Showcase

Title: Use of a network of sensors to upgrade Eindhoven WWTP and improve ecological status of its receiving water

Sector: Drinking water (treatment):

☐ drinking water sources

☐ drinking water treatment

☐ drinking water distribution

☒ wastewater collection / influent

☒ wastewater treatment

☐ wastewater effluent / receiving water

☐ other

Utility: De Dommel Water Management Board, the Netherlands

Date: 2012

Introduction & Background Information

Dutch water management boards are regional governmental bodies charged with managing water levels and quality in Dutch surface waters. They are also responsible for management and maintenance of water barriers (levees, dikes) and the maintenance of waterways. To control quality of surface water (canals, lakes, ponds and streams), waterboards fulfil several tasks: policy making, planning and building projects, issuing permits (sewage discharge requires a permit) and the treatment of sewage and by-products. The various municipalities within the geographic area covered by a waterboard are responsible for collecting sewage from households and industries, but waterboards treat the sewage. Figure 1 shows an overview of the current waterboards and their locations across the country.

De Dommel Water Management Board (indicated as No. 22 in figure 1) is responsible for the Dutch part of the catchment of the Dommel River as well as that of the Zandleij River. The Dommel River is a small lowland river with its origins in Belgium and has a length of 120 km before its confluence with the Meuse River at 's Hertogenbosch. The lower 85km of the river's length fall within the area of De Dommel Water Management Board. Its area of responsibility includes the urban centres of Tilburg and Eindhoven, with a combined population totalling approximately 1 million.

De Dommel Water Management Board operates eight wastewater treatment plants, the largest of which is the Eindhoven WWTP, which treats the water for the city of Eindhoven and surrounding municipalities. It has a treatment capacity of 750,000-person equivalents, making it one of the biggest WWTPs in the country. The Eindhoven WWTP discharges its effluent to the Dommel River.

Water Quality Challenges

The Dommel River, as European surface water, is subject to the water quality targets defined by the Water Framework Directive (WFD). The WFD defines good chemical and ecological status of water bodies, with exact goals being defined by the nature of the water body. The waterboard has recently (2003 – 2006) invested substantially in the improvement of the water quality in the Dommel River; the Eindhoven WWTP was renovated and expanded, primarily to reduce the load of nutrients discharged to the Dommel River. The treatment process consists of removal of course materials (bar screens & sand traps) followed by primary clarification. Influent pumping is limited to a max of 35,000 m3/h and hydraulic capacity after the primary clarifiers is 26,250m3/h. In case the total flow exceeds this value, surplus water is diverted to a 8,750m3 stormwater storage tank. Any further surplus is directly discharged to the Dommel River.

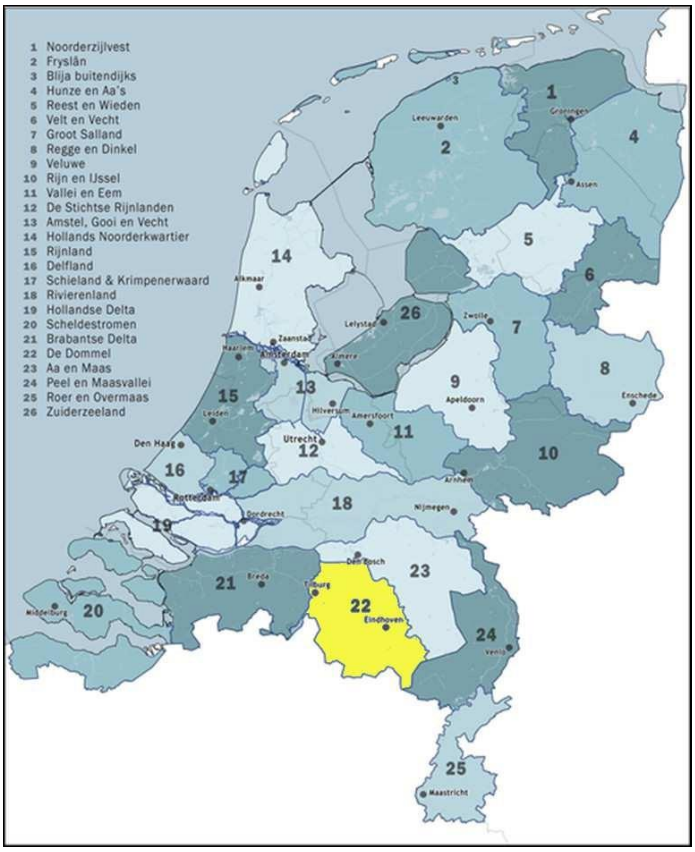

Figure 1 Overview of the Dutch water management boards, the Dutch part of De Dommel catchment is highlighted in yellow. (Image source: Janwillemvanaalst via Wikipedia Commons)

After primary clarification, wastewater undergoes biological treatment, by way three 3 activated sludge tanks with anaerobic, aerated and denitrification zones (UCT process) followed by secondary clarifiers after which it is discharged to the Dommel River.

In addition to updating the WWTP, the river has partly been restored to its natural state as part of the improvement and modernisation project. Despite these investments, however, the quality of the water still was under pressure from discharges of oxygen depleting contaminants from the wastewater treatment plant as well as from 200 combined sewer overflows (CSOs) in the Eindhoven agglomeration. During normal flow conditions, the WWTP effluent constitutes approximately 50% of the river's base flow (typically 2 – 4 m3/s but this can increase to around 90% during prolonged rainfall (with river peak flow up to 14 m3/s). Despite the modernisation of the treatment plant, both peak loads of COD and ammonium from the plant itself as well as from CSOs still disturbed the oxygen balance. Incidents with dissolved oxygen (DO) concentrations below 2mg/L still occurred (Figure 2), which had a direct negative impact on the aquatic ecology. In addition, the high peak loads of ammonium caused acute toxicity for fish. Finally, the CSOs still caused summer average loads for nitrogen and phosphorus above the levels specified according to the WFD.

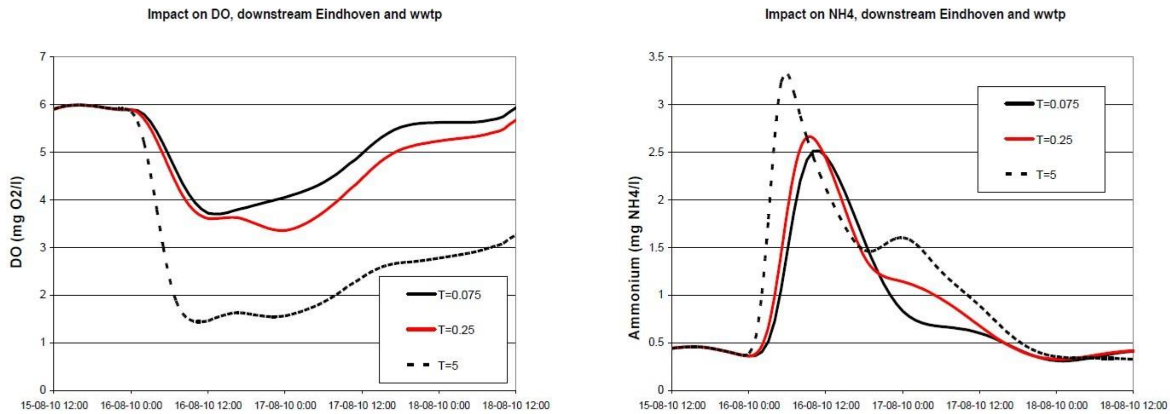

Figure 2 Impact of storm events on DO (left) and ammonium (right) in the Dommel River (Source: Langeveld et al.).

Approach and Implementation

The focus of the activities in the Eindhoven wastewater system was on protection of the aquatic environment in the Dommel River from oxygen dips and ammonia peaks caused by the combined discharges of the biologically treated WWTP effluent, a rain water buffer (RBT) settling tank at the WWTP and the over 200 CSOs within the Eindhoven area. In addition, the level of nutrients and suspended solids in the Dommel River had to be reduced to be able to comply with the maximum summer average concentration levels in the river of 0.15 mg Ptotal/l and 4 mg Ntotal/l and solids and sludge accumulation in the river needed to be controlled.

A number of options was available to further improve the water quality of the Dommel River beyond that achieved by the WWTP modernisation. These measures included the following options:

- reduce CSO emissions by increasing dry storage capacity at CSOs and/or at the WWTP.
- improve the use of hydraulic retention of the wastewater in the sewer and WWTP - this required an improved real-time control (RTC) strategy built around real-time measurements in the sewer network
- increasing nitrification capacity at the treatment plant using dissolved air flotation

(DAF) as an additional pre-treatment step in combination with additional aeration capacity.

- aeration of the WWTP effluent and/or river water.
- use of sand filtration of the effluent to remove nutrients.

The KALLISTO Project

In 2010, De Dommel Water Management Board launched a comprehensive applied research project (KALLISTO) in order to identify the most cost-effective set of measures that would allow it to meet the WFD requirements. This project focused on using an integrated approach which combined impact-based control and a minimum of additional measures. An innovative combination of monitoring, modelling and controlling water flows within existing infrastructure was used. Furthermore, the construction of adequate technical measures such as pumping facilities and advanced treatment facilities was investigated, with the goal of actively controlling storm water and wastewater flows and water treatment on the basis of actual water quality and quantity (so-called pollution load control). Leading in this real-time decision-making and optimisation are the chemical and ecological surface water composition of the Dommel River. For that reason, the water quality of the river needed to be monitored continuously and modelled to be able to determine - depending on the actual (seasonal) situation - where, when and for how long discharge of effluent or overflow water could be tolerated at major storm water events or whether additional measures have to be taken.

The KALLISTO project was a cooperation between water a number of international partners. In various work packages De Dommel Water Management Board cooperated with the municipality of Eindhoven and the nine other municipalities connected to the Eindhoven urban sewer system. Engineering companies Royal Haskoning/DHV and Witteveen+Bos assisted with the hydraulic modelling of sewers and the optimisation of the sewer and transportation system for wastewater and storm water. Ghent University (Belgium) participated in the optimisation of the aeration process and the waterboards Vallei&Eem and Brabantse Delta cooperated in research on new advanced treatment methods for effluent, CSO discharges and SST effluent at WWTP Eindhoven. The chemical and ecological effects of the discharge of nutrients and oxygen demanding constituents to the Dommel River was evaluated together with Wageningen University. Finally, dissemination and communication of project results were coordinated by the Dutch Foundation for Applied Water Research – STOWA.

The total budget for the KALLISTO project amounted to 3.8 million Euros, 2.7 million of which were a research grant from the Dutch Ministry of Transport, Public Works and Water Management.

Development of the monitoring programme

The monitoring activities in the KALLISTO project was built upon five years of research in the

Showcase

Eindhoven Area concerning the use of online water quality and water quantity monitoring instrumentation in sewer networks and wastewater treatment plants. This work was performed within a project which started in 2006 and aimed at exploring the potential of real-time control to maximise the in-sewer storage capacity and the hydraulic capacity of the WWTP. As part of this project, referred to as the RTC project, a sensor network was set up in the Eindhoven agglomeration wastewater system to monitor the dynamics of the wastewater system and the receiving waters.

The Eindhoven urban wastewater system consists of the municipal sewer systems of the ten connected municipalities, three transport mains, 200 CSOs and the Eindhoven WWTP. The northern transport main is a gravity main transporting the wastewater from the communities of Nuenen, Son and Bruegel to the WWTP. The western main is a gravity main transporting the wastewater from the city of Eindhoven to the WWTP. The southern main is the longest main and is basically a gravity main which is divided into four sections by three control stations. These control stations regulate flow in such a way that the hydraulic retention capacity of the mains is utilised. Individual municipalities are connected either by gravity mains or pressurised mains. Furthermore, a small section of the southern main itself is pressurised where water is pumped from one valley to a neighbouring valley. Figure 3 presents an overview of the Eindhoven urban wastewater system.

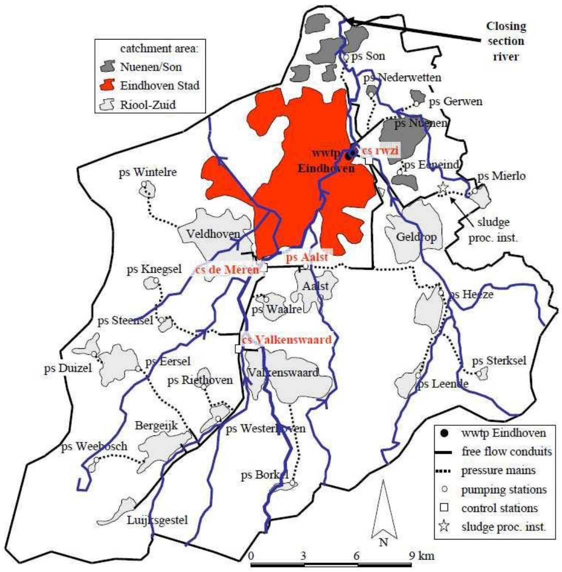

Figure 3 Sewer network of Eindhoven and surrounding municipalities. Area discharging through the Eindhoven sewer main marked in red, through by the Nuenen-Son sewer main in dark grey and through Riool Zuid system main in light grey. Source: Liefting et al.

As part of the RTC project, a network was set up consisting of twenty-five rain gauges, seven flow sensors (in pressure mains), twenty-three flow sensors (in partially filled sewer pipes and wet wells), thirteen level sensors and seven water quality sensors (in the influent pumping station of the WWTP). A schematic overview of the installation sites of the sensors in the wastewater system is provided in Figure 4. This monitoring network was designed to specifically address the goals of the RTC project:

1. gain experience with the use of online sensors in a sewer environment.
2. gain insight into the variations (both in temporal and in concentrations) of pollution loads in the 3 sewer systems feeding into the Eindhoven WWTP.
3. determine the effects of water quantity and quality variations in the sewer system on the WWTP influent.
4. determine the effect of variations on influent quality and quantity on the WWTP effluent quality.

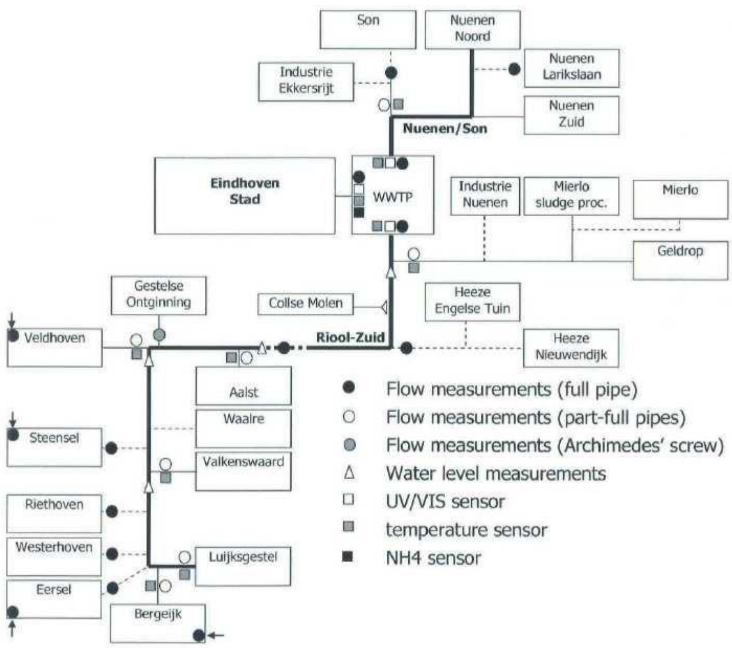

Figure 4 Schematic representation of the sewer network in Eindhoven and surrounding municipalities, including the monitoring network (rain gauges not shown). Source: Schilperoort et al., 2012b.

While the RTC project was ongoing, the De Dommel Water Management Board decided that monitoring in the wastewater chain (collection, transportation, treatment, effluent, receiving waters) as initiated in the RTC project was to be a core responsibility of the waterboard. This decision was made at board level and made possible the professionalisation of the monitoring programme and the allocation of the required resources. The approach to monitoring changed from being project-based, with a defined beginning and end-point, to being a regular operational task. This also allowed the waterboard to initiate and formalise the cooperation with the

neighbouring municipalities and to agree on a division of work, where De Dommel Water Management Board took on the responsibility for managing and maintaining the common monitoring network and the municipalities covered the capital investment for acquisition and installation of the instrumentation.
The policy of a common monitoring network (CMN) was put into effect with the drawing up of a common monitoring plan in 2009 by the ten municipalities involved. The basis for this monitoring plan were information requirements for the discharge permits of the municipalities. This needs for this monitoring network therefore were limited to five rain gauges and “only” 200 level sensors at the 200 CSOs in the wastewater system.

The KALLISTO project was initiated at the same time. The information requirements were much higher within this project, t. Despite an overlap with the CMN, KALLISTO necessitated a further upgrade of existing monitoring network, which included:

- 400 level sensors and 40 flow sensors in the sewer system.
- five well-equipped rain monitoring stations combined with rainfall radar.
- modernisation of instrumentation, automation and control at the WWTP.
- extensive monitoring in the river, comprising continuous monitoring of dissolved oxygen and ammonia, combined with automated sampling and ecological surveys.

Within the KALLISTO project, results from this extended monitoring network were primarily used for:

- calibration and validation of fully detailed models of sewer system, WWTP and receiving water.
- simplification and integration of the sub-models into a single sewer-WWTP-river model.
- global sensitivity analysis to identify the control structures with a significant impact on receiving water quality, revealing the key control structures for the RTC strategy.
- composing and evaluating RTC strategies.

Although the overlap in monitoring needs in the common monitoring network and the KALLISTO project was seen as an opportunity for dual benefit of the instrumentation, it actually resulted in a conflict of interests with the collection of the information for KALLISTO within the limited timeframe of the project. In the CMN, the approach had been to use as much data as possible from sensors already installed, including those in the monitoring networks of the participating municipalities. The integration of these data streams, however, required considerable effort and resulted in delays in KALLISTO, because access to the municipal data networks proved difficult. Furthermore, once access was obtained the results were often of insufficient quality, nonetheless requiring installation of new sensors. A further cause for delay which resulted from the combined approach was the necessity to procure the new instruments through a European tender procedure. Although this resulted in substantial cost saving (approximately 50% on capital costs), the time required to go through all the steps of the tender procedure meant the network was not installed within timeframe scheduled for KALLISTO.

Monitoring instruments and results

Various types of instrumentation were used, including rain gauges, flow sensors, level sensor and water quality instruments. The latter comprised UV/Vis sensors, turbidity and conductivity measurements and online analysers for ammonium and phosphate. The results and experience obtained with a selection of these types of instrumentation is briefly summarised below.

Flow and Level

Two types of sensors were used for the flow measurement; measurement of the water level with a pressure sensitive membrane and measurement of the flow speed with electromagnetic sensors. Both sensors were installed at the bottom of the sewer. This proved to be problematic, as the sensors were regularly covered by a layer of sludge, impairing the measurement. Unfortunately, in some cases, this was not immediately noticed, resulting in some occasions in the loss of up to 50% of the data from these sensors. Fouling of the sensors, including covering up by sludge, could often be directly deduced from data analysis as it resulted in constant measurement values, unrealistically low values and/or the absence of typical daily flow patterns. In addition to the fouling issues, some of these sensors were found to exhibit large systematic errors. In-situ calibration at the installation site was crucial for proper operation and good quality data from these sensors, a fact that was only realised late in the project, causing further loss of useful data.

Because fouling is inevitable in sewer installations it is important to install instruments in easily accessible location, as frequent maintenance (cleaning) is required. Sometimes this can mean it is economically more efficient to construct a new access / monitoring site than to install a sensor in an existing but poorly accessible location.

Setting up the CMN and monitoring network for KALLISTO benefitted from these lessons, both in the design and site selection phase as well as in allocation of personnel for maintenance. This resulted in 90%+ of the data being of high quality.

Rain gauges

A total of twenty-five rain gauges was installed. Unfortunately, it had to be concluded that all data collected with these sensors was not fit for use. Statistical evaluation showed that due to fouling and clogging of the instruments, approximately 25% of the data was unreliable. However, upon comparison of the remaining results with simultaneously collected measurements from the monitoring network of the Royal Netherlands Metereological Institute, large and inconsistent deviations were observed for all gauges. Data collected by the twenty-five instruments could only be used for rainfall detection, but not for measurement of the quantity of precipitation.

Evaluation of the installations showed that on the grounds of cost as well as practical aspects, incorrect installation sites had been selected. For example, sensors had been installed on the sites of waterboard facilities as these offered easy access to power, and instruments were secure and not at risk of being vandalised. Correct procedures for siting rain gauges, however, had not been observed. For example, no attention had been paid to the rain shadow of trees and buildings Furthermore, no site acceptance tests had been performed. Such a test prescribes a calibration and would have shown the discrepancy between the rain gauges and their counterparts in a national network at an early stage. The idea that sufficient quantity in sensors would be able to compensate for lower data quality proved erroneous.

In the CMN and the KALLISTO project, a total of only five rain gauges has been installed, but as a result of the preceding experience the proper procedures were followed and necessary support and maintenance has been included in the monitoring budget.

Results from the hydraulic measurements

Using the flow and level measurements, it was possible to identify structural and geometric errors in the hydraulic models. For example, the measurements helped identify sewer pipes that were not included in the models or dimensioned incorrectly and an unknown connection between the influent chambers of the western and southern sewer systems at the WWTP pumping station was identified. This cross connection could directly lead to sewer overflows in the western (Eindhoven city) sewer network in case of high levels in southern sewer main. This relationship between the two sewer systems was previously unknown.

Another issue identified through the hydraulic measurements was an error in the control logic of the WWTP; when the pumping station between the primary clarifiers and the aeration basins detected a high water level, the entire control of the influent pumping station would be briefly shutdown and reset (1 - 2min.). As a result, fluctuations in the level of the water in the sewers of up to 50cm would occur, which in some instances directly resulted in overflows. This error was a legacy of the modernisation project completed in 2006 and had not been identified.

The most extensive flow and level monitoring network was set up along the southern sewer main. The reason for this was the use of these main for both wastewater transportation and for providing storage capacity. Maximising retention is part of the strategy for reducing CSOs and therefore the functioning of the southern main was thoroughly investigated. This showed that the retention capacity was fully used in the southernmost section (upstream from the control station De Meeren, see Figure 3). Downstream from De Meeren, however, two issues were identified: 1) the pumping station at Aalst had insufficient capacity to pump all water into the next section of the mains at times of high flow because maximum pump capacity was lower than the maximum combined flow in the upstream sewer systems, and 2) the retention capacity in the main between Aalst and the WWTP was not being fully used. This was the result of the system design, the main being designed to transport part of the wastewater from the Eindhoven city system. This connection between the two systems, however, had never been never realised resulting in spare capacity. This spare capacity is now being used for rainwater retention.

Water quality sensors

The data yield from the water quality sensors in the RTC project was substantially higher than of the other instrument types. Specifics are given below, but it is important to note that the higher data yield was (at least) partially related to an intensive support of the installation and maintenance of these sensors, including intensive (manual) cleaning. As a result, data loss is primarily the result of sensor failures and not of loss of data connectivity (see paragraph on Data Collection) or fouling.

UV/Vis sensors

As part of the RTC project, four UV/Vis s::can spectro::lyser spectral sensors were installed. Three instruments were installed in the influent pumping station, one each in the influents of each of the three sewer mains. As in-situ installation of the instruments in the influent chambers in the pumping station was impossible, water was pumped from the chambers into a flow-through monitoring set-up located in the pump house. The monitoring set-up was redesigned several times in order to reduce the maintenance needed to keep the sensors clean; initial designs of the set-up suffered from rapid build-up of sludge in the flow through tanks, which interfered with the measurements. Furthermore, in the first design, the suction pumps were installed in the raw sewage, in front of the bar screens. This resulted in clogging and blockage of the pumps, and as a result the pumps had to be moved to a position in the suction chambers, behind the bar screens.

The final installation solution included a shallow flume in which the instruments were installed in parallel with the flow (to maximise flow velocity around the instrument) and compressed air was used to periodically remobilise materials that had settled on the bottom in the flume. Also, the instruments were moved into an external cabin, as the installation inside the pumping station itself was problematic due to corrosive gasses emanating from the raw sewage. As this meant that the building was regularly off-limits, interfering with the accessibility of the instruments, and caused corrosion of the equipment, the instruments and controllers were installed in an external cabin in the final station design. This resolved the accessibility issues, eliminated the corrosion issues and also offered more hygienic working conditions.

The biggest operational challenge with the use of the spectrometer probes was the cleaning of the optical windows. It was found that these windows fouled rapidly. The three instruments monitoring the raw sewage could be kept relatively clean by using the automatic cleaning with compressed air that the manufacturer supplies, although failures of the compressor which supplies the air affected instrument availability. Despite the use of automatic cleaning, regular verification (monthly) of the cleanliness of the instruments, including manual cleaning and checks with distilled water, were still necessary. A fourth instrument installed in the framework of the RTC project, monitoring the water pumped from the primary clarifiers to the activated sludge tanks, suffered from such severe fouling that it produced no useful data.

In the RTC project a total of nineteen months of raw data (spectra, TSS, COD and filtered COD) was collected with the instruments monitoring the WWTP influent. The instruments were calibrated on the specific matrix in which they were installed to improve accuracy, as the manufacturer calibration resulted a correct order of magnitude in the parameter results, but in quantitative terms the results were unsatisfactory. Furthermore, a dry weather and wet weather calibration was made, as the composition of the wastewater is very different under these conditions.

After validation, a useful set of data covering a total of one year remained. These results were combined with flow measurement to estimate pollution loads. The results clearly showed the daily recurring variations in wastewater composition. Similar patterns were observed for the Eindhoven and the Son/Nuenen sewer systems. The southern sewer main, however, showed a marked difference, with a high peak recurring around noon on weekdays. This peak was traced to a sludge treatment plant which discharged concentrate accumulated during the night in the morning hours of the following day (but not on weekends). During the monitoring campaign, approximately 40 rain events were registered. These events show a brief peak in suspended materials and COD in the early stages of such events (first flush) followed by a period of relatively low pollution concentration due to dilution effect. The high flow means that the total pollution load is higher than during dry weather flow. This is due to the fact that during rain events in addition to the normal dry weather loads additional pollutant streams are collected: dirt flushed into the sewers by the rainwater and materials that are remobilised from the sewers by the high flow.

Long term analysis showed that approx. 25 – 50% of the data was lost due to various reasons which included: cleaning activities, failure of the compressor (for compressed air supply), software and hardware updates, data communication failures, instrument failures, by-pass pump failures and as a result of course materials (hair, etc) becoming stuck in the measurement section of the instrument blocking the light beam and resulting in measurement failure. Most of this is avoidable loss and not due to the instrumentation used. With proper installation and support, up to 90% + was expected to have been achievable.

In the KALLISTO project, the number of UV/Vis instruments has been expanded to seven (with additional instrument being installed in the nitrification basin, the storm water collection tank and the WWTP effluent). The results from the UV/Vis probe were primarily used for the fine-tuning and calibration of the WWTP models. The lessons learnt in the RTC indeed provided the necessary inputs to develop improved operating procedures to increase the data availability.

Turbidity and conductivity to monitor pollution loads in wastewater

The use of the combination of turbidity and conductivity monitoring for the estimation of pollution loadings in WWTP influent and at CSOs was investigated in KALLISTO. Both turbidity and

conductivity can be measured with relatively simple and cheap sensors. Conductivity measurement can be used to monitor dilution of the wastewater in case of rain events. Turbidity measurements can used to monitor the particle concentrations, especially due to re-suspension during increased flow events.
Previous results had shown that using turbidity only, it was impossible to determine the pollution load during rain events as the particle loads depended on the location of installation and also varied strongly between rain events. However, the combination of turbidity with conductivity was shown to provide a robust indicator for the wastewater composition, especially for COD. Using this information it was possible to identify “clean” and “dirty” CSOs.

Costs and Maintenance

The costs associated with various proposed measures was estimated to span from €160 million in necessary investment for construction of sufficient dry storage buffer capacity to prevent CSOs and overloading of the treatment plant, to € 36 million for construction of the DAF treatment stage and € 1 million investment costs for river aeration. The price for simply increasing the retention capacity with more dry storage volume was unacceptably high. However, using any single option of the less costly instruments was insufficient to meet water quality goals.

Quality Assurance / Quality Control

In the RTC project, data quality was not verified until after the data collection stage had been completed. At that point, a lot of issues with data quality were identified, but it was too late to take corrective measures. For the newly constructed common monitoring network, which also collected data for the KALLISTO project, near real-time data validation was implemented to prevent a repeat of this issue.

Further improvements implemented included:

- installation according to available guidelines (e.g. for raingauges).
- performing site acceptance tests (including calibration).
- making available sufficient personnel capacity to support installation, operation and maintenance of the monitoring network; aailability of personnel to support the monitoring network was an issue in the RTC project, which reduced the overall data yield and the quality of the data collected – the embedding of the monitoring strategy in the organisation on a management level has resulted in professionalisation of the approach. Sufficient resources (financial and personnel) have now been allocated. A total of 2.5 FTE is available for support of the monitoring network.

Data Collection and Storage

The use of GPRS for data transfer in a large monitoring network was novel for De Dommel Water Management Board when first attempted in the RTC project. As a result, data losses due to data communication problems amounted to approximately 20% of total data points collected by the sensors. This data loss was the result from a combination of issues, including:

- hardware malfunctions (broken routers);
- poor signal strength;
- re-booting SIM cards, which could take up to 30 minutes;
- phone company merger, which resulted in a lower priority for data communication on the GPRS network used, causing the loss of data from several stations for weeks on end;
- routers along national borders, which would switch over to Belgian GPRS networks and would lose data connection.

Another issue which was not related to wireless data communication was the need for correct signal translation. As many sensors used provided their data in the form of an analogue 4-20mA signal, signal conversion was necessary before transfer across a GPRS connection was possible. Such a conversion required accurate programming of the measurement ranges in the D/A convertor and required the use of the correct resolution on the convertor (in this case, 14 bit). Errors were easily made, which caused data to be erroneous.

The primary reason for loss of data, however, was the absence sufficient on-site storage to buffer data during loss of communication. If this had been available, data could have been transferred as soon as the communication had been restored.

Losses in data could have been reduced by:

- using local data storage as backup, to guarantee continuity in data.
- ensuring the contract with the supplier of the communication solution was based on performance (e.g. minimum up-time) instead of a minimum effort.
- purchasing data instead of instrumentation – in the case of a data supply contract, the responsibility for data availability and quality lies with the contractor; in the case of De Dommel Water Management Board (and most water and wastewater utilities) the instrumentation is purchased, and the utility personnel is responsible for maintenance. The (limited) experience in the Dutch water sector with data supply contracts has been positive so far. Nevertheless, De Dommel Water Management Board has opted to pursue a more traditional approach.

Data Handling

In the RTC project, De Dommel Water Management Board set up a network for data collection from remote monitoring locations in the sewer network. The data collection system was built around the IHistorian database already in use for data collection and storage of the measurements at the WWTP. Measurement data was collected on site using data loggers that also performed primary data validation (checking measured results against static thresholds). Data was then transferred to a central FTP server over a GPRS network. For secondary validation, automatic routines were implemented on the central data server.

Validation of results in (near) real-time has proven crucial; in the RTC project, much of the data was not analysed until after the project. This meant that large amounts of data were lost due to failure to timely detect various issues with the data collection and transmission and with the instruments themselves. Had these issues been identified during the project, they could have been rectified and a lot more data would have been available for processing.

In CMN as well as KALLISTO, primary validation was used to provide information on the technical functioning of the sensors. In addition, secondary validation attempted to find relationships between the measured values and behaviour of the wastewater in the sewer system. It compared results from different measurement sites and looked for (lack of) correlation. It also looked at relationships between different sensor types (e.g. rain gauges vs. in sewer level measurements). The results from the validation were reviewed the next working day at the latest. This validation approach and associated maintenance activities led to a data yield of around 90% for the entire monitoring network (against sometimes less than 20% for some sensors in the RTC project). In 2012, a further validation step was added to detect linear trends in data. This extra validation step led to a temporary decrease in 'good' data to 70% as this test required six months of historical data. During the initial phase of using this filter, data was being labelled as unreliable because the filter lacked sufficient historical data to access it, not because there was a real issue with the data quality. After the run-in phase, data yield was back to 90+ %.

Evaluation of Successes and Limitations

The KALLISTO-project showed the large-scale monitoring networks in the sewer system can help a great deal in understanding the system. Modelling makes it possible to accurately assess the hydrodynamic behaviour in the network, but only if the model has been calibrated and validated on the basis of real measurement data. The substantial deviations between measurement and calculated results in non-validated models, which are often employed and were also observed in KALLISTO, show that verification of model performance is essential. KALLISTO also showed that boundaries between systems need to be defined with care in such models: whereas it is easy to draw a boundary in a model; if such a boundary is not present in the real system, the model will be incorrect. Modelling on a high level, in this case including the networks of all the connected municipalities, was shown to produce a significant improvement in the quality of the modelling results.

KALLISTO resulted in a set of integral optimisation scenarios. This was primarily a set of control solutions which made use of existing infrastructure, in combination with buffering and controlled discharge. The most cost-efficient solution consisted in in-stream river aeration to tackle DO depletion and WWTP DAF pre-treatment to reduce NH4 peaks. Only when the effect of these measures is not sufficient to reach the necessary improvement in ecological status of the Dommel River, additional physical measures in the sewer system or in the treatment plant will be considered.

A comparison with the cost calculated before the start of the project, based on the adoption of conventional methods like addition of sewer retention volumes, revealed that a saving of about 70% of investment cost (from an initially estimated 150 million) and of about 50% total costs were possible despite reaching the same environmental objectives.

Operational Changes

The original RTC strategy aimed at maximising the use of the in-sewer storage capacity and of the hydraulic capacity of the downstream WWTP, resulting in a volume-based RTC strategy. Although this strategy ensured maximum use of existing infrastructure, it still resulted in intermittent discharges from CSOs and WWTP effluent, leading to water quality issues in the Dommel River, specifically DO depletion and ammonia peaks.

As a result of the KALLISTO project, which evaluated various strategies of further improving water quality in order to meet the objectives set forth in the Water Framework Directive, a number of additional measures were defined. The most cost-efficient solution for achieving the required water quality consisted in a further optimised RTC approach (developed using the improved and fully calibrated hydraulic and WWTP models) combined with in-stream river aeration, to tackle DO depletion, and the use of WWTP DAF pre-treatment to reduce NH4 peaks.

The river aeration and RTC have been implemented, as these are cost effective and required relatively little investment. The impact of these measures is being monitored until 2015-2016 and the final set of measures to be implemented will be based on the improvement in the river ecology that remains to be achieved. Furthermore, more detailed knowledge of the ecological quality of the Dommel River in relation to CSO discharges, WWTP effluent composition as well as on the contribution of the DAF is still being collected. Any further measures will be implemented in 2017-2024.

Lessons Learnt

- Consider well which experience and capacity is available in-house and which activities can/should be outsourced. It can, for example, be more efficient to outsource the installation of sensors in difficult-to-access places in the sewer system
- Consider whether purchasing instrumentation or opting for a data supply suits your needs best.
- Whether purchasing equipment or outsourcing services, take into account the long timeframe associated with a (European) tendering procedure
- Realisation of a cooperation between utilities with regards to data exchange, especially of online instruments, can require time and effort. It may be more efficient to set up new monitoring sites instead of using the data from existing sites in monitoring networks of neighbouring utilities
- Good data validation is the key to high data yields, despite the fact that introducing data validation may ostensibly reduce data yields in the short term.

Conclusions

De Dommel Water Management Board set itself the goals of gaining experience with online monitoring under the reality of working in a wastewater environment. It was willing to take risks, explore the boundaries and learn from mistakes. This has resulted in many lessons learnt, which were put to good use in the KALLISTO project. The KALLISTO project is an exemplary case of using monitoring results to calibrate detailed models which describe the dynamics of the whole Eindhoven urban wastewater system. These models have been used to evaluate the cost-effectiveness of different upgrade scenarios, addressing the need to improve water quality in order to comply with water quality regulations. The results of the evaluation showed that a combination of relatively cheap strategies could be used to address the water quality issues. The integrated model proved to be a very powerful tool to quickly investigate interactions, synergies and conflicts in the whole urban wastewater system, allowing for the identification of effective solutions to achieve the defined receiving water quality objectives.

By setting up a common monitoring network, De Dommel Water Management Board and the neighbouring municipalities took an important step towards effective management of the entire urban wastewater system. Cooperation was a cornerstone in coming to a successful implementation of this network. The success of the cooperation is demonstrated, amongst others, by the recent decision to build a new central, main control room. This new control centre will further increase the information exchange and simplify the analysis of the combined wastewater and sewer systems.

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