

Smarter Wastewater Treatment Plants with Digital Twins

DHI CityFlow Live

Presenters:
Fabio Polesel
Henrik Refstrup Sørensen

Panel:
Ryan Sanford
Pierre Hoevelt

Agenda

3.00pm	Introduction by AWS Chair
3.05pm	Introduction to CityFlow Live (Henrik)
3.10pm	CityFlow Live Treatment Plant
3.10	Concepts and Use Cases (Henrik)
3.20	Eindhoven Case w. Live Demo (Fabio)
3.30	Integrating AI/ML approaches in CityFlow Live (Fabio)
3.35	Lessons learned (Henrik)
3.40pm	Questions and Answers

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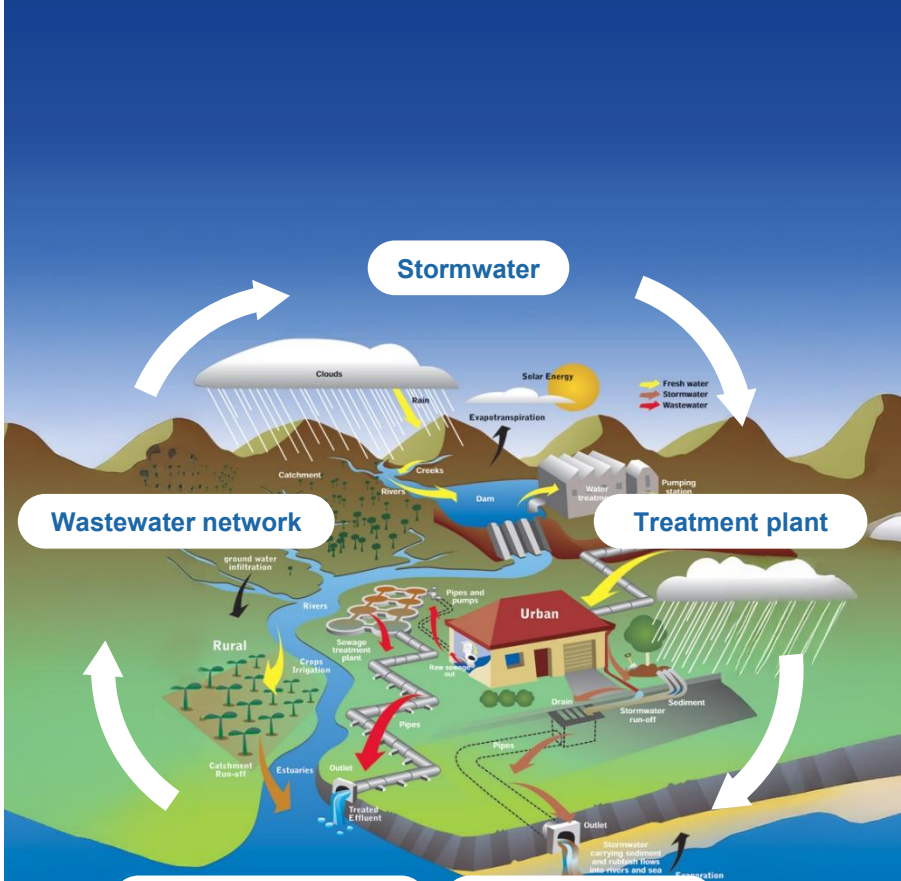
What is DHI CityFlow Live?

A **digital twin** for water in cities

IT CONNECTS

- Multiple **model domains**
- **SCADA** and live **data**
- **Planning** with **operations**
- The whole **organisation**

Enables **efficiency** and **compliance**



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True integrated operation and planning

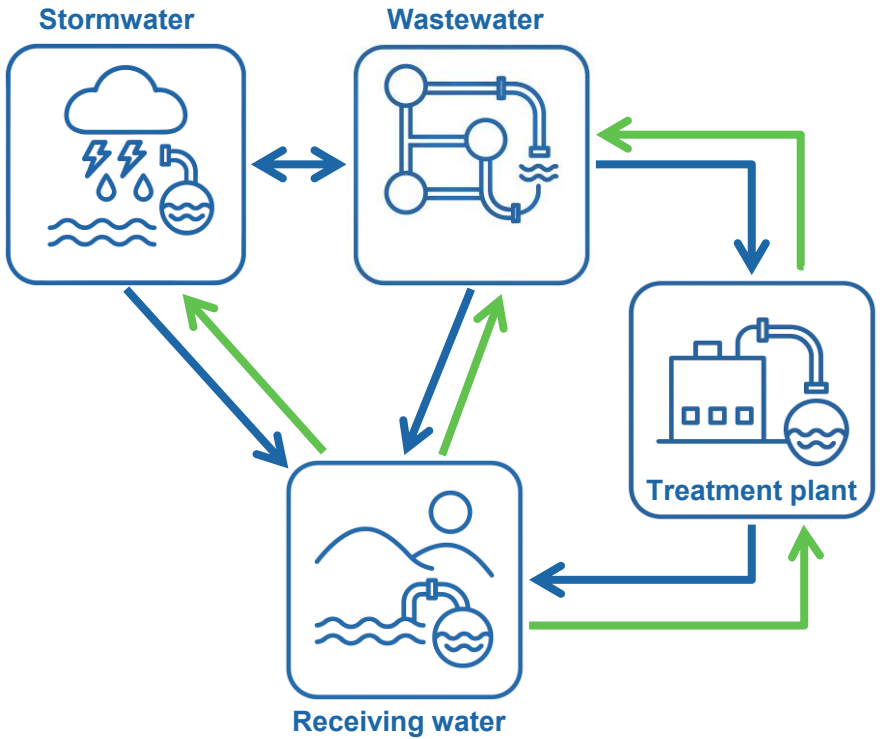
WHAT YOU CAN ASSESS

1. **Weather → networks**
   How rain and weather affect your urban water networks

2. **Networks → treatment**
   How inflow and infiltration affect treatment performance and effluent

3. **Overflows → receiving water**
   How sewer overflows and stormwater outlets affect receiving water quality

4. **Upstream upgrades**
   Which infrastructure upgrades meet environmental regulations and water quality goals



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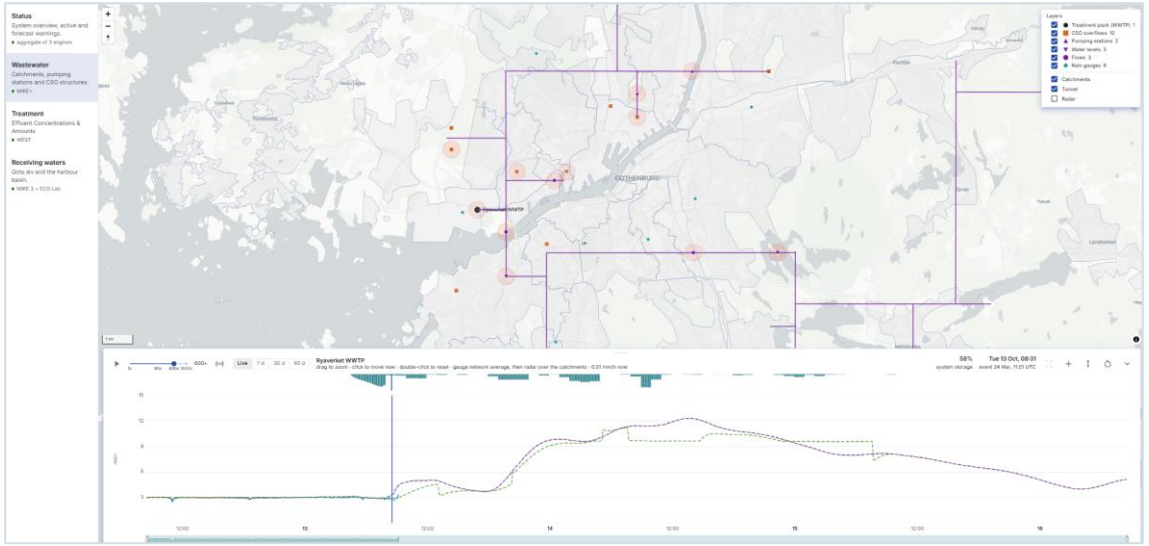
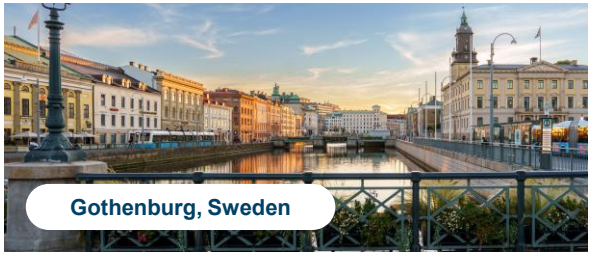
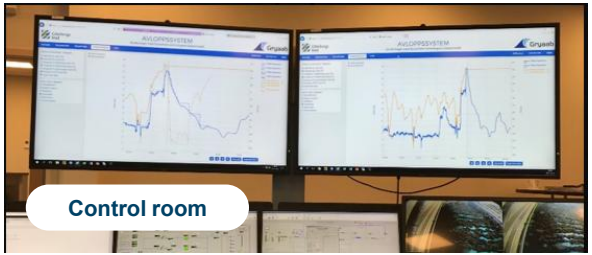
CityFlow Live – Integrated Digital Twin

Reducing the environmental impact of combined sewer overflows (CSOs) in Gothenburg, Sweden







ONE LIVE TWIN · THREE LINKED MODELS

Sewer network
MIKE+

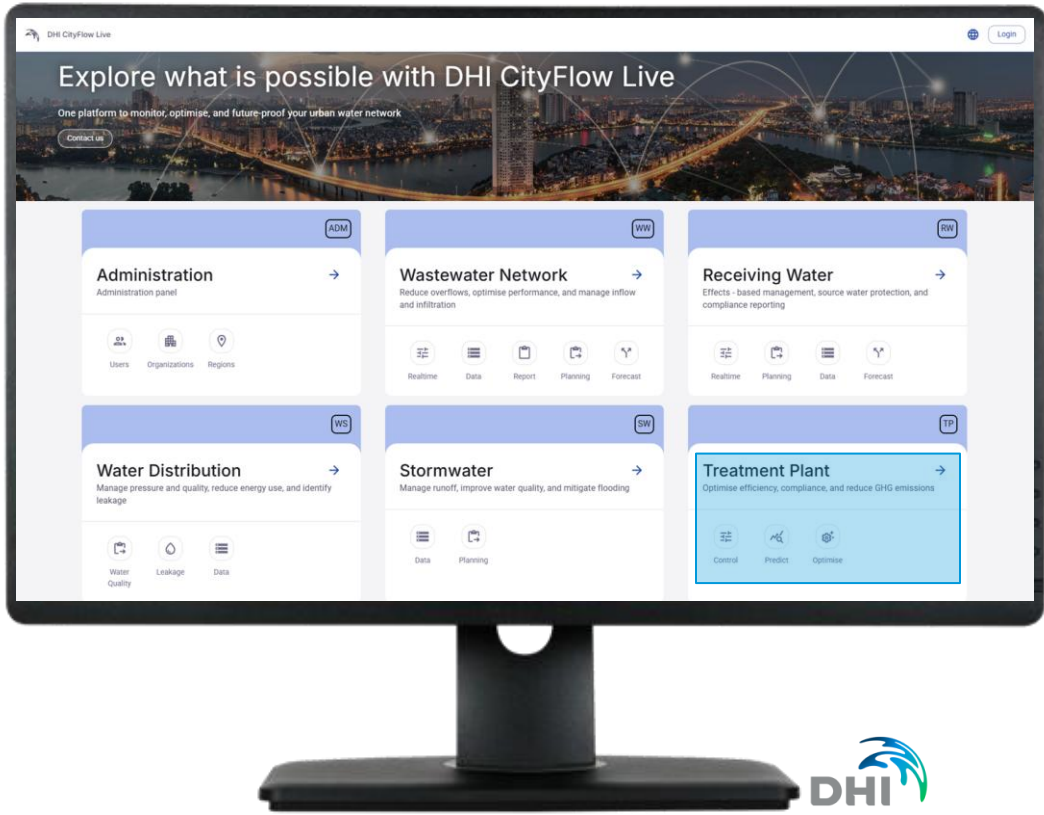
Treatment plant
WEST

Receiving waters
MIKE 3 + ECO Lab

Live demo

DHI CityFlow Live – 5 integrated user domains

- ✓ Wastewater Network
- ✓ Treatment Plant
- ✓ Receiving Water
- ✓ Stormwater
- ✓ Water Distribution



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What is a digital twin?

A live virtual copy of the plant that helps operators decide before they act



Physical WRRF

Water resource recovery facility: processes, instrumentation and equipment

DATA

Sensors, weather forecasts

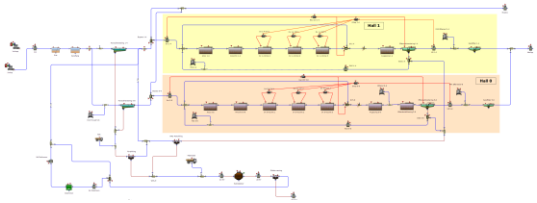
ACTIONS

Decisions, controller set-points



Human in the loop

The operator reviews and decides



Digital twin

Process models and forecasts, kept in sync with the plant

Built with **WEST**

Why digital twins?



From data to decisions

Transform plant data into actionable information

Optimise the whole plant

Reduce costs, energy use and carbon footprint while staying compliant

Build and retain knowledge

Support training, knowledge transfer, replacement and recruitment

CityFlow Live Treatment Plant

Concepts and structure: from process control to an optimising digital twin

Balancing Objectives

Effluent quality | Energy | Carbon footprint | Costs

PHYSICAL PLANT



Sensors

Blowers, pumps, dosing

SCADA

Control settings

T, DO, NH_4, NO_3, PO_4, SS

Set-point = f(DO, NH_4)

Data

Live data

1 Data & Control

SCADA link (OPC UA), data storage and DHI's process controllers

Data-driven settings

2 Learn & Predict

Live WEST model with load forecasts simulates effluent, energy, carbon and costs



Process model

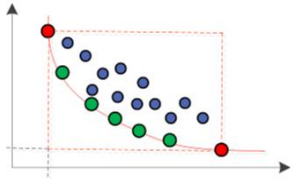


Forecasts

Model-assisted settings

3 Optimise

Finds the best set-points across multiple objectives – as advice or sent automatically



Optimisation model

Optimised settings

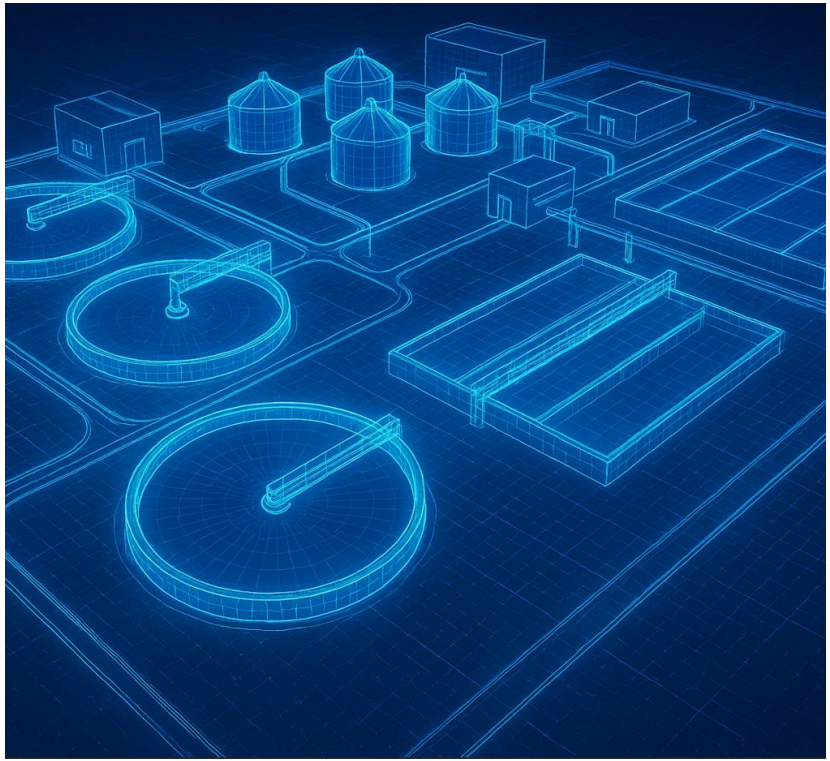
Advanced process control

Digital twin

DHI

My Digital Twin

I can experiment and learn safely and quickly on my virtual plant





PLANT OPERATOR

Questions I can explore on my virtual plant

How will my plant respond to operational changes?

What happens during unusual or future load scenarios?

What happens if I have serious equipment failures?

How can I run my plant even better?

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User Story – Maintenance

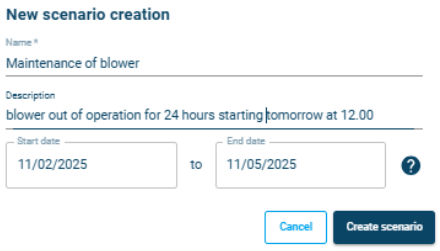
It helps me plan maintenance tasks and understand their impact



PLANT OPERATOR

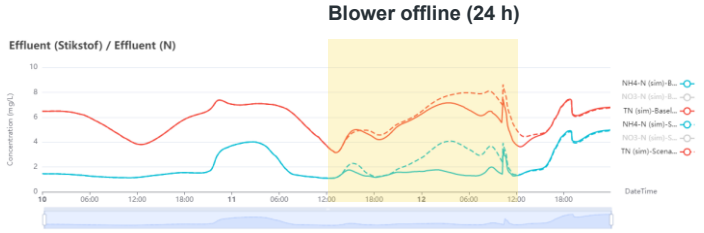
“One of my three blowers will be out for maintenance for 24 hours. What impact can I expect on effluent quality?”

1 Create scenario



Describe the event: blower out of operation for 24 hours from tomorrow at 12:00.

2 Simulate impact



Dashed = scenario, solid = baseline. Total nitrogen rises during the outage, then recovers.

3 Decide

“Total nitrogen will increase in the effluent, but it won’t be a problem. We can do the maintenance tomorrow.”

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User Story – Process control

I can test my ideas in the digital twin rather than on the physical plant



PLANT OPERATOR · EGAA WWTP

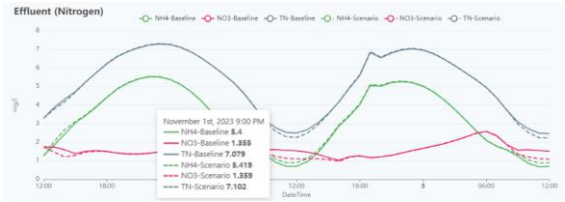
“What happens if I reduce my NH_4 set-point from 1.8 to 1.0 mg/L for the next 48 hours?”

1 Create scenario



Define the set-point change and the 48-hour simulation period.

2 Simulate impact



Cost/m3	↘	-0.003 [DKK/m3]
Energy cons aeration	↘	-29.392 [kWh/d]
Energy cons mixing	→	0.000 [kWh/d]
Energy cons pumping	↘	-6.322 [kWh/d]

Aeration energy drops by about 29 kWh/d while effluent nitrogen is almost unchanged.

3 Decide

“I’m saving energy and costs, and the effluent is still OK. I’ll change the set-point in SCADA.”

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User Story – Process control

I can test my ideas in the digital twin rather than on the physical plant



PLANT OPERATOR

“What happens to my CO_2 footprint if I increase the active biomass from 5,000 to 6,000 mg/L and keep a constant reject water flow?”

1 Simulate impact



KEY RESULTS

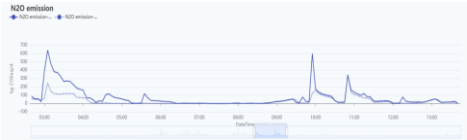
Carbon footprint (kg CO_2eq/m³)

1.11 → 0.48 (−56 %)

Carbon footprint per PE

0.35 → 0.13 (−62 %)

N_2O emission, baseline vs scenario



2 Decide

“I’m reducing my CO_2 footprint significantly and effluent concentrations are still good. Changes look promising”

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User Story – Optimised control

It helps me optimise set-points to save energy



PLANT OPERATOR

“The optimiser suggests changing my set-point to save energy while still maintaining good effluent quality.”

1 Review the optimiser’s recommendation

Aeration NH4 set-point optimization

Optimised parameter values

Parameter	Units	Current value (SCADA)	Optimised value
NH4 set-point	[-]	1	1.5

Optimised KPI change

KPI	Units	Absolute change	Relative change
Effluent Quality (mg/L)	mg/L	-0.04	-0.93%
Energy Efficiency (kWh/d)	[-]	-656.23	-6.81%

KEY RESULTS

NH_4 set-point (current → optimised)

1.0 → 1.5

Projected energy saving

656 kWh/d (−6.8 %)

Effluent quality

−0.04 mg/L (−0.9 %)

2 Decide

“Looks reasonable – I’ll push the new set-point to SCADA.”

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User Story – Optimised control

It helps me optimise set-points to reduce our carbon footprint



PLANT OPERATOR

“The optimiser suggests changing my DO set-points to reduce the carbon footprint.”

1 Review the optimiser’s recommendation

Aeration set-point optimization

Optimised parameter values

Parameter	Units	Current value (SCADA)	Optimised value
Max DO set-point	[-]	2	1.5
Min DO set-point	[-]	1	1.5

Optimised KPI change

KPI	Units	Absolute change	Relative change
Carbon Footprint	kg CO2eq/m3	-0.84	-45.47%

KEY RESULTS

Max DO set-point (current → optimised)

2.0 → 1.5

Min DO set-point (current → optimised)

1.0 → 1.5

Projected CO_2eq reduction

0.84 kg/m³ (−45 %)

2 Decide

“Looks reasonable – I’ll push the new set-points to SCADA.”

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Case story and live demo

Eindhoven WWTP, The Netherlands



Photo: Waterschap De Dommel

Drivers and objectives

- Models available for daily operational use
- Training of WWTP staff (engineers, operators)
- Support planning and process optimization

Integrating AI/ML approaches

DATA

Sensors, weather forecasts

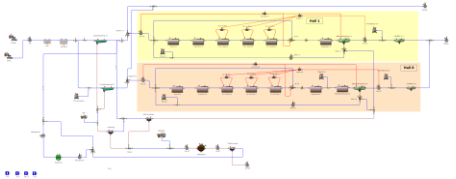
Physical WRRF

Processes, instrumentation, equipment



Digital twin

Models, forecasts, kept in sync with the plant



ACTIONS

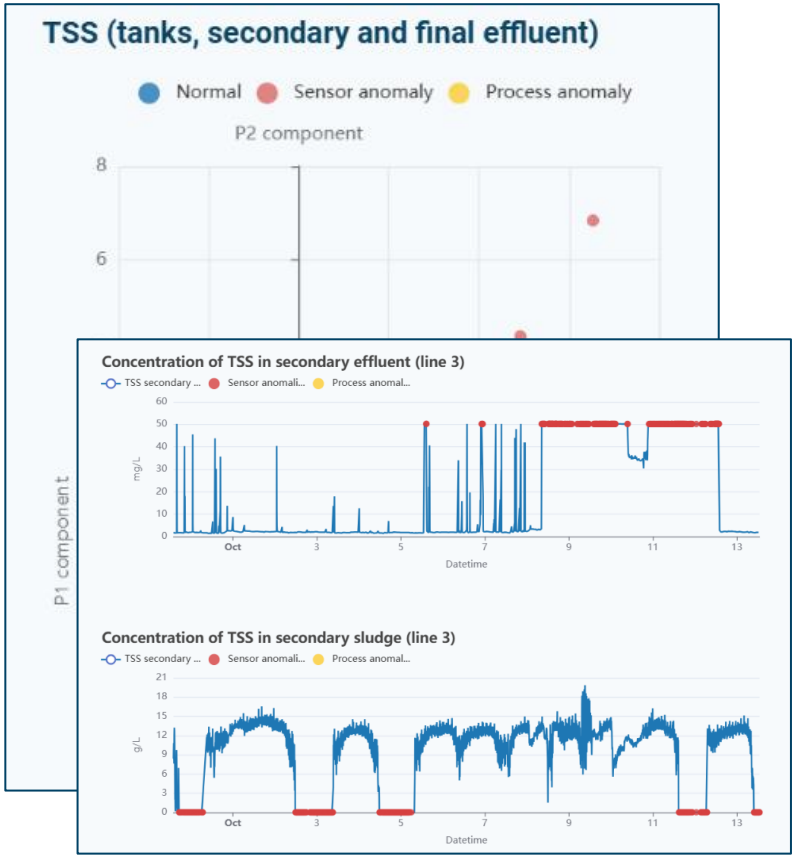
Decisions, controller set-points

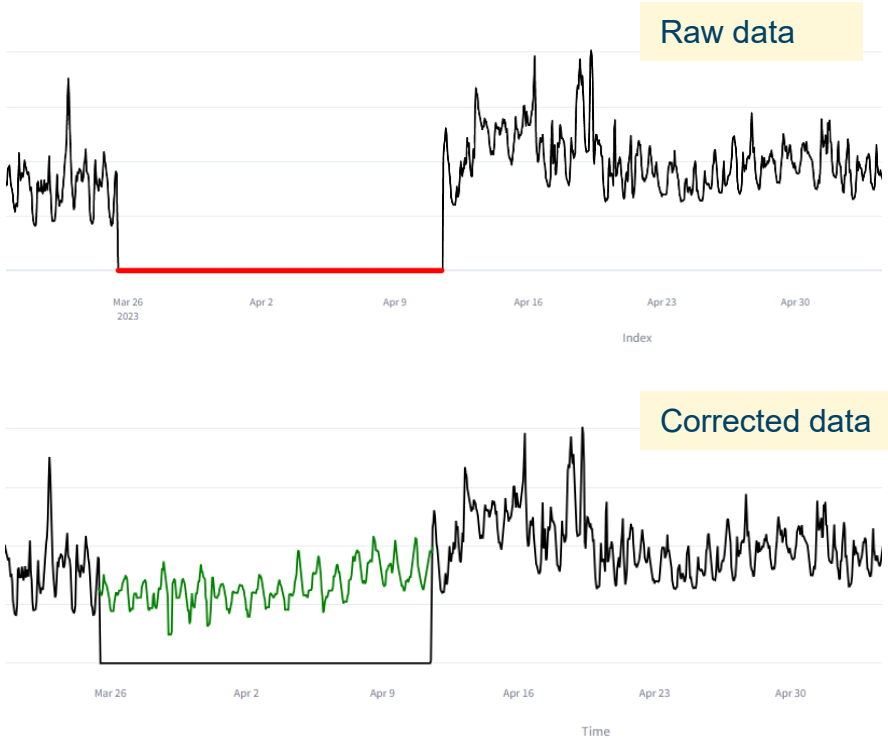


Human in the loop

Anomaly detection and data correction

Integrating AI/ML Approaches



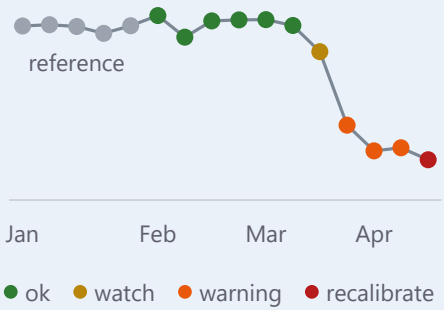


Automated model calibration

Integrating AI/ML Approaches

1 Detect drift

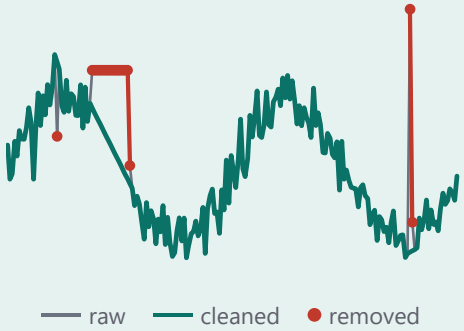
weekly fit score



Scored against the plant each week. A lasting drop means drift.

2 Clean the data

one sensor, two days

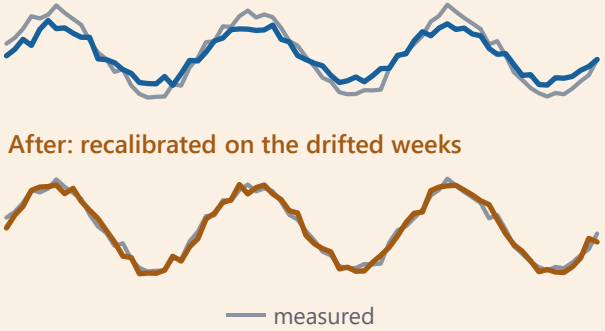


Spikes and flat lines are removed and filled in before recalibrating.

3 Recalibrate

same three days in Apr

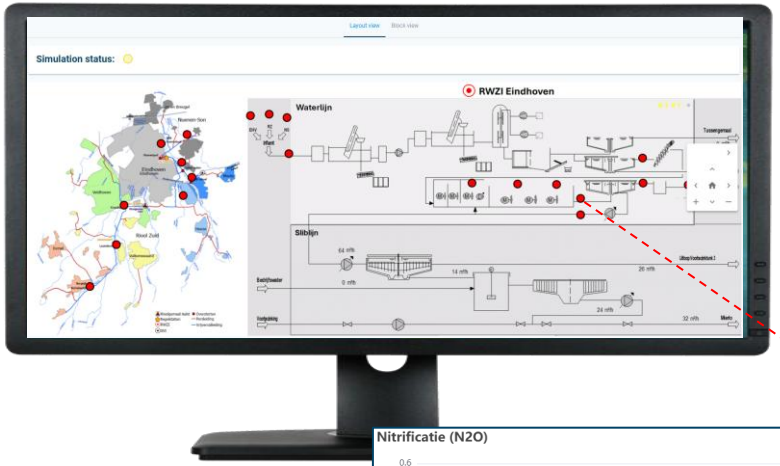
Before: the model as calibrated



Recalibrated on the weeks that drifted, then watched week by week.

Hybrid (mechanistic + ML) forecasting

Integrating AI/ML Approaches

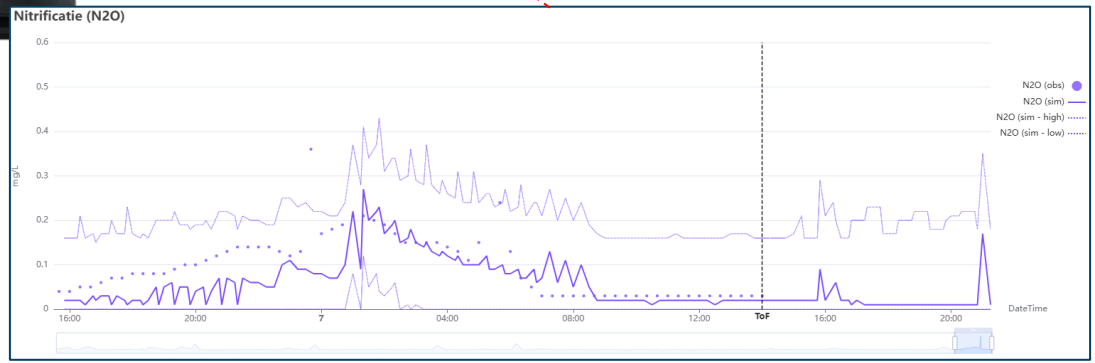


WWTP data
Weather forecast

Mechanistic process model

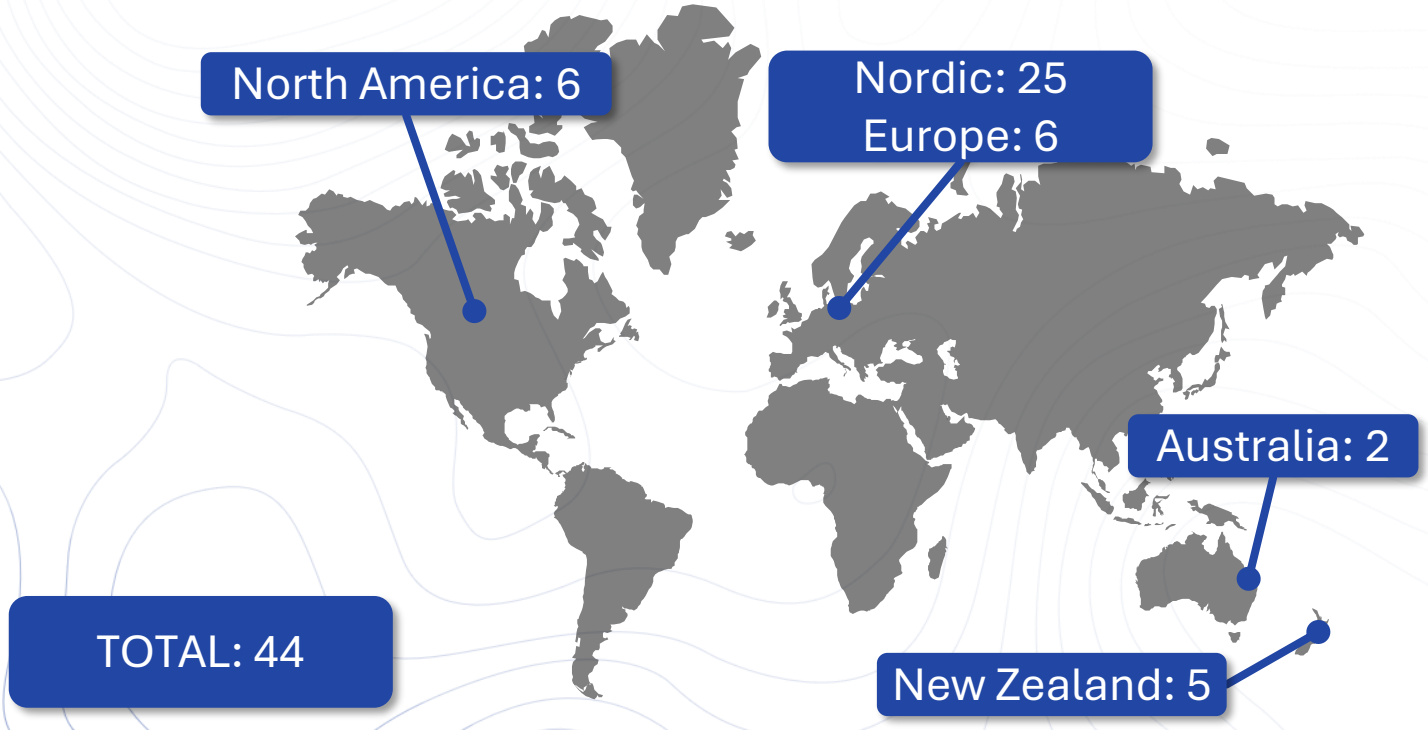
Machine learning (ML) model

N_2O



DHI CityFlow Live

Geographical Coverage



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Lessons Learned

Operationalising a digital twin takes time



The potential value of the digital twin is not fully released

The transition from project to operation is too slow or fails.

Lessons learned

Four barriers

Roles & responsibilities

A clear digital twin team is often not defined in the receiving organisation.

Resources

Time and funding to keep driving uptake after go-live.

Data availability & quality

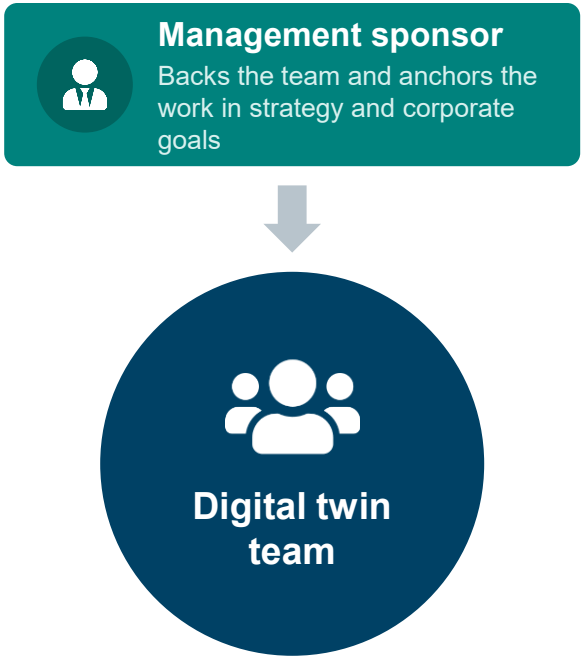
Missing or flawed data undermines trust in the digital twin as a whole.

Trust

Predictive capability must be shown and maintained. Continuous engagement with WRRF staff is essential.

Lessons learned

Roles, Responsibilities and Resources



Elements of success:

- **Objectives and use cases,** identified with stakeholders and linked to corporate goals
- **Ambassadors & specialists,** continuously supporting and drive internal uptake
- **Dedicated time** for digital twin team to experiment and work with digital twin
- **Performance goals:** team and personal goals linked to the use cases

Lessons learned

Building Trust

Our experience

- Predictive capability is questioned
- Staff, often operators, fear losing influence or even their job

Elements of success:

- **Early engagement of operators** to capture their knowledge, provide input and feedback, and let them test their own ideas
- **Support, not replace** by positioning the digital twin as decision-support for operators
- **Systematic digital twin update** through automated model re-calibration and verification

Lessons learned

Building Trust – Early and continuous engagement of stakeholders

”The DT is a good base for training of new operators”

” For scenarios it would be good to see the pre-conditions, e.g. 1-2 day before implementing the scenario changes”



”It’s great that we actually sit together and see the model and the data in real-time. Being able to play around with controller settings would be very useful”

”The first impression is good. Scenario capabilities to be discussed with operators.”

Lessons learned

Building Trust – Maintaining predictive capabilities

1 Clean the data

one sensor, two days



Spikes and flat lines are removed and filled in before recalibrating.

2 Detect drift

weekly fit score

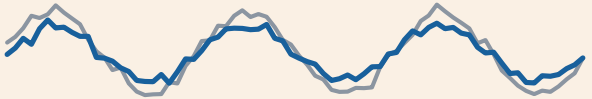


Scored against the plant each week. A lasting drop means drift.

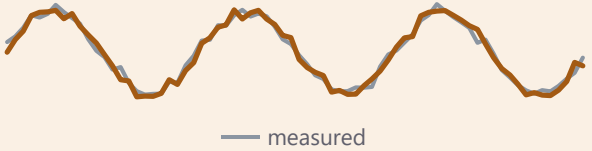
3 Recalibrate

same three days in Apr

Before: the model as calibrated



After: recalibrated on the drifted weeks



Recalibrated on the weeks that drifted, then watched week by week.

Lessons learned

Takeaways

Roles

Build a digital twin team, involved from kick-off to full ownership

Resources

Give it time, performance goals and a management sponsor.

Data

Invest in a robust data pipeline with automated safeguards.

Trust

Prove predictive power, keep models up to date, involve WRRF staff.

What success looks like

Taking ownership



Co-create

Staff shape objectives and features from day one and take part in the process modelling.

Operate

The team keeps the twin running, resolves issues and updates the configuration independently.

Champion

Internal and external ambassadors, showing value against use cases and corporate goals.

Rely on

Used every day – seen as a critical tool by operators and process engineers.



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