DIGIWATER

Co-funded by the Erasmus+ Programme of the European Union

R3.4 REPORT ON DEMO-CASES

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PROJECT INFO

Project title	Digitalisation of water industry by innovative graduate water education
Project acronym	DIGIWATER
Project reference number	621764-EPP-1-2020-1-NO-EPPKA2-KA
Action type	Knowledge Alliances in Higher Education
Web address	http://waterharmony.net/projects/digiwater/
Coordination institution	Norwegian University of Life Sciences (NMBU)
Project duration	01 January 2021 – 31 December 2023

DOCUMENT CONTROL SHEET

Work package	WP3
Ref. no and title of task	T3.4 Development of demo-cases with end-users
Title of deliverable	R3.4 Report on demo-cases
Lead institution	KU Leuven
Author(s)	Daan Buekenhout (KU Leuven), Kato Schoeters (Sumaqua), Sevde Korkut (ITU)
Document status	Final version
Document type	Report
Document version and date	v.05 05/02/2024
Dissemination level	Public/ Restricted to other programme participants (including Commission services and project reviewers)

VERSIONING AND CONTRIBUTION HISTORY

Version	Date	Revision description	Partner responsible
v.01	03/05/2023	Initial draft	KU Leuven
v.02	05/06/2023	Revision of draft	Sumaqua
v.03	21/09/2023	Final revision of demo-cases Leuven	KU Leuven
v.04	17/11/2023	Final revision of demo-cases Istanbul	ITU
v.05	05/02/2024	Final revision of one-pagers	KU Leuven, ITU

Contents

1. INTRODUCTION

This report discusses the last step of the *Digital Water Living Lab*, the third work package (WP3) of the DIGIWATER project. The trajectory of WP3 started with a concepts design workshop, in which the DIGIWATER consortium developed concepts and rough prototypes to tackle needs within the water sector. The project consortium identified these earlier on in WP1. This approach was further pursued in the principal component of WP3: the student innovation camps. In the two face-to-face camps, an international group of students, under guidance of academical and industrial partners, was challenged to come up with innovative ideas and concepts for the range of water-related problems identified earlier on in the project, with a focus on the use of novel digital technologies related to Internet of Things and Big Data. In the weeks and months after the innovation camps, students and project partners jointly developed these novel ideas into prototypes.

The capstone of these brainstorming and prototyping efforts within the *Digital Water Living Lab* is the evaluation of five selected prototypes within the infrastructure of end-users. The goal is to assess the added value of the developed prototypes and to receive valuable practical feedback. The five selected demo-cases are:

- Impact assessment of drought measures in Flanders
- Water balance of (navigable) waterways
- Optimization of Flood Control Areas in tidal areas
- Smart Sense: intelligent water protection
- Quick reaction on a cyber-attack to guarantee clean drinking water

This report further elaborates each of these demo-cases. Both the initial prototype as developed following the innovation camps in Leuven and Istanbul, respectively for the first three and last two demo-cases, and its application within the demo-case are described, as well as a conclusion. *One-pagers* have been developed for the demo-cases as well and can be found in annex to this report. These one-pagers serve as a practical summary of each demo-case and elaborate on the involved end-users. This report ends with a global conclusion on the demo-cases.

2. DEMO-CASES

2.1 Impact assessment of drought measures in Flanders

During the past few years, serious droughts have affected the region of Flanders, Belgium. Beginning in 2017, Flanders has seen no less than 5 seriously dry summers – every year except 2021 and 2023. At the same time, because of climate change, the risk of new and worse droughts is higher than ever. This urged the Flemish Government to initiate a large investment and research program – the Blue Deal[1]. This program mostly consists of realizations in the field, which aim to reduce water use or increase the infiltration and availability of water. However, it was unclear at the start what the combined impact of all included projects could be. As a variety of stakeholders, ranging from municipal governments and private actors to government departments, conducted these projects, a simple but effective method to monitor the impacts was needed.

The drought impact assessment should be effective as well as simple, as different actors within government departments are meant to carry it out. The assessment was initially envisioned to be rolled out for four hydrological focus areas: wastewater, surface waters, groundwater, and water use. After development and implementation, the relevant technical administrations would have to be able

[1] See bluedeal.integraalwaterbeleid.be/about-blue-deal for more information.

to easily start working with the tools. Additionally, they should be able to retrieve relevant information to feed departmental and government decisions.

As part of the DIGIWATER demo-cases, Sumaqua chose to develop or extend a range of algorithms which would enable assessment of the four focus areas. As a large number of data sources were already available, the idea was to build these algorithms on top of these existing data sets. As such, the initiatives that were already up-and-running could be extended by the new algorithms. Finally, this was only possible for the focus areas of groundwater and wastewater. For surface water and water use, data were also available, but still lacking for a regional drought impact monitoring set-up. In what follows, the implementation of the impact assessment prototype for groundwater, which is the most extensive, and its demo-case for Flanders are discussed. Finally, this section presents the conclusions of the demo-case.

2.1.1 Prototype

For groundwater, the impact assessment builds upon Pastas, a Python package for groundwater analysis and modelling (Collenteur, et al. 2019). The principal goal for groundwater was to assess whether changes seen were worse than what could be expected based on long-term observations. Said differently: given a long-term impact, is there any additional short-term impact, whether it is positive (e.g., field implementations by the Blue Deal) or negative (e.g., additional field drainage or sealed surfaces)? A long-term impact can be more easily assessed than this short-term impact, but the latter is more informative for government decisions, especially within the framework of the Blue Deal.

Using Pastas, groundwater models are calibrated for each monitoring well with adequate data. In this calibration, precipitation, evaporation (both inputs) and groundwater level (output) data sets are coupled, allowing for a simulation of groundwater levels based on a given precipitation and evaporation. Given a reference year, all data before the start of this year is used for calibration. Precipitation and evaporation data after the start of the reference year are used for simulation. The results of this simulation present what would happen without any additional anthropogenic impact and can thus be compared with the actual observations. If enough observations after the start from the reference year were outside the lower bound of the 90%-prediction interval of the simulations, the studied monitoring well are said to be drier than expected given the meteorological input. Conversely, if enough observations were outside the upper bound of the 90%-prediction interval, the given monitoring well are said to be wetter than expected. This workflow is illustrated in Figure 1.

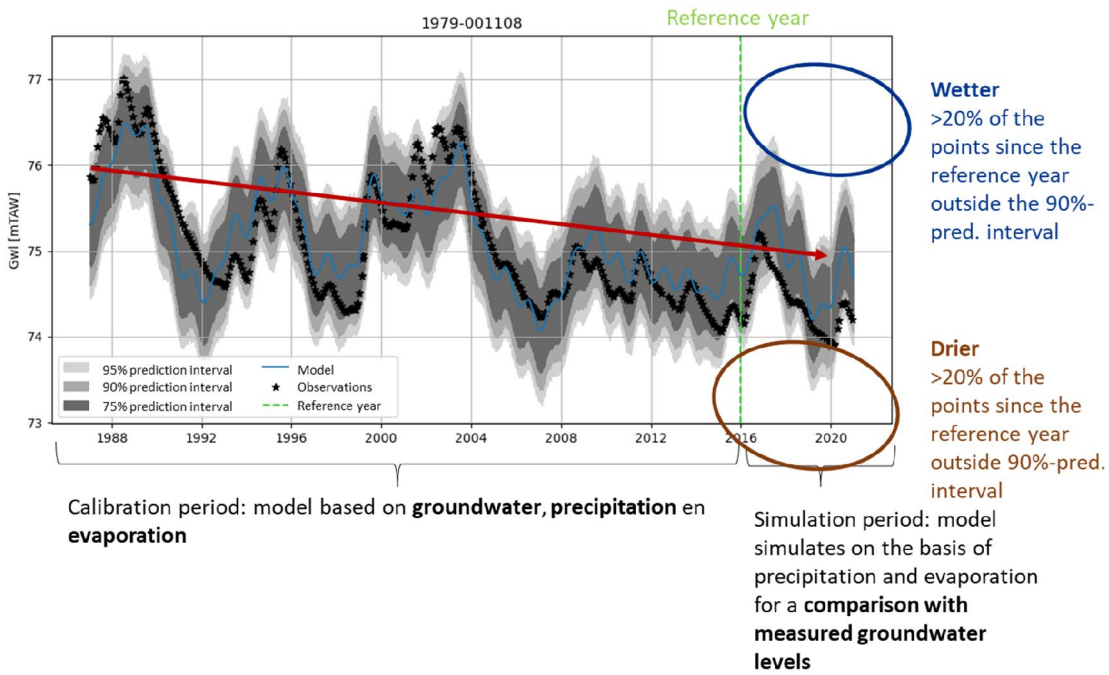

Figure 1: Illustration of the assessment for groundwater monitoring wells. Groundwater levels are in mTAW, which is m above sea level, based on the sea level in Oostende, Belgium, according to the 'Tweede Algemene Waterpassing' (TAW)

The described method has several assumptions that should be considered. First, it depends on a proper calibration of the model. Therefore, monitoring wells with inadequate data are not withheld. The next paragraph describes what constitutes (in)adequate data. Additionally, the quality of the fit in the calibration period determines the prediction interval. A poorer calibration implies a larger prediction interval, and thus a lower chance that enough points will fall outside the prediction interval. Second, it can only assess changes after the start of the reference year, which thus determines which effects are considered in the calibration and which are not. However, as the calibration is driven by meteorology, the impact of the reference year should be limited. Third, the method can only assess structurally drier or wetter wells in comparison to the expectation based on meteorology: absolute drought or wetness depends on the location and is much more difficult to assess. Last, the method can only be linked with locally implemented measures if they are located close to the monitoring well – which is usually not the case. Thus, if any improvement in the groundwater levels is found, it can only be assumed that there is some change in the nearby water system, but the nature of the change itself cannot be pinpointed.

As mentioned in the previous paragraph, having adequate data at a monitoring well forms the basis for this type of assessment. However, 'adequate data' is rather vague, and the data needs are twofold. First, only wells with qualitative data are considered. Data were considered qualitative if 1) the well was active in 2021, 2) there were at least 60 measurements from at least 5 distinct years and 3) the measurements were on average monthly. Second, to be able to calibrate and simulate with a proper Pastas model, 1) the measurements had to be more or less regular, 2) measurement frequency should not often change and 3) enough measurement had to be available for calibration and to compare the simulations with. The next section discusses the effect of these requirements for the impact monitoring in Flanders.

2.1.2 Demo-case

The impact assessment is carried out for all of Flanders. Despite the substantial number of phreatic monitoring wells, only a limited number could be studied. Starting from all publicly available data, only 408 wells passed the 'qualitative data' check, with only 186 having enough data for modelling with Pastas. Nevertheless, as illustrated in Figure 2 and Figure 3, the assessment leads to some relevant results for Flanders. Figure 2 shows that 57% of the monitoring wells are classified as 'drier than expected', whereas only 9% is wetter dan expected. Additionally, 32% shows no additional effects (beyond the long-term trends) and 2% of the wells is both drier and wetter than expected, with the exact status depending on i.e., time of the year. Thus, there is a clear tendency for monitoring wells to become drier, which implies that implementation and uptake of the Blue Deal actions are necessary. Figure 3 additionally shows that this is relevant for all of Flanders: there is not one specific region with clearly more or fewer monitoring wells becoming drier than expected. However, it is also clear from the figure that a higher density of monitoring wells is necessary for a fully informative assessment, especially in the west of Flanders.

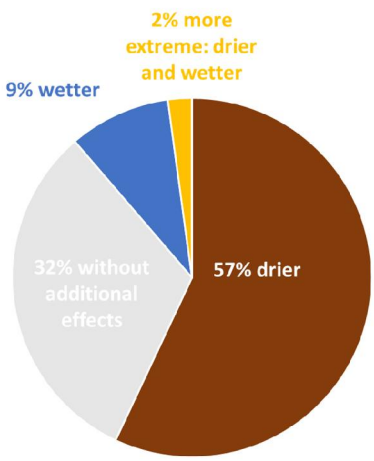

Figure 2: Main results for the drought impact assessment of Flanders

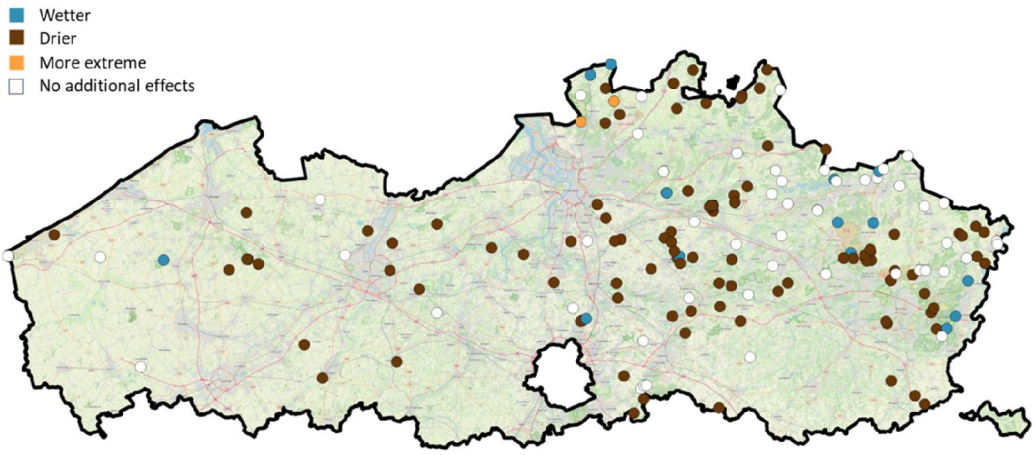

Figure 3: Geographical distribution for the results of the drought impact assessment of Flanders

As Figure 3 illustrates, the main challenge for the current approach is the lack of adequate data. For an analysis with a proper geographical spread, many more monitoring wells with adequately long and qualitative time series are needed. Nevertheless, the available time series indicate that more action is urgently needed to decrease the number of wells drying out. As such, the results are considered a call-to-action and investments in groundwater monitoring are increasing. Besides the importance for geographical spread, the number of applicable monitoring wells and their current geographical spread additionally implies that is difficult to link a local drought adaptation measure with changes in a monitoring well. This will only be possible if one of the studied monitoring wells is by chance close to the measure. Yet, the results indicate that it is possible to assess and follow up the short-term drought management status at the level of Flanders, which is an important step forward. Another challenge, as indicated by the end-users, is the lack of a quantitative framework in which to distinguish long-term impacts, e.g., by climate change, older soil sealing or drainage systems, and the short-term additional impact. As illustrated in Figure 1, both can be relevant, and a quantitative distinction could further inform policy decisions.

2.1.3 Conclusion

For Flanders, an impact assessment system was set up on the basis of the existing groundwater monitoring wells. The goal of this system was to assess the short-term drought management status: was it possible to distinguish additional drying or wetting of monitoring wells? The former would indicate that local anthropogenic measures worsen the infiltration in the soils, whereas the latter would indicate that the implementation of drought measures, as initiated by the Blue Deal, ameliorated the situation. As illustrated by the results of the demo-case in Flanders, the impact assessment can be applied for this goal. Yet, for many monitoring wells a deterioration in groundwater levels was noticed, indicating that even less infiltration occurred, possibly by human influence as such, further action and a broader uptake of the Blue Deal initiatives is necessary. The method as implemented in the demo-case can consequently be applied to follow up on these initiatives.

Although the proposed method can already yield relevant results, further steps could make it even more relevant for policy information. A first step, which is beyond the scope of the method as presented here, is the increase in qualitative data availability. Currently, there are too few monitoring wells with qualitative data for a fully-fledged analysis of all of Flanders. Second, changes in the method should make it possible to quantify the impact of climate change (or other long-term effects) on the one hand and impact of recent changes on the other hand. This would further increase the applicability and allow for a more efficient implementation of policy measures. Last, a very dense and local monitoring network would allow the proposed method to directly link drought measures and their impact on groundwater levels. However, this seems to be the most difficult and hence long-term step, and seems unattainable on the short term. Thus, the method should first focus on a proper assessment of groundwater levels over all of Flanders, with an increase in density as a secondary goal.

2.2 Water balance of navigable waterways

Due to the increasing occurence of drought in Western Europe the need for fast calculating and easily adjustable models is high to support water allocation decisions during periodes of extreme drought. This is especially the case in the Flanders region which is extremely vulnerable to drought due to the lack of big rivers and thus a low water availability, the high population density and a high percentage of impervious surfaces.

As part of the DIGIWATER demo-cases, a conceptual water balance model capable of simulating a wide variety of scenarios with short calculation time has been developed. The model includes most of the navigable waterways in Flander and takes into account water usage (e.g., industry, drinking water production and shipping), the regulation schemes used by operators to manage the waterways' water levels and boundary conditions like a tidal river or the sea. Due to its high flexilbility, the model can be used to forecast both the near future, including the effect of short term measures during droughts, as well as simulating long term scenarios, for example to estimate the effect of climate change or redesigned infrastructure.

The model was build in close collaboration with De Vlaamse Waterweg (DVW) which is the government agency managing most of the navigable waterways in Flanders. During the last summers DVW had to implement a series of measures to counter the negative effects of drought on the water availablity. These measures include the installation of pumps, the increase of waiting times for ships at locks and reduction of certain extractions for nature and agriculture.

2.2.1 Prototype

The proposed water balance model consists of different storage cells with each cell representing a (part of a) waterway. For each cell, the water balance is made by considering all waterflows to or from that part of the waterway (see figure 1). This requires a good insight in the water flows which can only be acquired if enough data is available. Interaction between the cells is possible based on the dynamics of the management of the waterway. An important assumption is that the water level in each cell is constant, so no hydraulic effects are considered.

To gain a good insight in the water balance of each cell detailed information is necessary about all the waterflows like, for example, lock losses due to shipping, evaporation, rainfall runoff, sewer outflows, extractions by industry, etc. Available data was inventoried and can consist out of a discharge measurement, registrations of extraction, registrations of lock operations, etc. This is all extracted from various sources and combined in a single database that contains all waterflows per cell. The water balance is then calculated and the interaction between the cells simulated. The model reports the results as a water level or a discharge at a certain location.

Calibration and validation are performed by comparing measurements of water level and discharge with the model results both via a visual comparison as a statistical analysis. Furthermore, the operators of the modelled waterways were involved in the validation process to better understand the dynamics of the waterways.

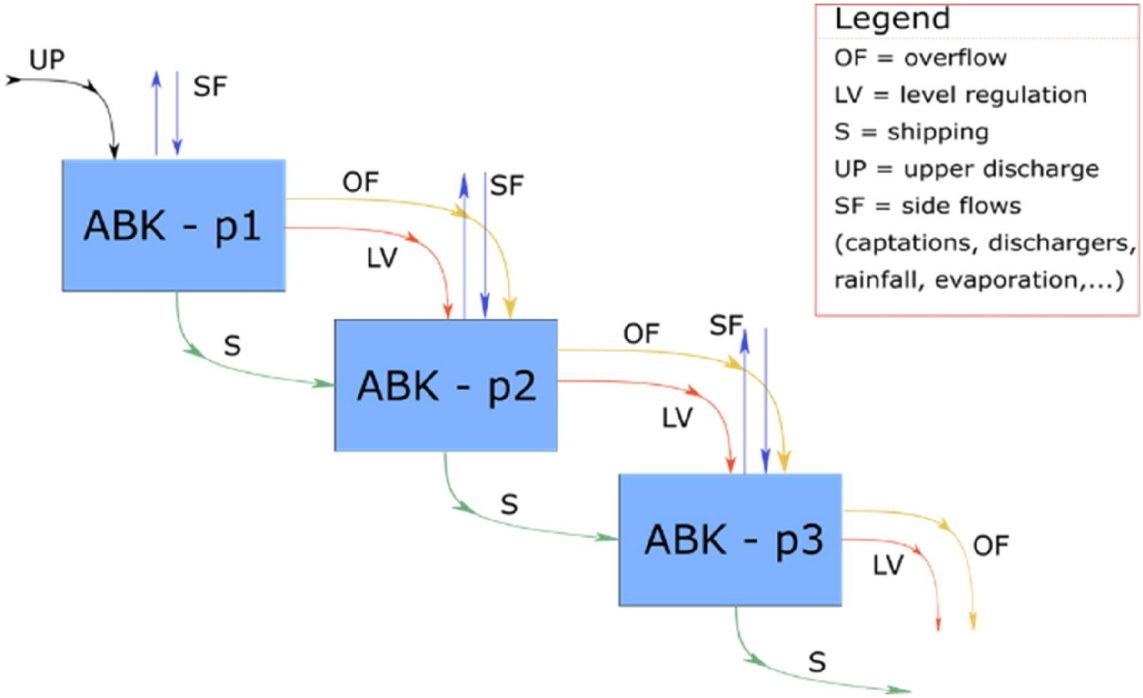

Figure 4 Schematic overview of the conceptual model for the first three trays of the Albert canal.

2.2.2 Demo-case

The prototype was thus demonstrated to the waterway operators and based on their feedback adjusted. More detailed data about extractions and lock operations were provided as well as more detailed regulation schemes. Due to the lack of discharge measurements on every waterway the feedback of the operators is essential to gain insight in the dynamics of management on the waterway.

The model was thus adjusted and later applied in a short-term scenario analysis in the Leie-Scheldt basin (see figure 2). In which it provided a forecast of the discharge on both Leie and Scheldt for different meteorological scenarios during a summer period.

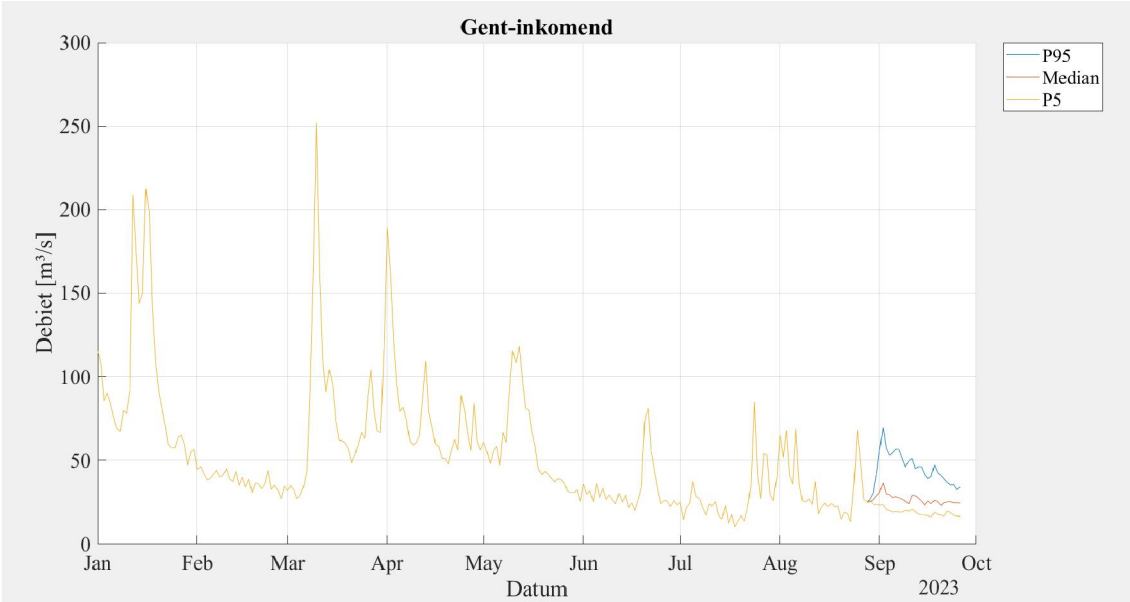

Figure 5 Short term forecast of the discharge in Gent for different meteorological scenarios. Forecast starts on 30 august. All three scenarios start from the same historical conditions.

2.2.3 Conclusion

The model combines flexibility with a short calculation time which makes it a very usable decision support tool for water allocation strategies both on the short-term during periods of extreme drought as well as on the long term for investigating the impact of climate change.

From the applications of this model, it became clear that even a cell-based model can give an excellent insight in the management of a complex system of waterways and is able to provide an answer to complex water allocation challenges. This is the result of the calibration and validation taking into account both measurements as well as the feedback of the operators which is essential to understand the dynamics of a waterway.

However, there are gaps in the information about the studied waterways. About certain waterflows information is partly missing, this is for example the case for the extraction of water for agriculture. Another issue is the lack of discharge measurements on the waterways. There are already a lot of measurements available but not on every waterway and this makes the validation more difficult. More measurements and better registrations are thus of utmost importance to close these information gaps and increase the model's performance.

2.3 Optimization of Flood Control Areas in tidal areas

The Flemish governement, through «De Vlaamse Waterweg» (dVW), an independent government agency for the water management of navigable rivers and channels, has invested since 1976 in the design and construction of the Sigmaplan. The Sigmaplan is a water management plan for the Schelde river and tidal tributaries that focuses on improving flood safety, nature, recreation and economic functions. The main flood safety measures are high and strong dikes and about 40 Flood Control Areas (FCAs). Many of the planned FCAs are already built, while the remaining ones will be constructed by 2030. In the project "Klimaatrobuustheid Sigmaplan" it was requested to study if these measures (dike levels, FCAs, FCA-RT, depoldering, wetlands) will be adequate to avoid overtopping of the current banks under the most recent climate change scenarios for horizons 2050 and 2100.

Figure 6 Sigmalan projects (source: https://www.sigmaplan.be/en/projects/)

During the analysis of the future climate scenarios, it is observed that new measures are required. By studying the design of new FCAs, it is observed that existing FCAs are less effective in reducing water levels in the river under future climate scenarios. The main issue is that the FCAs fill up too rapidly for the design event, meaning they have no capacity left when the peak of the event arrives. However, by either increasing the inlet's invert or by reducing its width (or both), an effective reduction of the river water levels can be achieved.

Therefore, it is proposed to create a tool that improves the optimization process of the FCAs (both existing and new ones) for any given return period and (historic and future) storm event. This tool should also consider the tidal nature of this area and the ecology impact in the FCAs.

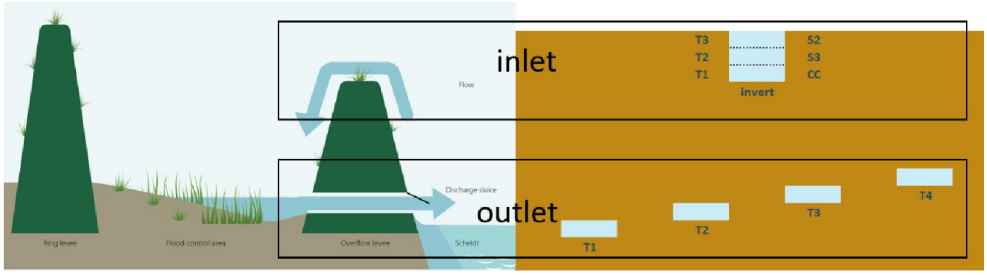

Figure 7 Inlet/outlet schematization at the overflow banks towards a Flood Control Area.

2.3.1 Prototype

A conceptual model for the FCA and an optimization tool for the inlets is built in Python 3.9. The study area is the new FCA, Battenbroek (Figure 8), located along the Grote Nete (Benedenete), just upstream where the Benedennete and the Dijle join into the Rupel.

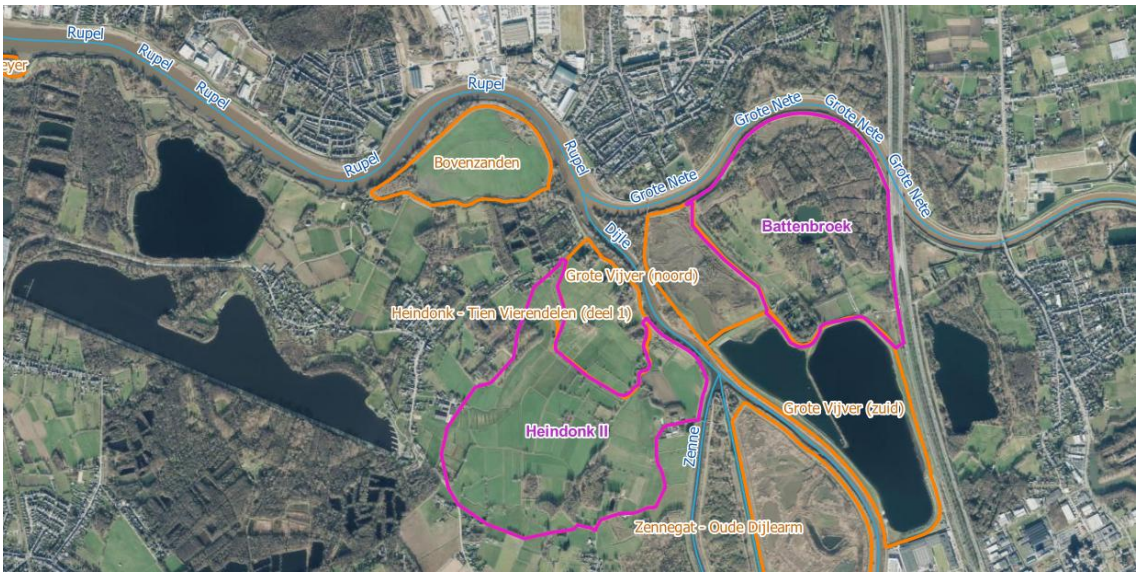

Figure 8 Flood control areas along the Dijle, Grote Nete and Rupel, including the new FCA Battenbroek.

Assumptions

- The geometry of the FCA is fixed, the tool will not optimize the extension of the FCA.
- The water levels at the river do not change when the inlet is added.
- The optimal inlet allows that the maximun fill capacity at the FCA is just reached for the design storm.
- The optimal outlet should keep the FCA as empty as possible before the peak storm.
- For each target storm there is a continuos (~logarithmic) line of optimal sets of invert=f(width). For lower inverts, narrower widths are optimal and vice versa.
- A maximum possible width is given based on a GIS estimation.

Data requirements

- The geometry of the FCA (fuchsia polygon in Figure 8)
- The timeseries of water levels along the river, next to the FCA, for all the climate change scenarios.
- A set of invert levels for the inlets for which the optimal widths will be estimated.
- Target elevation (Sigma dike level or Sigma dike level-security level)

Methodology

- The geometry of the FCA (fuchsia polygon in Figure 8) is processed in QGIS to obtain its hypsometric curve, the area corresponding to each elevation. This height-area table is converted to height - volume table.
- A conceptual model of the FCA is calibrated using the results of the Mike11 model (no measurements are availabe, it is a planned FCA). This conceptual model estimates the volume that goes in and out of the FCA for each time step. This volume is added to or extracted from the FCA using its height-volume table.

- For each given storm and for each given invert level, the widht of the inlet is optimized following optimization algortithm shown in Figure 9 and Figure 10. In Figure 11 and Figure 12 it is verified that different combinations of invert/width can lead to the same reduction of water level in the river.

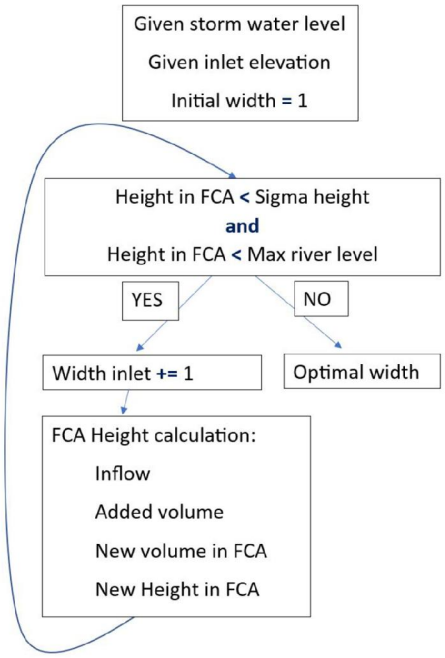

Figure 9 Scheme of the «inlet» optimization algorithm (source: Lebrun et Vandeweyer, 2023).

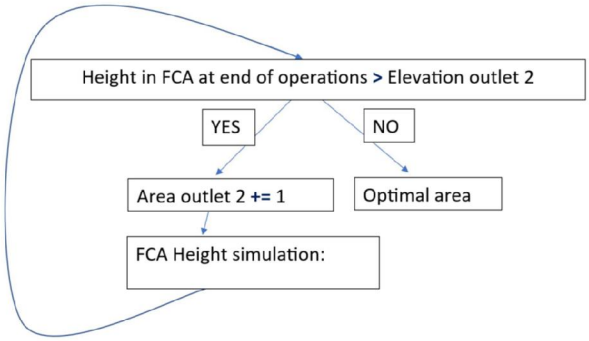

Figure 10 Scheme of the outlet optimization algorithm (source: Lebrun et Vandeweyer, 2023).

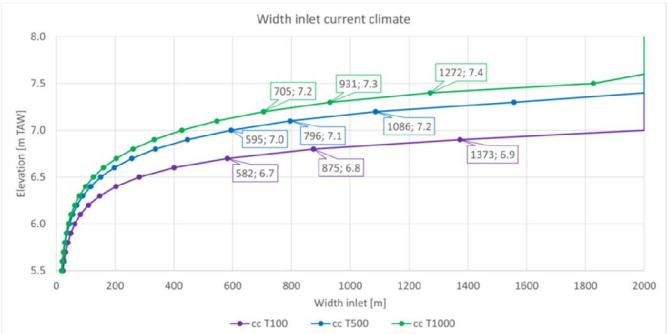

Figure 11 Selected combinations for the validation in the current climate (source: Lebrun et Vandeweyer, 2023)

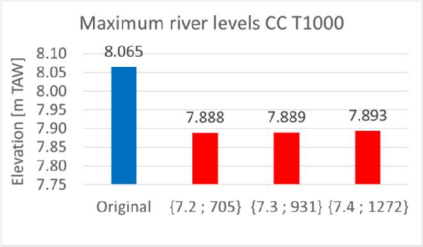

Figure 12 Maximum water level in the river for CC T1000 for the original cases, {invert [m TAW]; width [m]} (source: Lebrun et Vandeweyer, 2023)

Lessons learned from previous feedback

- The water levels at the river do change when the inlet is added. That is actually the purpose of adding FCAs. This effect is not in the conceptual model but is simulated in Mike11, meaning a new optimization is required, 1-2 iterations seem to be sufficient.
- The calibration of the tool could be done in an existing FCA, with the advantage that its existing measurements could be used instead of to the results of the Mike11 model.
- The current manual optimization of the FCAs is done per cluster. Where the invert of each existing FCA was chosen based on its target use, so the invert should either remain the same if possible or otherwise the change should be relative to other FCAs in the same cluster.

- We should first analyse the impact for FCA Kruibeke, which is the largest one and close to a point where future scenarios result in increased overtopping of the Sigma banks. It is challenging because KBR is subdivided in 2 FCA's, 2 FCA-RT and a creek with interconnected banks.
- A report per FCA should be provided with the optimal design per climate scenario. This falls outside of the scope of this demo-case.

2.3.2 Demo-case

Relevance of end-user for application of prototype

- The optimization of FCAs is particularly challenging because for each target storm event there is a continuous (~logarithmic) line of optimal sets of invert=f(width). For lower inverts, narrower widths are optimal and viceversa. So there is a wide spectrum of potential measures to choose from.
- This optimization is a very time consuming process that, besides flood safety impacts, also has to take into account ecological (water quality, protection or incentive of natura habitats) and economic impacts (boats transport, drinking water production). On top of that, the designs should be climate change robust and adaptable in time to the new climate conditions.
- The results of this tool let you visualize the full range of optimal solutions and can support designing a climate change robust (no regret) path of structural adaptations over time. For example, you can choose to keep the same invert and to reduce the width of the inlet instead for future scenarios. On the other hand, you can maintain the width and increase the invert. This allows for the required flexibility to also manage targets in the other concerned fields (e.g. cost, recreation, nature, ...).

Required adaptation of the prototype for integration within end-user infrastructure:

- A strategy to reduce the iterations needed during the optimization, due to the non-estimated reduction of the water levels in the conceptual model. This estimation can be computed in the model or approximated by application of a coefficient of increase in the 1st iteration results to avoid running many iterations.
- Dealing with complex areas like Kruibeke with several interconnected FCA's has to be improved.
- An optimization that attempts to replicate similar probability of filling in the FCA as in the current state can be added for existing FCAs.
- Preprocessing has to be further improved in the final solution so that the outputs from Mike11 or QGIS can be directly read by the tool.
- The tool can be tested in cases of a very narrow inlet where the invert is adaptable to the forecasting of oncoming storms.

Next steps:

1) Reduce the iterations needed due to the reduction of the water levels in the river when adding the FCA.
2) In existing FCAs, highlight optimal solutions that keep the flood frequency for future climate scenarios.
3) Improve the optimization of outlets.
4) Add reporting of optimization per FCA in the tool.
5) Add how to deal with complex areas like Kruibeke with several interconnected FCAs.
6) Incorporate the optimization in a flood control forecasting system (with use of IoT).

2.3.3 Conclusion

The results of this tool can speed up the optimization of FCAs. Visualizing the whole range of optimal solutions for different climate scenarios can enhance the selection of more climate change robust (no regret) measures that optimizes the designs from time to time. The tool has to be improved especially in the optimization of outlets, it has to be tested in more FCAs, and adapted to complex FCAs whith interconected areas. The pre- and post processing of the inputs and results has to be properly integrated with the user infrastructure. Ideally the developed principles can be used in adaptable inlets, used together with flood forecasting systems.

2.4 Smart Sense: Intelligent water protection

Istanbul's water distribution networks are a fundamental element of the city's life. These networks play a vital role for the sustainability of daily life. However, with cyber threats on the rise, the cyber security of these water distribution systems is of paramount importance. Cyber-attacks can negatively impact water supply and jeopardize public health.

Losses and leakages in water distribution networks are also a major problem. These losses need to be controlled for the sustainable use of water resources. In a large metropolis like Istanbul and Kocaeli, the efficient distribution of water, ensuring cyber security and preventing losses and leakages are of great importance both environmentally and economically. Therefore, special attention should be paid to the management and security of water distribution networks.

Our both stakeholders and end users are Istanbul Water and Sewerage Administration (İSKİ) and Kocaeli Water and Sewerage Administration (İSU). They are public authorities that provide water and environmental services such as water supply, sewerage, wastewater treatment and stormwater management in large cities. İSKİ and İSU regulate and supervise water supply, treatment, distribution and sewerage services. The main objectives of these institutions are to ensure the sustainable use of water resources, to plan water supply and wastewater management effectively and to work on environmental protection issues.

The proposed prototype 'Smart Sense: Intelligent Water Protection' is to develop an early alarm system for loss and leakage situations with the help of modeling in SCADA (supervisory control and management) where water distribution networks are monitored. At this point, the data of the SCADA currently used in Kocaeli ISU was analyzed and found to be fully compatible with the prototype.

2.4.1 Prototype

The details for setting up an early warning system in the SCADA system for detecting water leakage:

Sensors and Data Collection: Sensors are used to monitor water consumption within a specific district meter area. These sensors collect data on water flow rate and pressure. The SCADA system periodically gathers and records data from these sensors.

Data Analysis: The behavior of water consumption is analyzed, and a model of normal water consumption is created. Suitable water consumption intervals are defined based on this model.

Anomaly Detection: When water consumption falls outside the established normal consumption range, it is considered an anomaly and potentially indicative of a leak. Upon detecting a leak, the SCADA system identifies this anomaly and immediately generates an alarm.

Alarm Generation and Notification: When an alarm is triggered, the SCADA system uses configured communication channels to transmit this information to administrators and relevant personnel. These communication channels may include email. Alarms can be categorized by priority based on the severity of the event, ensuring that urgent situations are promptly addressed.

Determining the Leak Area: To identify the exact location of the leak, the SCADA system matches sensor data and the source of alarms. This allows for pinpointing where the leak has occurred.

Automation and Shut-off: If possible, the SCADA system can automatically intervene in the area affected by the leak. For example, it can control valve-closure systems to halt the flow of water to that specific area. In this way, monitoring water consumption behavior with the SCADA system enables the rapid detection of anomalies, such as water leakage, and notifies administrators. This early detection helps conserve resources, ensuring the water distribution system operates more safely and efficiently.

2.4.2 Demo-case

In demo-case, infrastructure in Kocaeli, which has a metropolitan municipality, was used. District Meter Area (DMAs) equipped with smart meters are preferred for monitoring and demo-case. The demo study was planned to be carried out by following the prototype scheme. The parts up to the last stage were implemented in the currently used SCADA system. The last stage of the prototype, that is, detecting the anomaly and automatically stopping the leak, could not be implemented in the system. Alarm values have been adjusted as seen in Figure 1. When the water level exceeded the set value, the system alarmed and created a red warning on the screen (Figure 2). The operator using the system continued to be the decision-making mechanism.

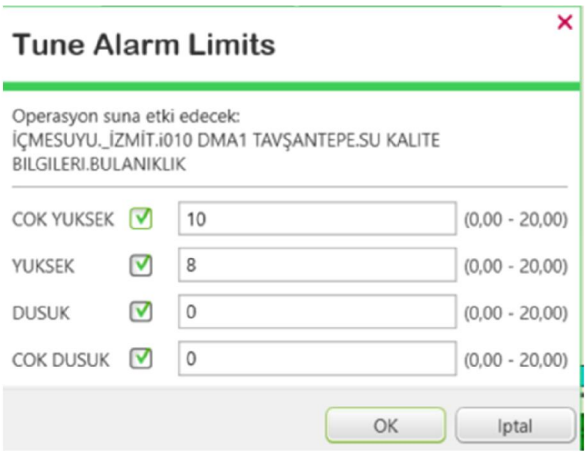

Figure 13 Screen for setting alarm limits (COK YUKSEK: very high, YUKSEK: high, DUSUK: low, COK DUSUK: very low).

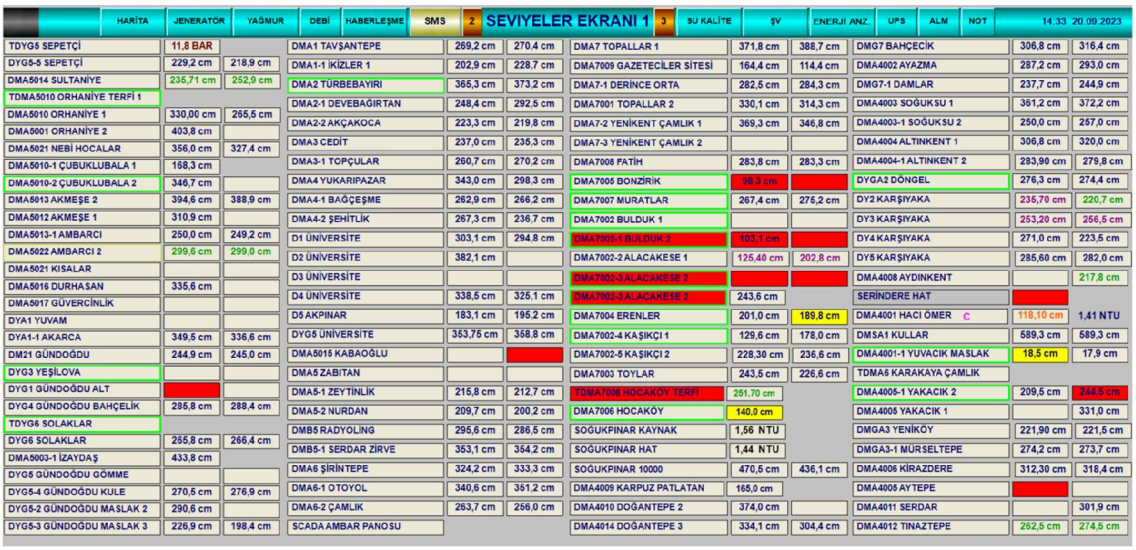

Figure 14 SCADA in general and alarm status (SEVIYELER EKRANI: Screen of water levels).

2.4.3 Conclusion

The outlined application is a work produced directly by the end user. The application provides an infrastructure in which the intended prototype is partially executed. It is essential that digital infrastructures in water distribution networks are protected against cyber-attacks and natural disasters. Although this was intended in the developed prototype, the implementation was carried out partially because end users had various restrictions on sharing data.

2.5 Quick reaction on a cyber-attack to guarantee clean drinking water

Regular monitoring of water pH, chlorine and turbidity levels is important to support efforts to maintain and improve water quality in water networks. Monitoring these parameters makes water supply systems more reliable and healthier, serving the goal of both protecting public health and managing water resources sustainably.

pH levels are used in water networks to determine the acidity or alkalinity of water. The role of chlorine in water disinfection is to neutralize microorganisms and pathogens in water and make water usable in a safe and healthy way. Chlorine is a disinfectant commonly used in water supply systems. Chlorine prevents the formation of microbial layers called biofilms in water systems. This limits the growth of microorganisms in pipes and tanks and keeps the water clean. Chlorine reduces the risk of microbial contamination during the storage and distribution of water. This ensures that water reaches the consumer in a clean and hygienic manner. Turbidity is a feature that reduces the clarity of water due to the dispersion or suspension of various particles and substances in the water. As optical transparency decreases, objects in water appear more obscure and faint. Turbid water distorts the appearance of the water due to the particles in it and reduces the perception of cleanliness of the water. Turbid water can make it difficult to visually inspect and track details and objects in the water. Particularly in water distribution systems, it can become difficult to monitor the quality of water and detect potential problems. Turbidity can increase the tendency for particles in water to settle. This may lead to sediment formation and blockages in systems during water storage or transportation.

Our both stakeholders and end users are Istanbul Water and Sewerage Administration (İSKİ) and Kocaeli Water and Sewerage Administration (İSU). They are public authorities that provide water and environmental services such as water supply, sewerage, wastewater treatment and stormwater management in large cities. İSKİ and İSU regulate and supervise water supply, treatment, distribution and sewerage services. The main objectives of these institutions are to ensure the sustainable use of water resources, to plan water supply and wastewater management effectively and to work on environmental protection issues.

The proposed prototype ‘Quick reaction on a cyber-attack to guarantee clean drinking water’ is to develop an early alarm system for suddenly occurring contamination with the help of modeling in SCADA (supervisory control and management) where water distribution networks are monitored. At this point, the data of the SCADA currently used in Kocaeli ISU was analyzed and found to be fully compatible with the prototype.

2.5.1 Prototype

The details for setting up an early warning system in the SCADA system for detecting sudden contamination:

Certainly, here is the translation of the technical details for the early alarm system demo within the SCADA system:

Parameter Monitoring and Measurement: The system continuously monitors pH, chlorine, and turbidity levels within the specified district meter area in the water distribution networks. Measurement data obtained through sensors is regularly collected and recorded by the SCADA system.

Normal Behavior Modeling: The general range of parameters is modeled, including determining typical values for pH, chlorine, and turbidity. Normal behavior typically involves a time-series analysis showcasing how these parameters change over a specific period.

Anomaly Detection: The model identifies values that deviate from the defined ranges or exhibit deviations from general behavior. When an anomaly is detected, it triggers an alarm, and notifications are sent to administrators.

Cybersecurity Controls: The system is protected by cybersecurity controls, including measures to detect unauthorized access attempts and preventive measures against cyber threats. Security infrastructure includes encryption, secure connections, and session monitoring, following cybersecurity standards.

Demo Area Limits: The demo is conducted within the specified district meter area, ensuring control over system performance and limiting the impact of tested parameters.

Cyber Attack Scenarios: The demo simulates specific scenarios based on cyber-attacks, such as unauthorized access attempts, data manipulation, or other potential security threats to the SCADA system.

Notification and Monitoring: Alarms resulting from anomaly detection are promptly communicated to administrators by the system. The SCADA system visualizes parameter changes in real-time through advanced monitoring tools.

2.5.2 Demo-case

In demo-case, infrastructure in Kocaeli, which has a metropolitan municipality, was used. District Meter Area (DMAs) equipped with smart meters are preferred for monitoring and demo-case. The demo study was planned to be carried out by following the prototype scheme. The parts up to the last stage were implemented in the currently used SCADA system. The final stage of the prototype, cyber-attack scenarios, could not be implemented in the system. Figure 3 shows the screens of the SCADA monitoring pH, turbidity and chlorine levels in the normal state. The screen in Figure 4 shows that the turbidity (BULANIKLIK in Turkish) value in the water in the line exceeds the set value and the drain valve is opened, and the water is discharged.

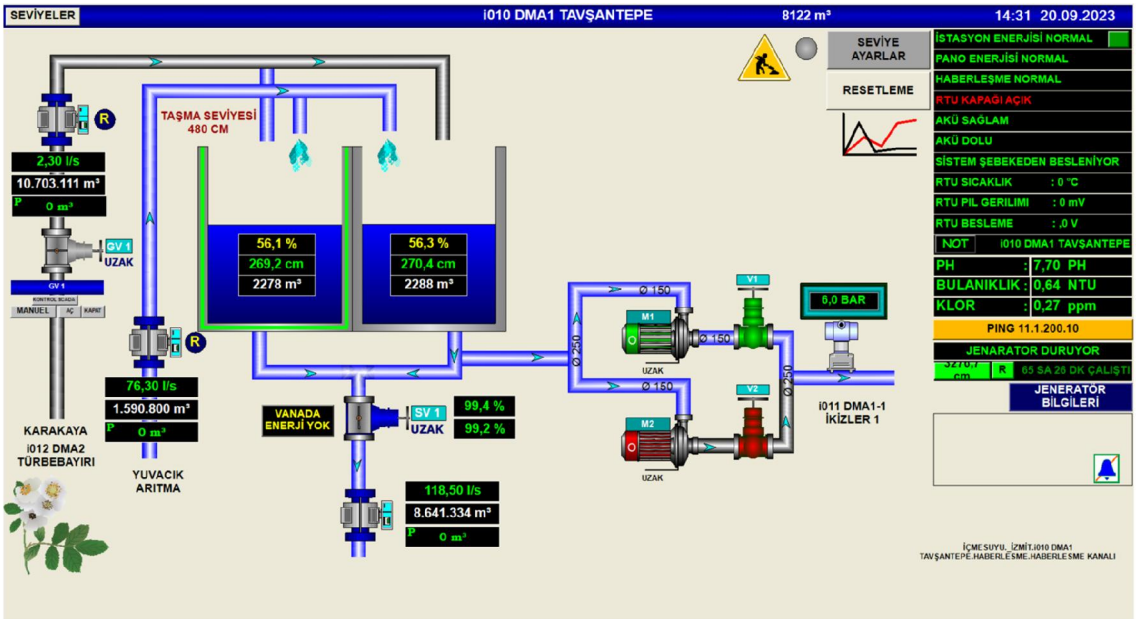

Figure 3 SCADA in normal status.

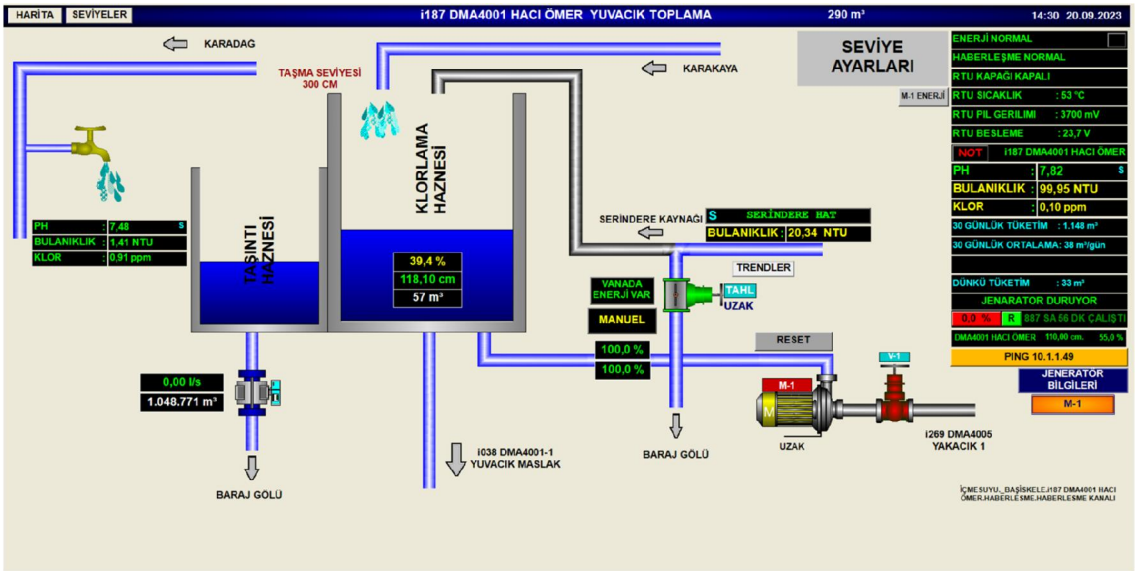

Figure 4 SCADA display of the situation when the turbidity value is high and in alarm.

2.5.3 Conclusion

The outlined application is a work produced directly by the end user. The application provides an infrastructure in which the intended prototype is partially executed. Digital infrastructures in water distribution networks must be protected against cyber-attacks and natural disasters. Although this was intended in the developed prototype, the implementation was carried out partially because end users had various restrictions on sharing data.

3. Conclusion

The aim of the WP3 is to strengthen the innovation capacity of the water industry and to improve social engagement of universities educating water specialists. The demo-cases descriped above show the final outcome. They are all innovative projects established throughout cooperation between academics, private sectors and governments, all focussing on water management.

These demo-cases are the result after an intense trajectory within DIGIWATER. The trajectory consisted of an online concepts design workshop, two innovation camps (one in Belgium focus on IoT and Big Data and one in Turkey focus on cybersecurity), two online evaluation workshops of prototypes (one with the focus on IoT and Big data and the other with focus on cybersecurity). Also outside of these camps and workshoups, effort has been put in elaborating the demo-cases, together with the different end-users.

Three demo-cases cover solutions on IoT & Big Data and two demo-cases revolve around solutions for cyber secure water infrastructure. The demo-case topics range from ground water monitoring to water balance modelling and from opitimization of flood control areas to monitoring and protecting our drinking water facilities. They are all tested in the infrastructure of end-users, which allowed sharing the innovative ideas with industry and simultaneously resulted in real-world feedback on the proposed demo-cases.

4. Bibliography

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5. ANNEX: ONE-PAGERS

DIGIWATER

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DEMO-CASE EVALUATION

DETAILS

Demo-case title: Waterbalance of navigable waterways

Student: Laurens Breugelmans (laurens.breugelmans@kuleuven.be)

End-user: De Vlaamse Waterweg

End-user representative: Niels Van Steenbergen (niels.vansteenbergen@vlaamsewaterweg.be)

DEMO-CASE DESCRIPTION

Due to the increasing occurrence of drought there is a need for a decision-making support tool which can help policy makers (e.g. De Vlaamse Waterweg) during such moments of severe drought. There is need for an overview of the waterflows on the waterways, both supply and demand, and more specific where shortages will occur and which measures can be taken to avoid severe damage to agriculture, shipping or drinking water production.

This need is answered by the construction of a conceptual water balance model which is flexible and fast calculating and thus capable of recreating historic situations to analyze the impact of measures implemented in those conditions, as well as making predictions of the impact of future conditions on the waterways. Those predictions can be short term forecasts focusing on the impact of specific measures on a certain location but they can also be on the long term focusing on changes in infrastructure or the impact of climate change.

END-USER FEEDBACK

The conceptual water balance tool developed by Laurens turned out to be very useful in replacement of another tool we used before, which was implemented in existing commercial software but which did not allow us to flexibly change the model structure and which had long computational times. The new tool allowed to implement flexibly any type of input and control actions along the network of navigable rivers and canals in Flanders. The tool was already applied in support of a number of water management tasks such as the impact analysis of climate change, impact analysis and optimization of a number of proactieve and reactive water management actions such as installation of pumps at the canal locks, discontinuing the hydropower stations, grouping of ships at the locks during droughts, canal level management, and changed water abstractions. So, in conclusion, De Vlaamse Waterweg is very much satisfied with this new tool. It will be of great value in support of our future water managament activities.

Signature:

Niels Van Steenbergen (Signature)

Digitaal ondertekend door Niels Van Steenbergen (Signature)
Datum: 2023.10.30 08:15:30 +01'00'

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DIGIWATER
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DEMO-CASE EVALUATION

DETAILS

Demo-case title: Optimization of Flood Control Areas in tidal areas

Student: Danitza Salazar Cortez (danitza.salazar@kuleuven.be)

End-user: De Vlaamse Waterweg

End-user representative: Jannie Dhondt (Jannie.Dhondt@vlaamsewaterweg.be)

DEMO-CASE DESCRIPTION

The Sigmaplan has being investing in constructing ~40 Flood Control Areas (FCA) since 1976. The design of these FCAs is based on a Social Cost-Benefit Analysis (SCBA) that aims for an "acceptable" flood risk (risk = frequency x damage) with variable design frequency along the Scheldt and tributaries. The damage is estimated using a Mike11 model, its boundaries are composite hydrograms and limnigrams designed for 12 Return periods(Trs).

Since the overflow dikes towards the FCAs are fixed, the FCAs are only optimal for storms of similar magnitude to its design storm. Due to Climate Change, the water levels along tidal rivers will rise, and the current designs will be less optimal for storms with similar Tr in the future. Besides, for the same storm, inlets with different sets of width and invert can lead to similar optimal reductions of water levels along the river. Given some optimal inlet dimensions for current climate; for future climate either its invert should be risen or its width should be reduced (or both) in order to get again an optimal reduction of water level along the river for the same Tr. Therefore, a conceptual model is built, it allows to get all the optimal solutions (a continuous curve) for each FCA and for all target Trs and climate scenarios. The tool drops the number of Mike11 simulations.

END-USER FEEDBACK

This tool to optimize the overflow crest levels and widths of flood control areas has been applied by Danitza to propose actions for the new, revised version of the Sigmaplan, taking recent climate change projections into account. The Sigmaplan protects the Scheldt and tidal tributary rivers in Flanders from flooding during extreme weather conditions, based on a chain of natural flood control areas in the river valleys. These areas can catch excess river water in a controlled manner, and does also provide opportunities for the development of river nature, recreational facilities and local economies. Although we did not use or check the tool ourselves, it appears the tool is a very promising instrument in support of the scenario investigations by reducing the number of iterative simulations required in the hydraulic model to find optimal solutions. Next to changing overflow dike crest levels and widths, there are other types of actions to be considered as well, which the tool cannot support, but it is definitely of interest in support of the design of the action on overlow dike crest changes.

Signature:

Patrick Willems (patrick.willems@kuleuven.be), academic supervisor of the demo-case

621764-EPP-1-2020-1-NO-EPPKA2-KA

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DEMO-CASE EVALUATION

END-USER DETAILS

Demo-case title: Quick reaction on a cyber-attack to guarantee clean water

Operator: Yusuf Zeren (yzeren@isu.gov.tr)

End-user: Kocaeli Su ve Kanalizasyon İdaresi Genel Müdürlüğü (Kocaeli Water and Sewage Administration, ISU)

End-user representative: Murat Sönmez (msonmez@isu.gov.tr)

Academic supervisor of the demo-case: Prof. Ismail Koyuncu (koyuncu@itu.edu.tr)

DEMO-CASE DESCRIPTION

In demo-case, infrastructure in Kocaeli, which has a metropolitan municipality, was used. District Meter Area (DMAs) equipped with smart meters are preferred for monitoring and demo-case. The demo study was planned to be carried out by following the prototype scheme. The parts up to the last stage were implemented in the currently used SCADA system. The final stage of the prototype, cyber attack scenarios, could not be implemented in the system.

The early warning system within the SCADA system for detecting sudden contamination involves continuous monitoring of pH, chlorine, and turbidity levels in a designated district meter area of water distribution networks. The SCADA system records measurement data obtained through sensors and models the general range of parameters, establishing typical values for normal behavior. Anomaly detection triggers alarms and notifications when values deviate from defined ranges or exhibit abnormal behavior. The system is fortified with cybersecurity controls to thwart unauthorized access and prevent cyber threats, employing encryption, secure connections, and session monitoring. The demo, conducted in Kocaeli, employs smart meters in District Meter Areas for monitoring. While stages up to detecting anomalies were implemented in the SCADA system, the final stage involving cyber attack scenarios was not realized.

END-USER FEEDBACK

Every system needs the monitoring mentioned in the prototype to ensure water safety in critical times and to maintain water quality in normal times. With the demo developed, water quality deterioration in the lines or tanks was monitored through changes in water quality parameters. In particular, alarms were activated in case of changes in pH, turbidity and chloride values, which are the monitored parameters.

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Rector

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DEMO-CASE EVALUATION

END-USER DETAILS

Demo-case title: Smart Sense: Intelligent Water Protection

Operator: Yusuf Zeren (yzeren@isu.gov.tr)

End-user: Kocaeli Su ve Kanalizasyon İdaresi Genel Müdürlüğü (Kocaeli Water and Sewage Administration, ISU)

End-user representative: Murat Sönmez (msonmez@isu.gov.tr)

Academic supervisor of the demo-case: Prof. Ismail Koyuncu (koyuncu@itu.edu.tr)

DEMO-CASE DESCRIPTION

The 'Smart Sense: Intelligent Water Protection' prototype aims to create an early alarm system for water loss and leakage using SCADA modeling in water distribution networks. The SCADA data from Kocaeli ISU was analyzed and found to be compatible with the prototype. The demo-case focused on Kocaeli's infrastructure, utilizing District Meter Areas with smart meters for monitoring. However, the final stage, automatically stopping leaks upon anomaly detection, was not realized. The system generated alarms when water levels exceeded set values, prompting operator intervention. The application, a product of end-user efforts, partially executed the intended prototype due to data-sharing restrictions. Protection against cyber attacks and natural disasters in water distribution network infrastructures remains crucial.

END-USER FEEDBACK

Every system needs the monitoring mentioned in the prototype to ensure water safety in critical times and water sustainability in normal times. With the developed demo, the amount of water in the lines or tanks was monitored via water level sensors. An alarm is activated when water levels fall below the set limits.

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