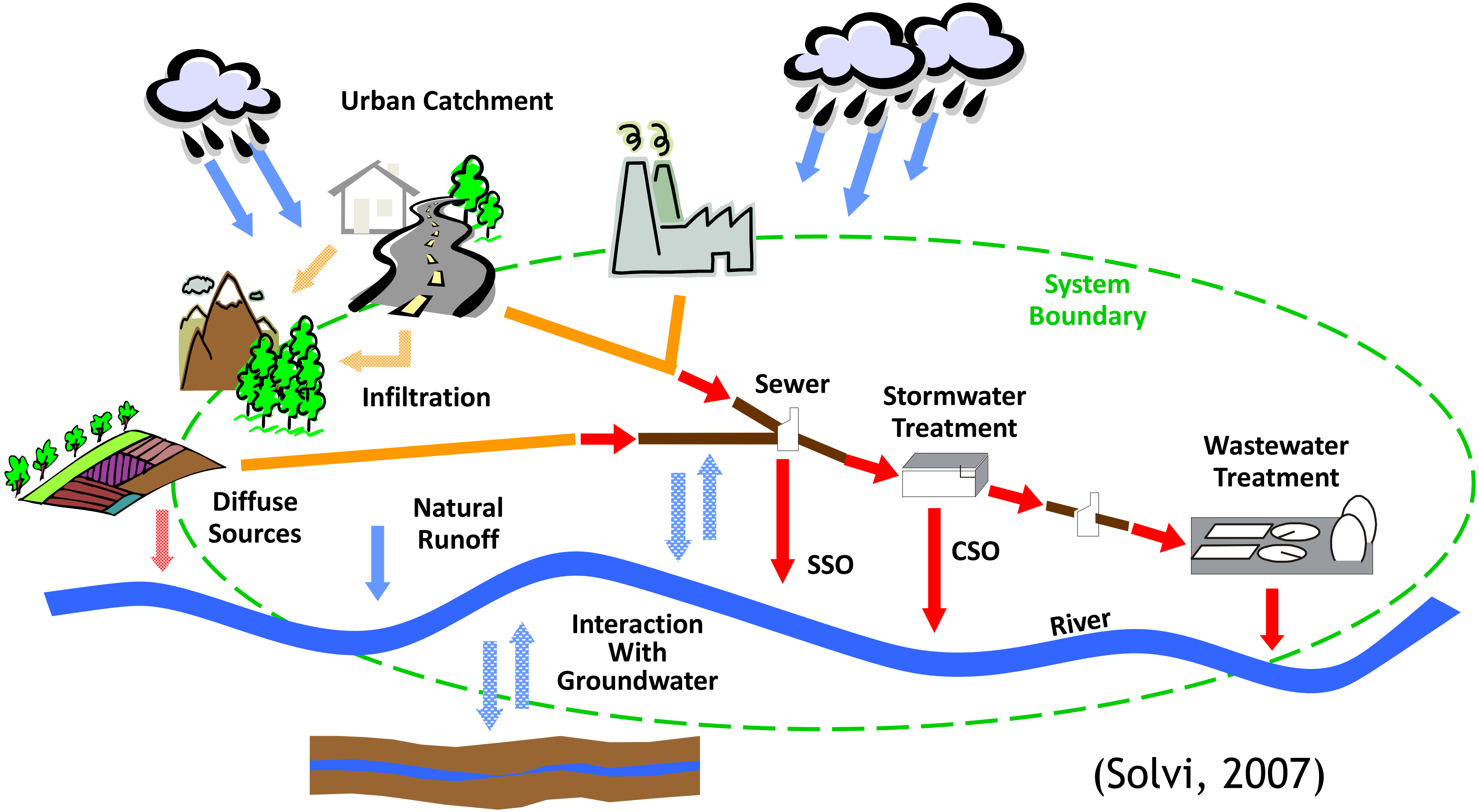
WATERWAYS

Content

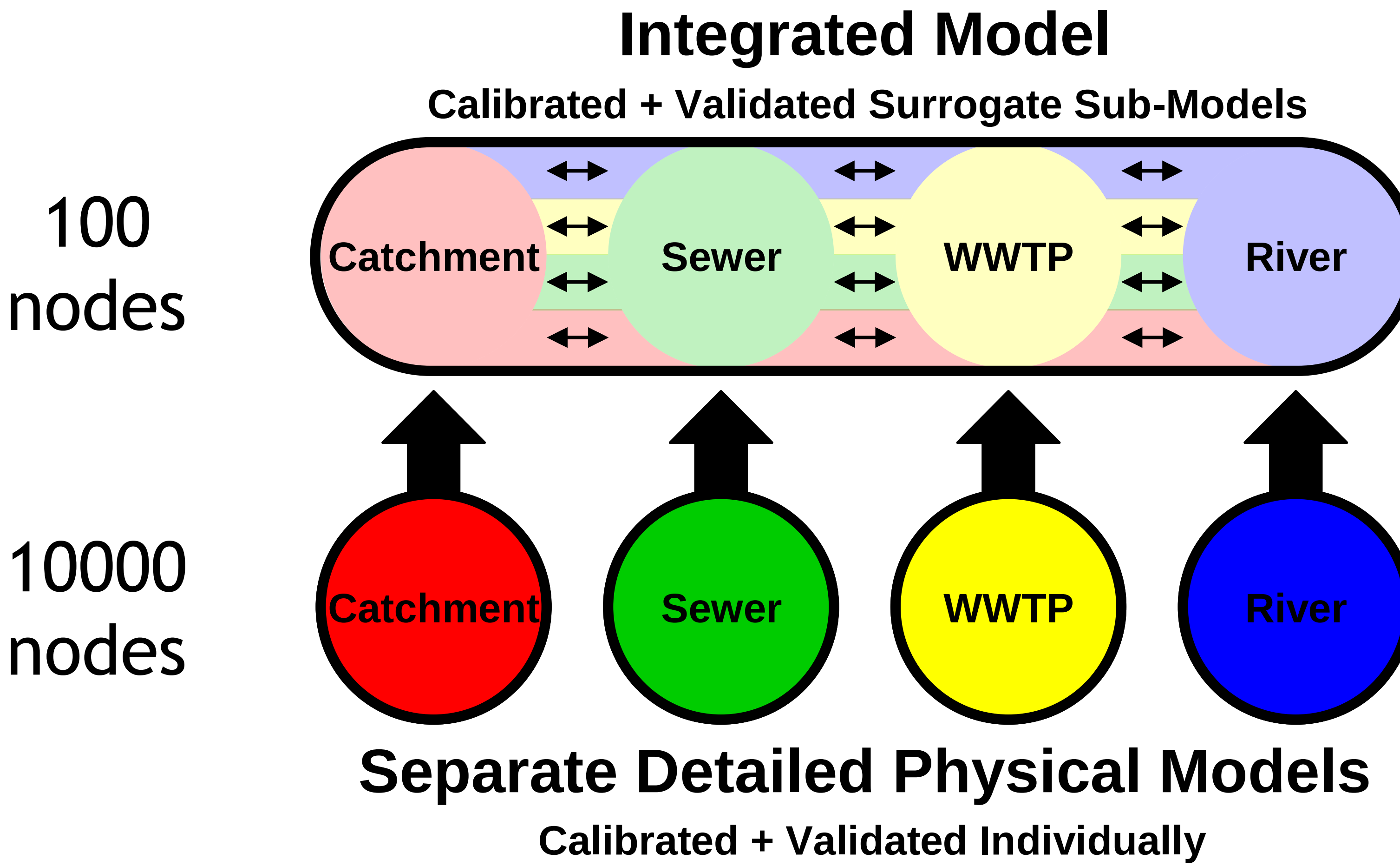
- Introduction
- Eindhoven (NL)
- Odense (DK)

System boundaries

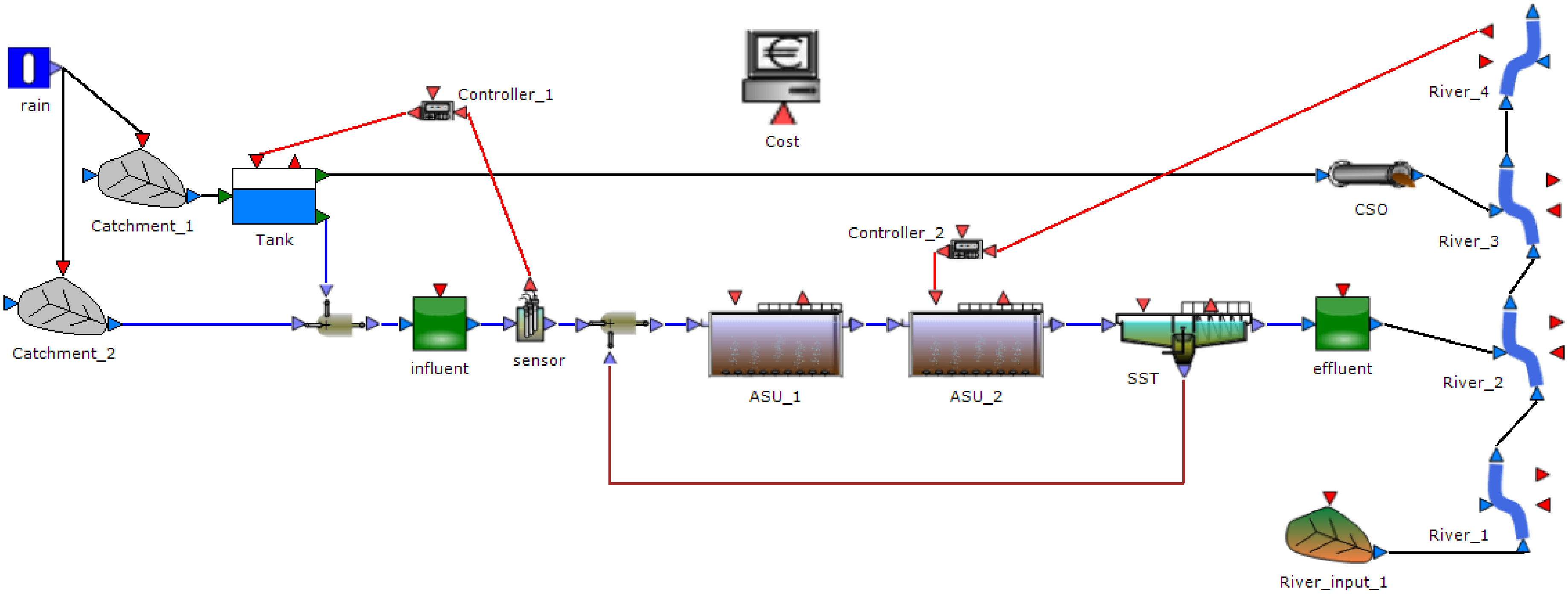


(Solvi, 2007)

Integration – single platform



Integration – single platform (DHI WEST®)



Advantages

- **One single** model:
  - Mass and information flows (impact on receiving water, integrated Real Time Control)
- A very **fast simplified** model:
  - Long-term simulation (10y in 3h)
  - Many scenarios
  - Monte Carlo for Uncertainty/Sensitivity Analysis

The Eindhoven system

Waterschap De Dommel

Complex combined wastewater system

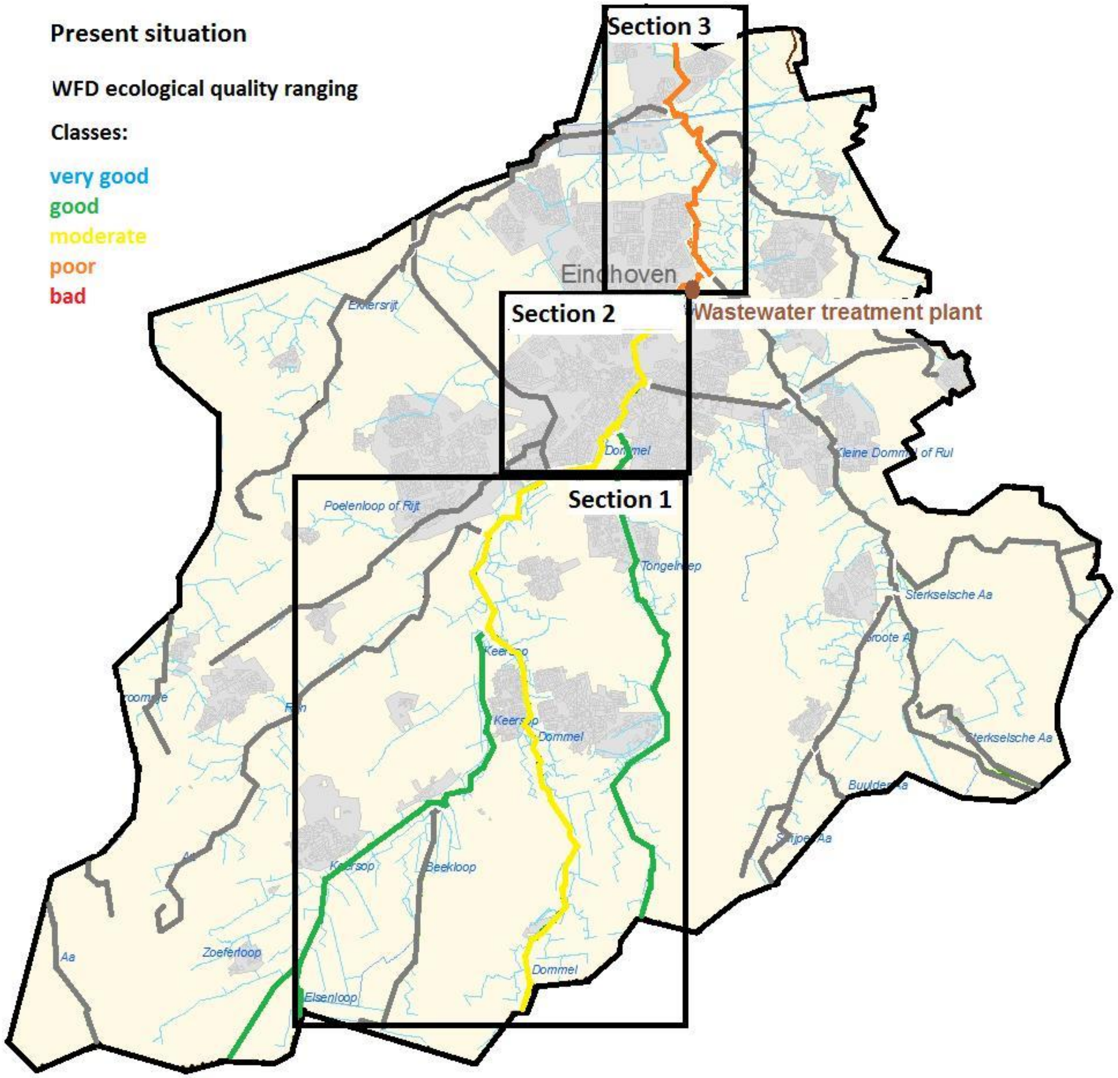
Large area with severe impact on vulnerable surface water

10 municipalities

750,000 PE WRRF

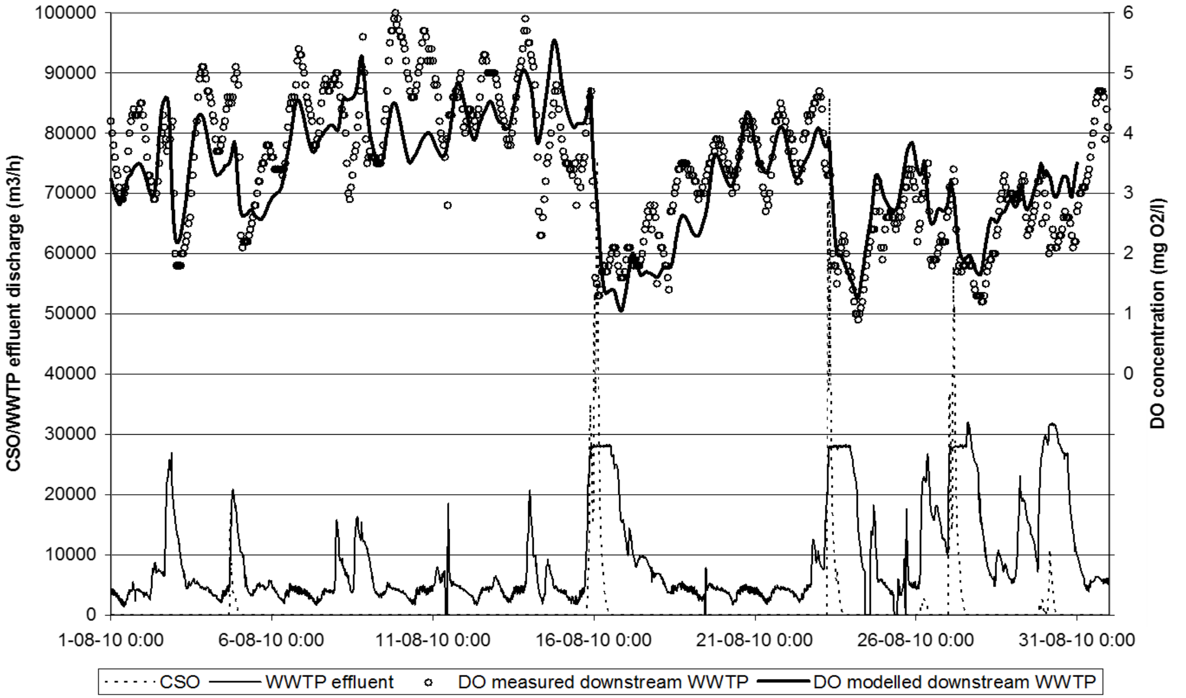
>200 CSOs

The Dommel River: ecological quality



The Dommel River: ecological quality

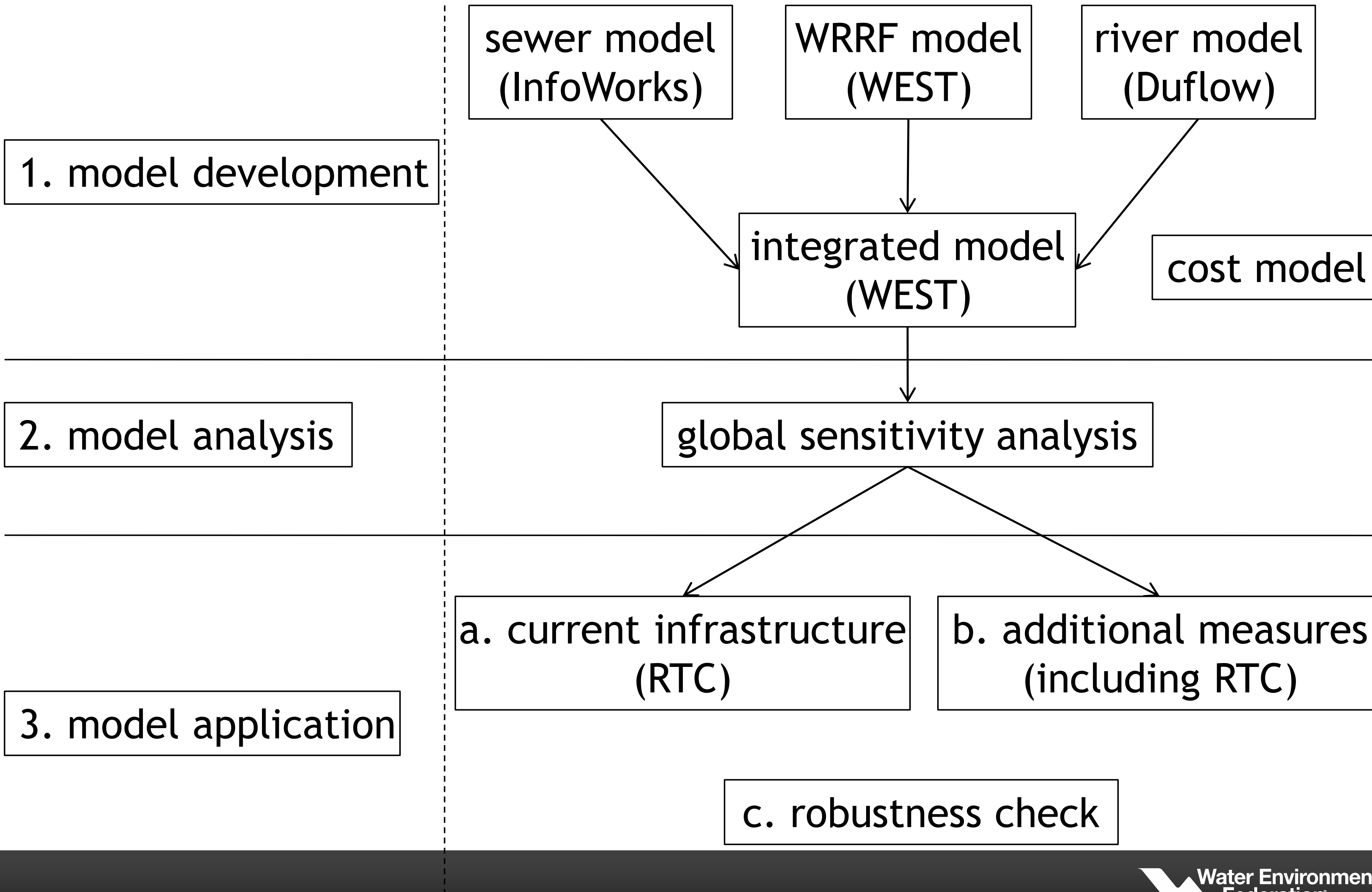
1. Chronic effects due to nutrients
2. Acute effects due to peak loads
   - DO dips
   - Ammonia peaks



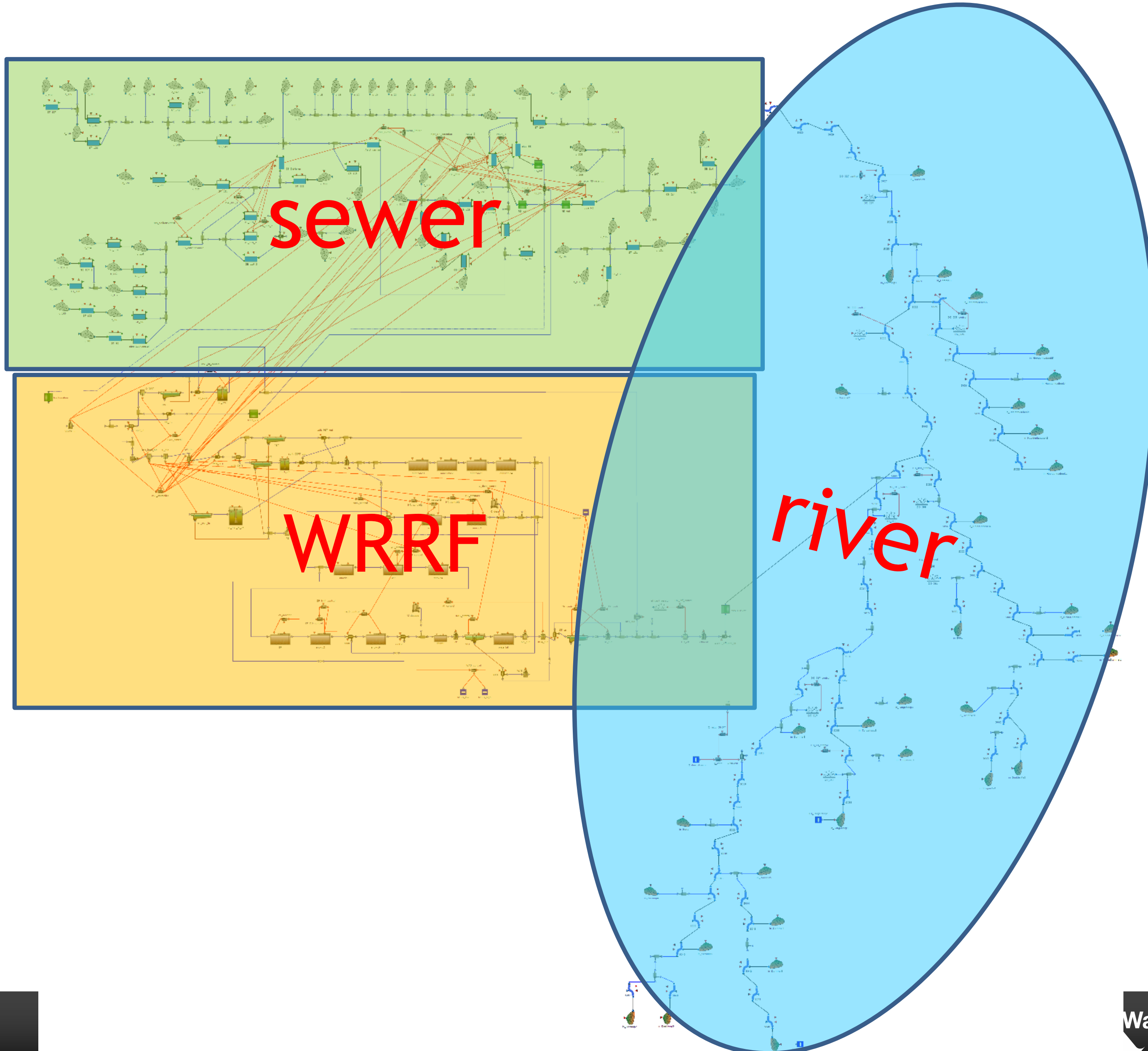
Challenge

- Complex system subject to dynamic impacts
- Large estimated CAPEX (155 M€) with "usual" solutions (sewer volume, increased treatment)
- Data and model needed to understand how to achieve the objective at minimum cost

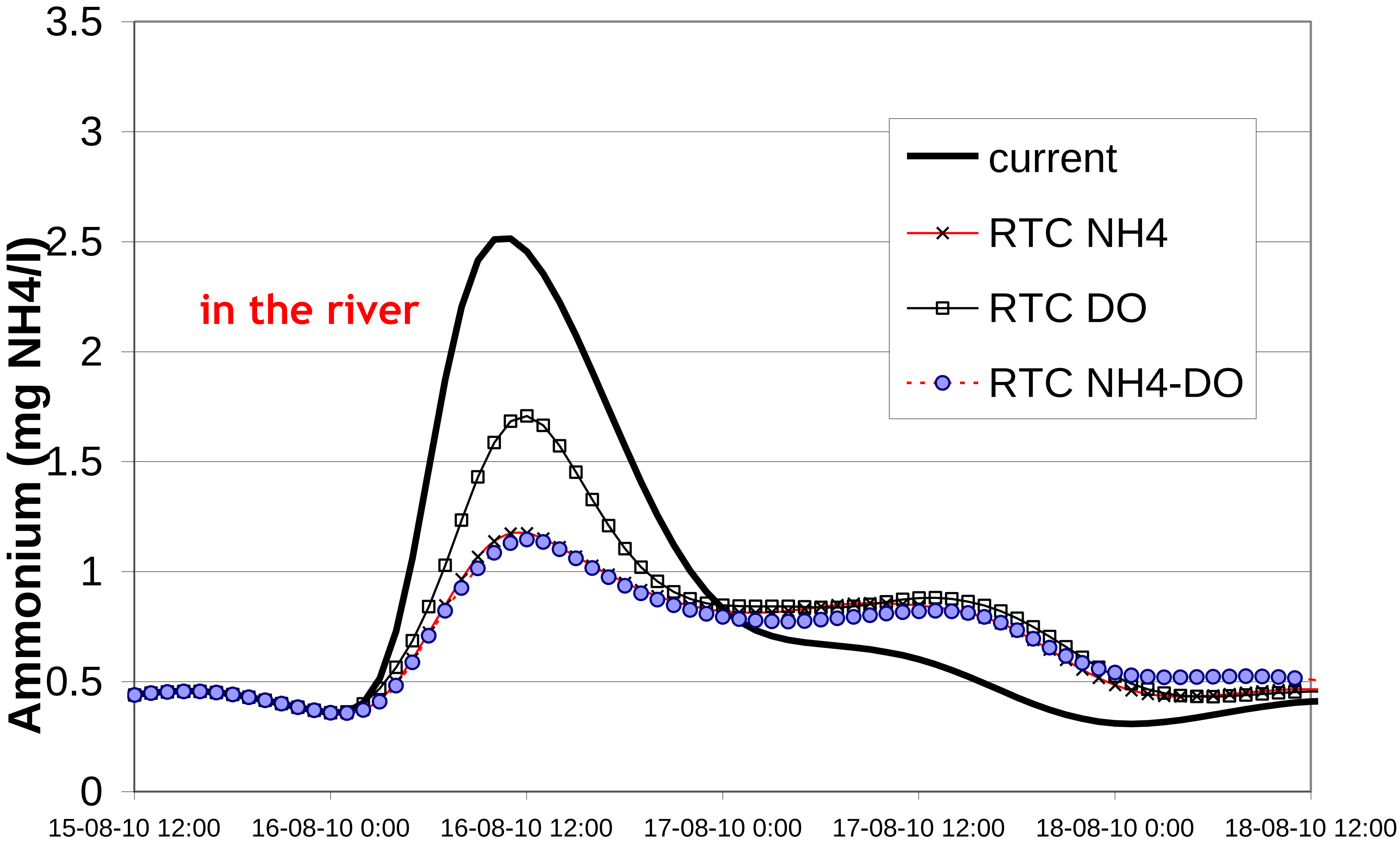
Modeling and monitoring



The WEST model



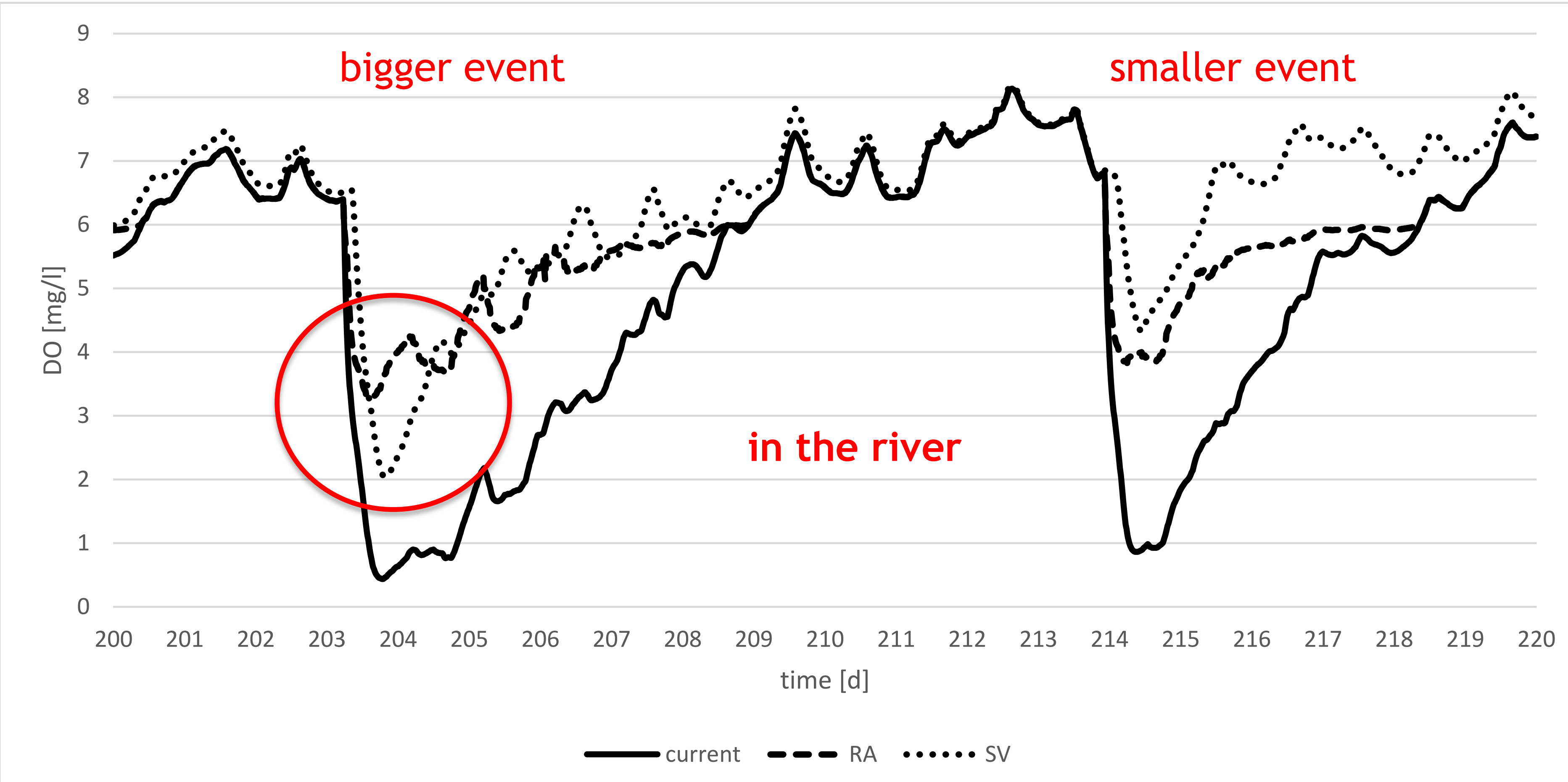
Results sewer RTC: storm event



Results sewer RTC: 10-year evaluation (potential ecological status, UPM FIS)

NH_4	*Duration of the event*				**current**						**RTC NH4-DO**					
		1 - 5 h	**6 - 24 h**	**> 24 h**												
Tolerated	**12**	1.5	0.7	0.3	4	5	5	15.5	80.7	45.2	3	5	2	14.3	34.6	10.8
frequency	**4**	2	1.2	0.5	5	5	5	20.9	62.7	24.1	4	5	1	7.9	15.6	0.8
per year	**1**	2.5	1.5	0.7	5	5	5	23.9	52.2	9.9	5	5	1	4.2	8.0	0.3
	0.2	4.5	3	1.5	5	5	2	8.3	6.8	0.2	1	2	1	0.1	0.2	0.1
DO critical	*Duration of the event*															
		1 - 5 h	**6 - 24 h**	**> 24 h**												
Tolerated	**12**	5.5	6	7	2	5	5	6.2	38.8	30.1	2	5	5	6.1	32.9	30.7
frequency	**4**	4	5.5	6	4	5	5	5.8	40.6	27.2	2	5	5	2.4	30.2	25.4
per year	**1**	3	4.5	5.5	4	5	5	2.0	23.8	20.2	1	5	5	0.5	14.0	18.6
	0.2	1.5	2	3	2	5	5	0.2	1.1	2.1	1	5	5	0.0	0.9	1.7

River Aeration vs. (200k m^3) Storage Volume



Storage Volume (200k m^3)

1	1	1	0.6	2.2	4.5
1	1	1	0.3	1.4	0.8
1	1	1	0.2	0.4	0.4
4	1	2	0.5	0.1	0.2
1	1	1	0.2	0.1	0.4
1	1	1	0.1	0.2	0.3
1	1	1	0.1	0.2	0.2
1	1	1	0.1	0.0	0.1

River Aeration

1	1	1	0.3	3.4	6.8
1	1	1	0.1	1.3	3.0
1	1	1	0.0	0.8	0.8
1	1	1	0.0	0.0	0.0
1	1	1	0.0	0.2	0.2
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

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

Upstream → Downstream

Scenario analysis: water quality

scenario (RTC + riv.aer. + CEPT)

WWTP ↓ (between S010 and S008)

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				S066						S000						S017						S010						S008						S031					
		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

Upstream → Downstream

Outcome – ‘Smart measures’

- Operational control: best use of existing infrastructure (RTC)
  - Sewer-South
  - WRRF
- Requiring (limited) investments
  - Surface water aeration
  - Effluent aeration
  - Some changes at the WRRF
- Stepwise implementation: ‘adaptive strategy’ (5-y cycles: modeling-implementation-monitoring)

Conclusions

Problem:

- Complex, dynamic, expensive

Solution:

- Integrated model that allows to handle the complexity and to make decisions based on sound science
- Significant savings compared to initial budget (now app. 40M EUR ➔ app. 75% saving)

Odense

3rd largest city in Denmark

Ca. 192 000 inhabitants

Birth place of H.C. Andersen

Pressures

Climate change

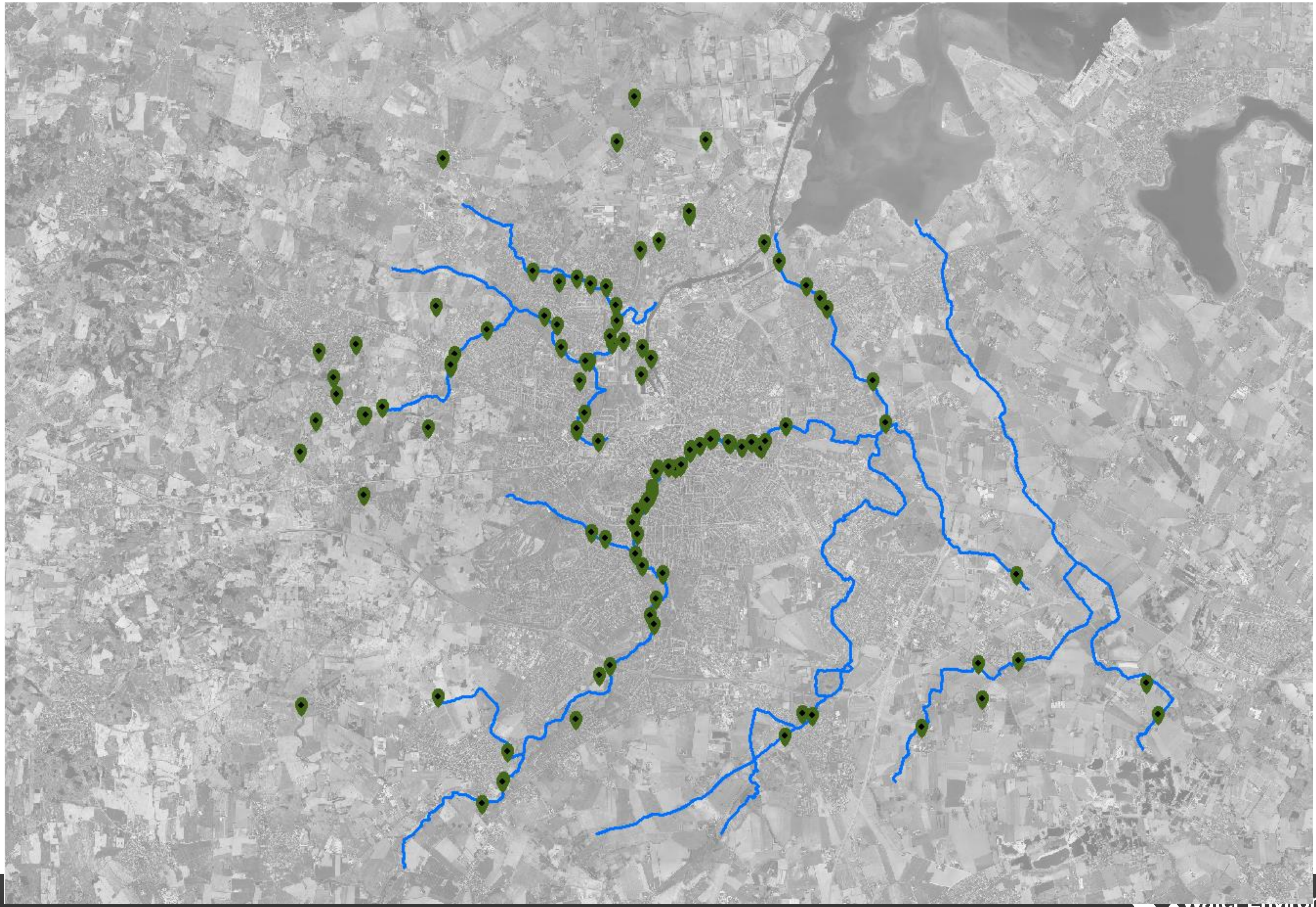
Urban development

Water Framework Directive -

Good Environmental Status

Reduction of CSOs

Rivers in Odense



Water Environment Federation
the water quality people®

Current basis for a CSO permit

Guidelines from National Masterplan

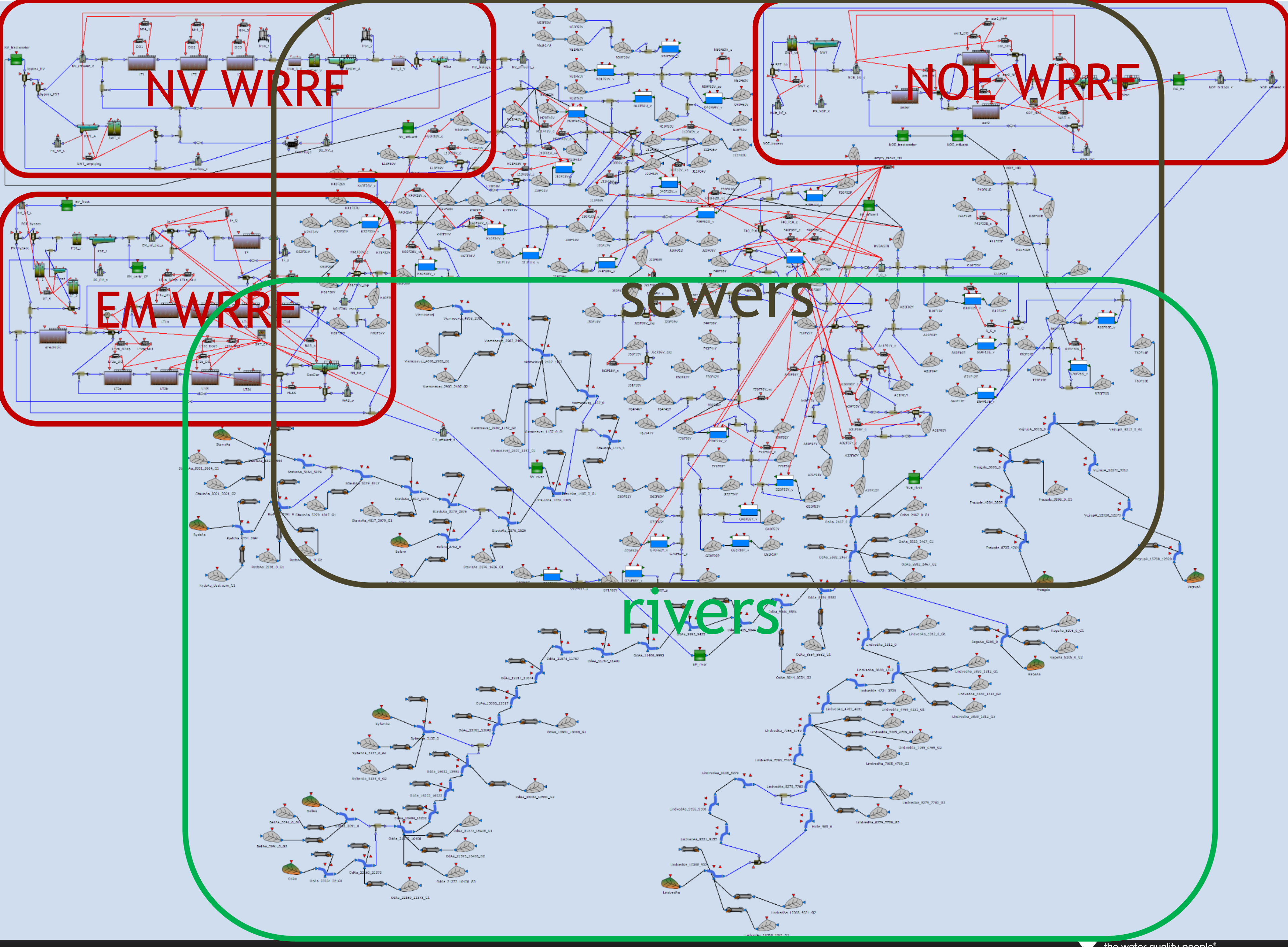
Maximum 5 overflows / year

Design: 250 m^3 / ha / year

Does not reflect the potential impacts of CSOs on the rivers!

Problem: how to prioritize investments?

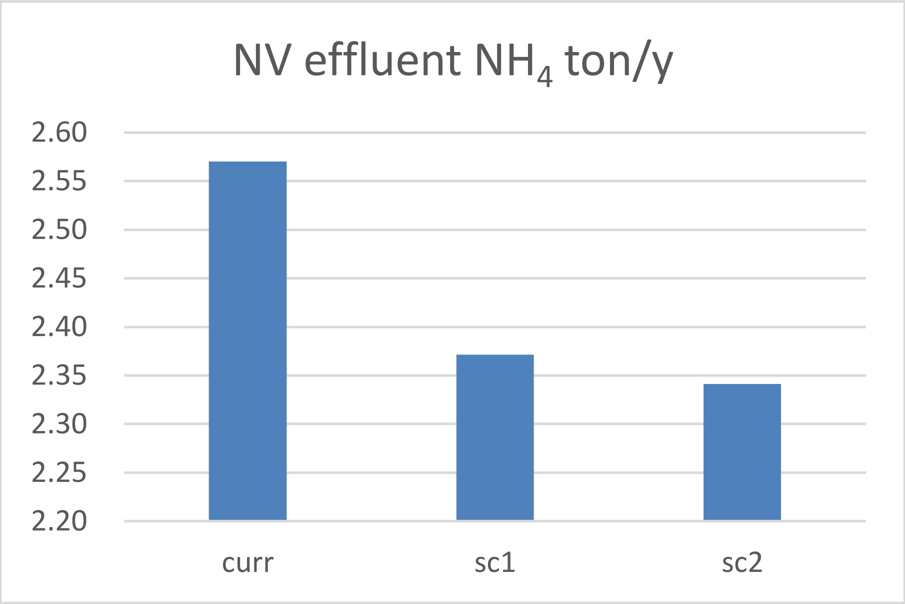
- What is the actual **effect** of CSOs on the **rivers**? How do we **quantify** this?
- What **operating** strategies might be the most effective in **wet weather** conditions?
- What are the **impacts** of planned upgrades of collection systems on the **WRRF**?
- What about **climate change**?
- Where **data** collection would be most needed? What type of data?

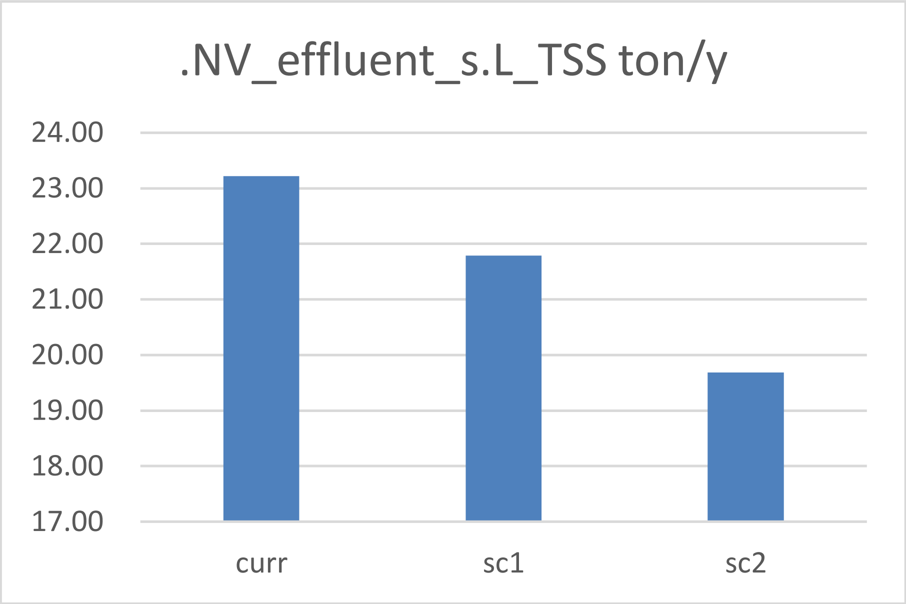

NV WRRF
NOE WRRF
EM WRRF
sewers
rivers

Scenarios

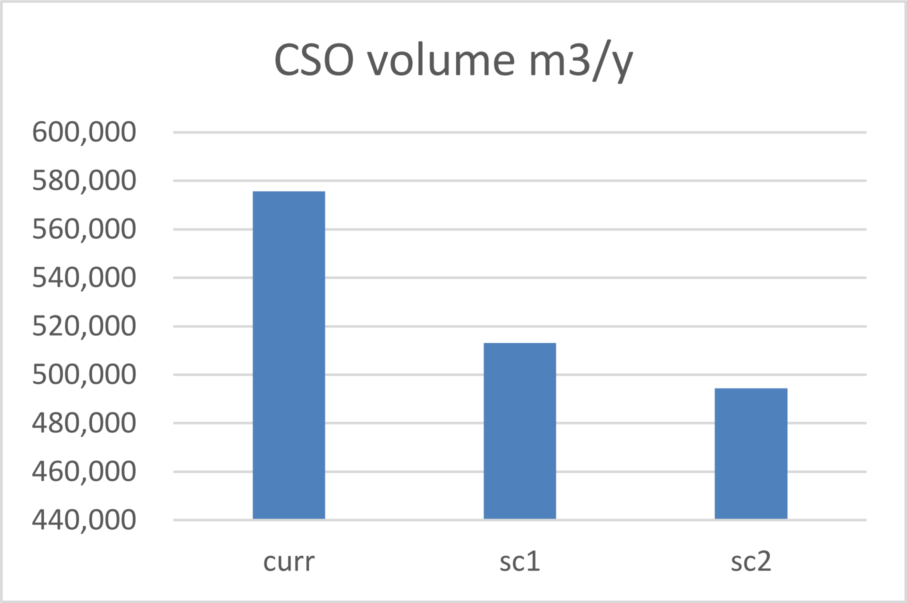
- Scenario 1 (**storage**) proposed by the **Regulator**:
  - 9000 m^3 of additional CSO storage volume at 9 locations
  - 3 upgraded pumping capacities (additional 60 l/s) at CSO structures
- Scenario 2 (**pumping**) proposed by the **Utility**:
  - 700 m^3 of additional volume at one CSO location
  - 9 upgraded pumping capacities (additional 500 l/s) at CSO structures
  - 2 new pumping stations (1000 and 500 l/s)
  - a new scheme to accept higher wet-weather flows at the NV WRRF

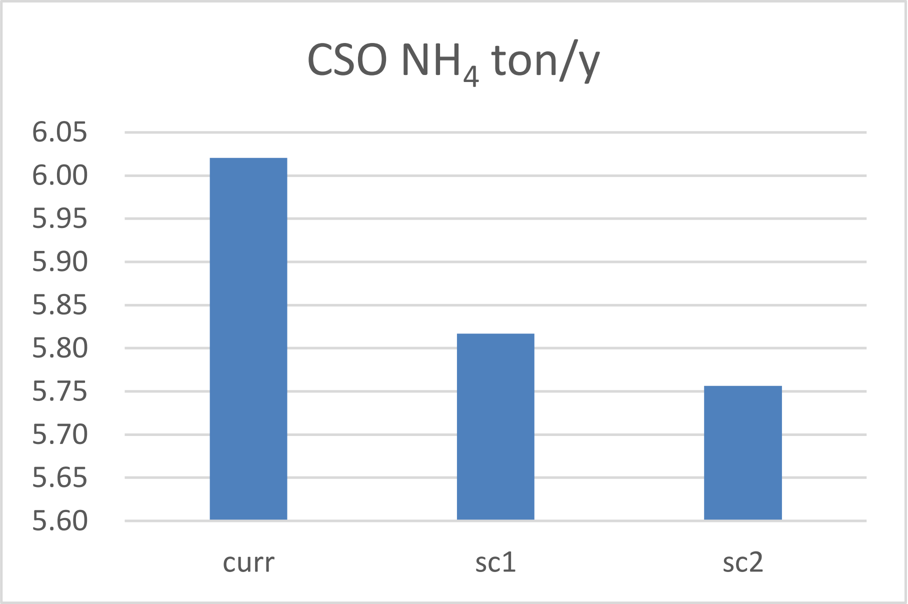
Scenarios: NV WRRF (final) effluent loads





Scenarios: CSOs



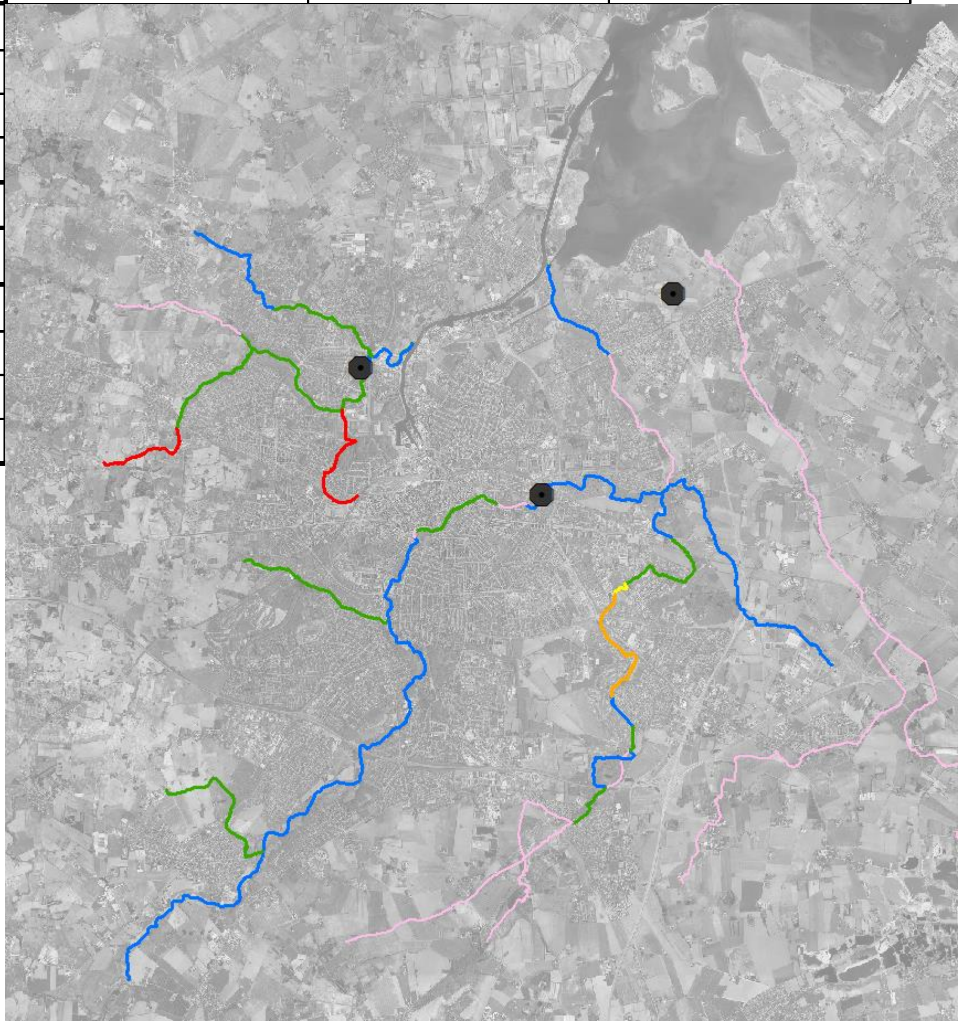


Scenarios – river quality

UIAc salm.	*Duration of the event*			
		1 - 5 h	**6 - 24 h**	**> 24 h**
Tolerated	**12**	0.065	0.025	0.018
frequency	**4**	0.095	0.035	0.025
per year	**1**	0.105	0.04	0.03

DO salm.	*Duration of the event*			
		1 - 5 h	**6 - 24 h**	**> 24 h**
Tolerated	**12**	5	5.5	6
frequency	**4**	4.5	5	5.5
per year	**1**	4	4.5	5

curr	sc1	sc2



Conclusions

Problem:

- Complex, dynamic, different opinions, only "gut feeling"

Solution:

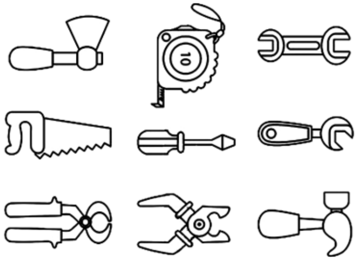
- Integrated model that allows to handle the complexity and to make decisions based on numbers instead of "gut feeling"
- Model results are used to engage with Regulator to agree best way forward for Utility, Environment, City and Water Customers

Conclusions – general

- Evaluation criteria (regulation) change faster than service life of infrastructure (sewer 80 years, WRRF 20-30 years), adaptive planning with adequate tools is required

- Fast integrated dynamic models are required to simulate long time series of river water quality for evaluation of measures

- These are the first real applications of integrated modeling for decision making in practice.



Thank You !

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WATERWAYS