Report defining Report defining the integration scope of the solution to be demonstrated

Deliverable DA1.1

Real-time pollution-based control of urban drainage and sanitation systems for protection of receiving waters

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1 Introduction

LIFE RUBIES project follows a previous LIFE project named LIFE EFFIDRAIN (2015-2019). This previous project aimed at developing and demonstrating new concepts for urban drainage control and Combined Sewer Overflow (CSO) mitigation. These new concepts rely on a not new idea which is to control wastewater based on pollutant fluxes rather than spilled volumes. However, the concepts and tools developed then are totally innovative (Ly, 2019).

During this previous project it has been demonstrated that such pollution-based approach could lead to improved pollution emission savings from the urban wastewater system when compared with classic volume-based control. However, this demonstration has been exclusively performed and assessed on virtual environments. Thus, the objective of LIFE RUBIES is to demonstrate the savings of these concepts on real urban areas, here namely Madrid (Spain) and Lille (France).

To do so, the concepts developed have to be adapted so they can comply with field reality to be robust and make sure that the system performance cannot be degraded. Then, these upgraded robust control modules must be encapsulated in digital systems capable of monitoring and controlling urban wastewater systems. Within this project, the digital solution that has been chosen is Aquadvanced Urban Drainage (AQDV UD), which is a Suez digital tool that is already running in many cities around the world. This experienced platform provides all the basics in order to apply the cutting-edge concepts of the previous LIFE EFFIDRAIN project. The mix of the upgraded LIFE EFFIDRAIN tools with the AQDV UD platform will compose the innovative and exclusive LIFE RUBIES solution.

In this deliverable, the main project aspects are presented, such as the pilot sites, the monitoring strategy concepts and the control tools.

1.1 Global pilot sites description

1.1.1. Spanish site of Madrid

In recent years, important drainage infrastructures have been undertaken in the city of Madrid in order to comply with the current legislation, especially regarding the Water Framework Directive (WFD) and the Tajo River Management plan, which defined those flows with a dilution less than 17 times the peak dry weather flow (DWF) must be conducted and treated in the wastewater treatment plants (WWTP). The new infrastructures built to fulfil these requirements were:

New interceptors, one at each side of the Manzanares river with a maximum capacity of 17 times the peak dry weather flow.

Detention tanks were built in the connections of the main sewers with these interceptors in order to retain the first and most polluted waters avoiding to discharge them to the river. Also, these tanks were equipped with regulation gates to guarantee that flows below 17 times the peak DWF reaches the interceptor.

In the main margin interceptors and previous to the WWTP several big detention tanks are built to retain flows and slowly treating them according to the capacity of the WWTP.

All the detention tanks are equipped to be automatically controlled from a central management operation which is also connected with the WWTP operation center. However, managing a system of this complexity is not easy due to the interrelation of the different elements and obviously this operation is different in dry weather or in rainy weather, being this last case the one that presents greater difficulties, and therefore more improvement options. It is because of this complexity that currently there is no centralized protocol between the different elements of the system. So nowadays the operation is carried out autonomously in each tank with the general objective of collecting as much water volume as possible limiting the untreated water to be discharged to the river.

Figure below provides a general overview of the whole Manzanares system with the location of:

- The two river margin interceptors (one at each side of the river)
- The main tributary sewers connecting to the interceptors.
- The 27 secondary tanks located in these tributary sewers with volumes ranging between 500 and 8000 m^3 for each one and a total detention volume of 77000 m^3
- The 6 main detention tanks.
    - Valdemarín (28000 m^3)
    - Pozuelo (30000 m^3)
    - Arroyofresno (400000 m^3)
    - La China (130000 m^3)
    - Abroñigales (200000 m^3)
    - Butarque (359000 m^3)
- The 5 WWTP:
    - Viveros: 2.2 m^3/s (approx. 1 million p.e.)
    - La China: 3.3 m^3/s (approx. 1.5 million p.e.)
    - La Gavia: 2 m^3/s (approx. 1 million p.e.)
    - Butarque: 3.5 m^3/s (approx. 1.8 million p.e.)
    - Sur: 6 m^3/s. (approx. 3 million p.e.)

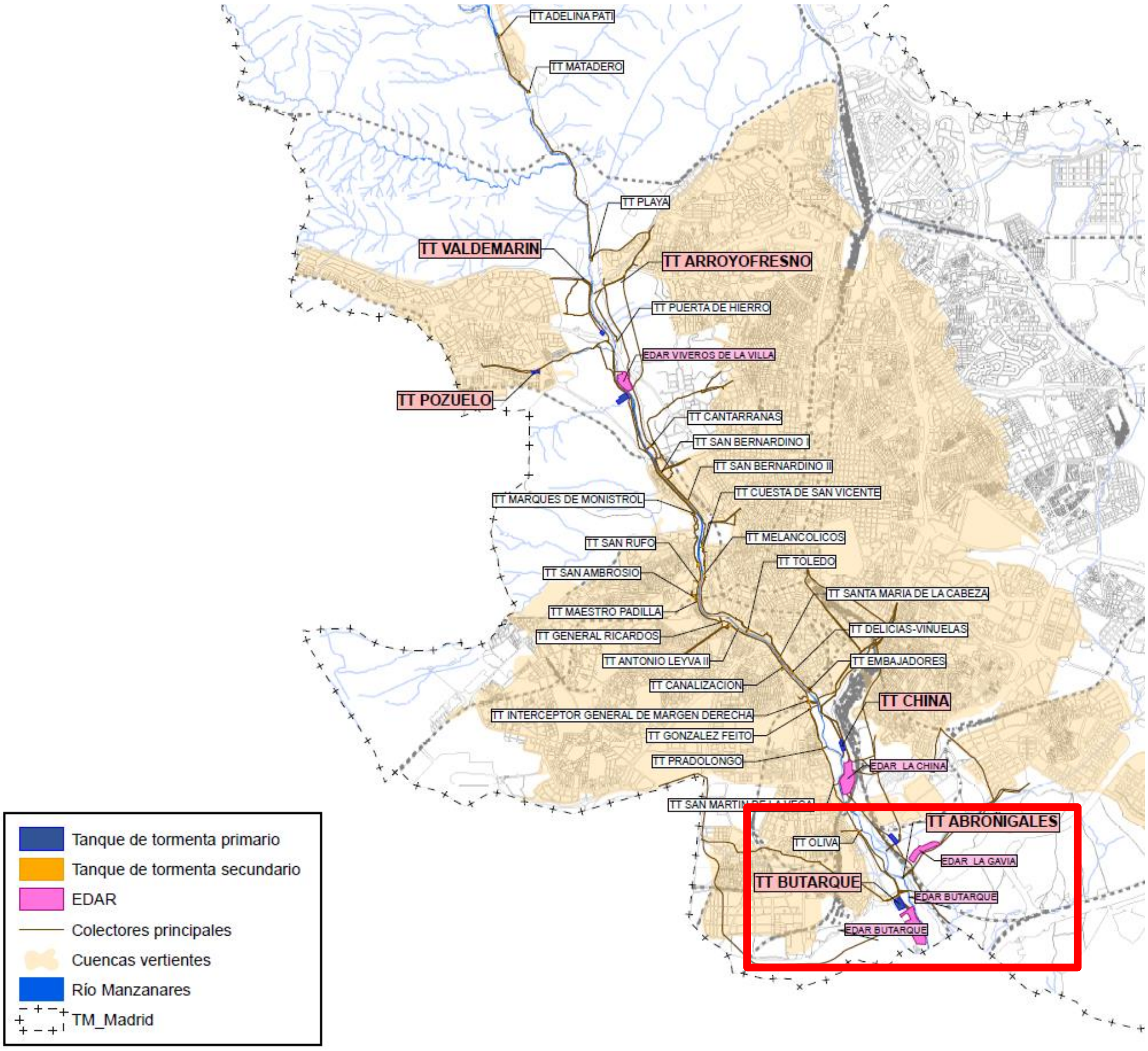

Figure 1 : Manzanares system overview with the location of the main sewers, main and secondary detention tanks and WWTP. Marked in red there is the selected pilot site for the LIFE RUBIES project in the southern part of the system

The system flows from north to south and the waters are driven through the main tributary sewers to the margin interceptors. In the north there is little treatment capacity and waters from both river sides are treated in the Viveros WWTP, but in rain events it does not have the capacity to treat all the flows generated, so important flows are diverted to the south part of the system by both margin interceptors.

It can also be seen that there is a significant imbalance between both margins. The only WWTP on the right bank is Butarque. Although in the north the water is diverted to Viveros WWTP by crossing the river, all the water collected throughout the city on the right bank reaches Butarque, whose capacity is insufficient, so immediately before the Butarque storm tank there is a by-pass conducting some water volumes to the left margin interceptor towards the Sur WWTP.

The pilot site is in the downstream part of the Manzanares system.This is the most complex part because it receives flows from all the system and a mass balance in this part is not easy since it depends not only on the basins characteristics and the sewers capacity, but also of the real operation in the upstream tanks and WWTPs. Also, there are flow divertions between the right and left margin interceptors and several other complex divertion chambers.

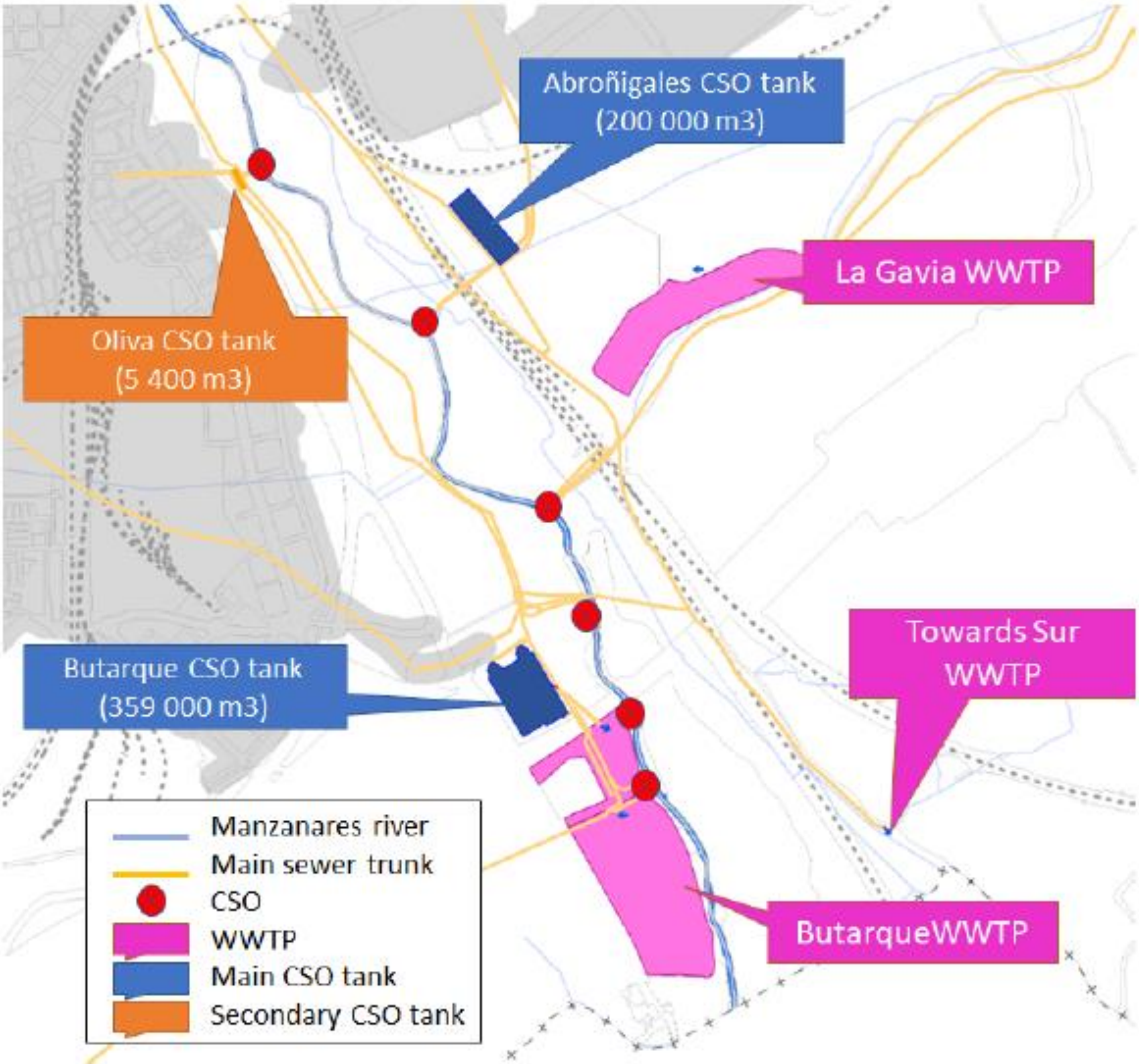

Figure 2 : Detail of the Rubies project pilot site in Manzanares system

The pilot site shown in the figure below, includes:

- 3 detention tanks: a secondary one, Oliva tank, and two main ones Butarque and Abroñigales.
- 2 WWTPs: Butarque and La Gavia although this last one does not have any upstream actuator to be included in the improvement operation in the project.
- 6 flow input points:
    - In_D1 and in_D2: Inflow points from upstream the right margin interceptor. In this part the collector is doubled.
    - In_D3: Inflow from the tributary sewer getting into Oliva tank

- In_D4: Inflow from the tributary sewer Butarque I
- In_D5: Inflow from the tributary sewer Butarque II
- In_I1: Inflow from upstream the left margin interceptor.
- In_I2: Inflow from the tributary sewer getting into Abroñigales tank

- 6 CSO discharging points:
  - CSO_D1: Oliva tank discharging point
  - CSO_D2: Right margin CSO point upstream main entrance to the Butarque tank
  - CSO_D3: CSO point located in the right margin interceptor upstream the Butarque WWTP.
  - CSO_D4: CSO point in Butarque II tributary sewer upstream the secondary entrance to the Butarque tank.
  - CSO_I1: CSO point in Abroñigales tanks
  - CSO_I2: CSO aliviadero sur point. In this point two discharging flows are met, the one coming from the effluent (and the non treated waters bypassed in rainy events) from La Gavia WWTP, and the flow exceedance from the left margin interceptor.
- 6 flow output points to the WWTP:
  - WWTP_Butarque: Influent main line entrance to Butarque WWTP
  - WWTP_ButarqueP: Flows treated in the primary treatment line of the Butarque WWTP (it only operates in rainy events when the main line is working at full capacity).
  - WWTP_Gavia: Influent to Gavia WWTP.
  - WWTP_Sur: Left margin interceptor drives the waters to the Sur WWTP. This WWTP treats these flows but also from other municipalities to the south of this point.

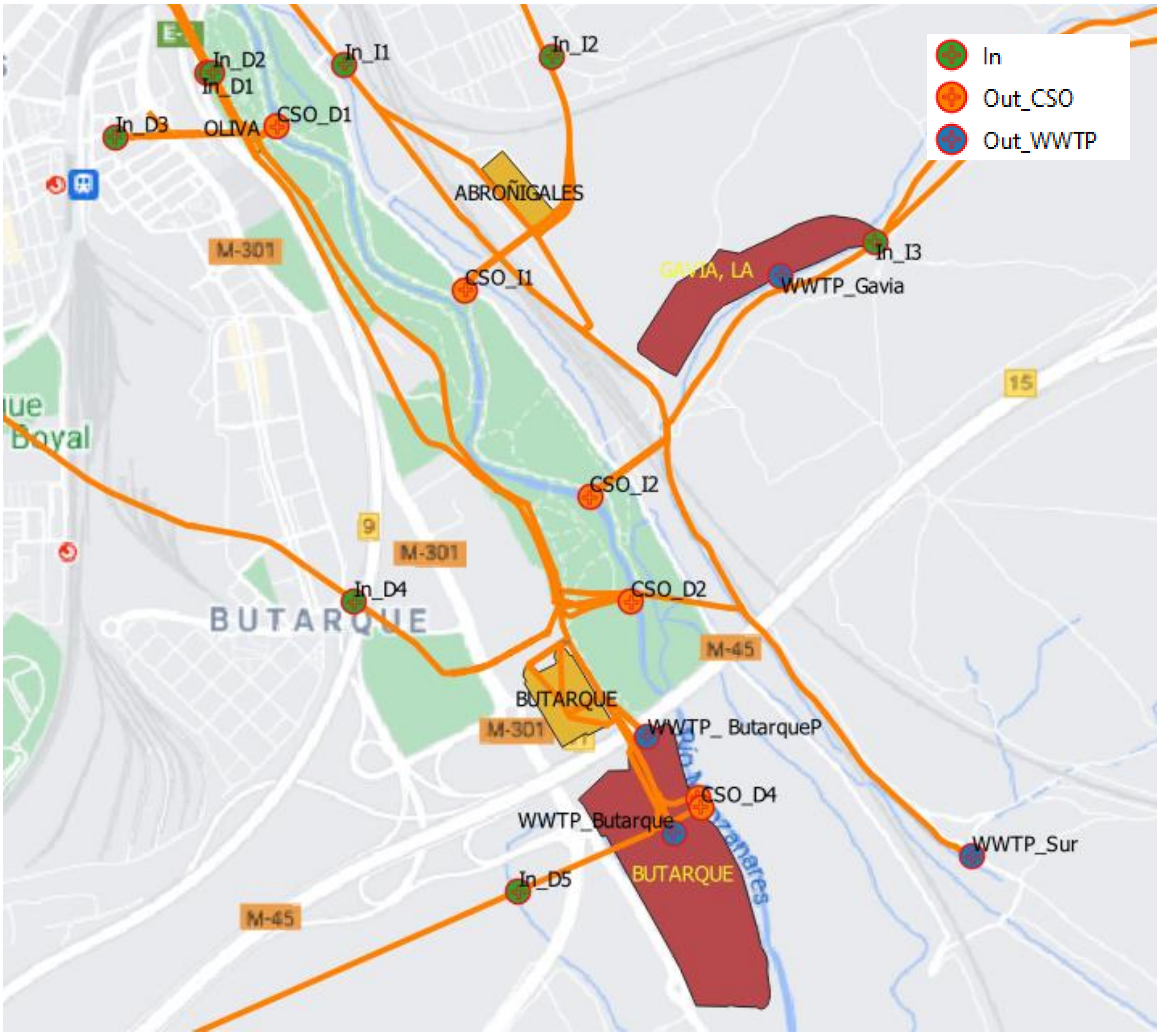

Figure 3 : Location of the flow inputs and output points in the pilot site

In this pilot area, several operational management improvements have already been detected, so that is the reason why it was chosen. The most important ones are related with the operation of the two main tanks in the area:

- Butarque tank: It has been checked that during rain events there are CSO discharges upstream of Butarque WWTP because its capacity is exceeded while the Butarque tank is far from being full.
- Abroñigales tank: Similarly, it has been verified that in rain events there are CSO discharges in Aliviadero Sur (located downstream the tank) while this tank is not full and water is being by-passed.

1.1.2. French site of Lille

The European Metropolis of Lille manages the sewerage of an agglomeration of 1.2 million inhabitants spread over 95 municipalities. The territory is divided into 17 sewerage agglomerations. The largest is Lille. It is this agglomeration that is the focus of this European project. The Lille agglomeration is located in the north of France, on the border with Belgium. The CPBO (gross organic pollution load) of the agglomeration is 540,933 p.e. The nominal capacity of the treatment plant is 533,333 p.e. (Figure 4).

Figure 4 : MEL territory and sewerage agglomerations

The Lille sewerage agglomeration covers 35 municipalities and 163 km², with a population of 523,466. It is a highly urbanised area with a few agricultural zones to the north and south of the agglomeration. Many industrial companies are present in the area and 21 industries are monitored.

The agglomeration includes:

- 191 pumping stations
- 220 storm overflow weirs
- 7 storage basins for rainy weather pollution control

- 51 self-monitored A1 discharge points (25 of which > 10,000 p.e.)
- 18 R2 characteristic points
- 6 rain gauges
- A wastewater treatment plant (nominal capacity 553,333 p.e.) with a reference flow of 258,249 m3/d (percentile 95 2020). It was commissioned in 2015. The treatment plant is located in the commune of Marquette.
- The plant comprises :
  - A biological treatment line with a maximum flow of 2.8 m3/s. The discharge is into the canalized Marque river at the outlet of the decanters
  - A stormwater treatment line with a maximum flow of 5.3 m3/s. The discharge is into the canalized Marque river downstream of the Marcq-en-Barœul sluice.

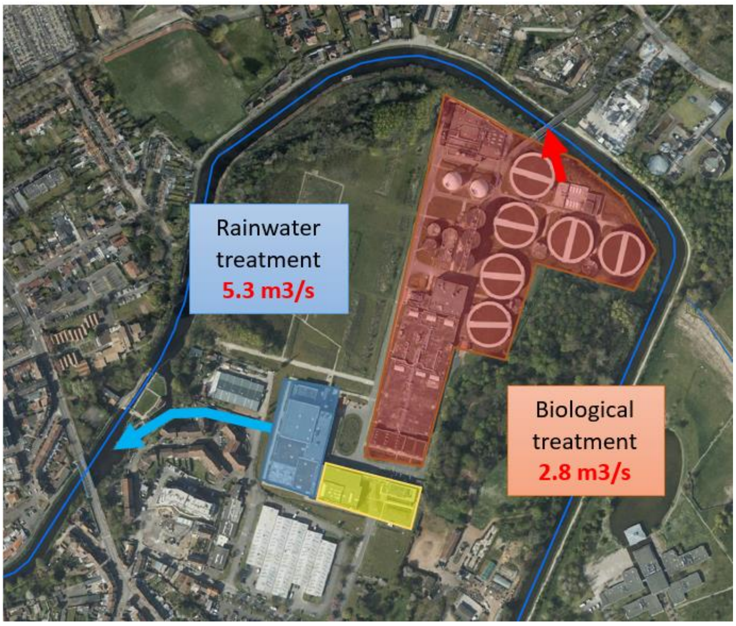

Figure 5 : Lille Marquette wastewater treatment plant - Biological treatment line - Rain treatment line - Discharge points to the canalized Marque river

1.2 Pilot sites context, challenges and objectives targeted with LIFE RUBIES

1.1.3. Spanish site of Madrid

Manzanares river flows entirely through the Community of Madrid (Spain) and is a tributary on the right margin of the Jarama river, which flows into Tajus river. Manzares river passes through the city of Madrid and flows into the Jarama river, in the municipality of Rivas-Vaciamadrid, after a distance of 92 kilometers.

The river hosts different ecosystems and crosses areas of great environmental value, which have received different levels of protection. Its upper basin, from its source to El Pardo mountain, constitutes the regional park of the "Cuenca Alta del Manzanares". Its lower course is also protected, within the "Parque Regional del Sureste". The water body is part of the Register of Protected Areas prepared by the Tajus river basin district authority within the category: Sensitive Area (Directive 91/271/EEC) and Habitat or Species Protection Area (Directives 92/43/EEC and 2009/147/EEC).

In Madrid, Manzanares is mostly channeled with concrete U-shaped structures. Downstream of the city riverbanks are protected by loose riprap protections. In its urban route, the course of the Manzanares is the result of decades of channeling and damming works. In 2016, in Madrid area the river was recovered to its natural flow discharge by opening floodgates, which led to an increase in biodiversity in this area. Upstream of Madrid city, river flow discharge is regulated by Santillana reservoir. In this area water quality is high and river is used for public water supply.

Since 1984, Madrid City Council has been responsible of Manzanares river monitoring and protection along its course through the municipal area, with a length of approximately 30 km, until the southern boundary of the municipality near to Getafe. The work carried out by the Manzanares River Maintenance and Operation Services includes monitoring the water quality, controlling the ichthyofauna and birdlife, cleaning the water surface, bed and banks, controlling the successive floodgates and permanent surveillance and collaboration with the municipal emergency services.

Nowadays, the Madrid-Río Plan, promoted by the Madrid City Council, contemplates a wide range of actions such as the management of the riverbanks and floodplains and the improvement of water quality through the construction of wastewater and stormwater treatment facilities. The water, diverted for supply in the upper course, returns to Manzaneres rivers after being treated by the municipality's Wastewater treatment plants.

But despite the existing WWTPs, Manzanares river remains as one of the most polluted rivers in Spain. Treated wastewater and combined sewer overflow (CSO) spills from the combined sewer system of Madrid metropolitan area are discharged into de river. The main pollution source in the studied area is related with the large amount of volume and pollution loads from Madrid WWTPs and CSO tanks. Therefore, 6 WWTPs in the municipality of Madrid and the surrounding area spill their effluents to Manzanares river, together with two other WWTPs that discharge into the Culebro stream, a tributary of the Manzanares in its lower catchment.

The situation in the Manzanares river is not conventional. Usually, large river receive small discharges of treated wastewater, so pollutants are diluted in the streamflow. However, in this case the natural flow discharge is quite reduced, and treated wastewater spills are one order of magnitude larger. This causes the opposite effect, i.e. river flow quality is like a slightly diluted WWTP discharge. As more WWTPs are discharged into the river, the small natural purification capacity of the river disappears.

A first assessment of the current physical-chemical water quality of the Manzanares river reflects problems with dissolved oxygen (DO) and ammonium concentrations. The concentration of DO is alarmingly low at some points in the river, reaching anoxic conditions in the Rivas-Vaciamadrid river section on many occasions. There is also a recent problem with ammonium concentration in the same place. Due to the lack or malfunctioning of nitrification biological processes in the treatment plants, large areas of the river present a very high toxicity for any type of aquatic life; these concentrations are incompatible with the water body good condition. In the records of the CEMAS and SAICA stations published by the administration, it's reported that in the Rivas Vaciamadrid station observations of over 20 mg/L of ammonium are common. On the other hand, all this discharged ammonium is a strong source of nutrients for the main course of the Tagus River and its reservoirs.

The water body in which the reach studied is located according to Hydrological Planning of the Spanish river basin management (Tagus river, planning cycle 2021-2027) is called "RÍO MANZANARES A SU PASO POR MADRID" (code ES030MSPF0427021) with 40.5 km long. Main conclusions obtained from river basin planning are:

- Its minimum ecological flow is 500 L/s in the months of July to September.
- This reach, as it passes through Madrid (some 20,6 km), is for the most part channelled with rigid structures.
- The water body is classified as HEAVILY MODIFIED. It has always had very low quality objectives, within the assessment of "ecological potential": LESS RIGOROUS OBJECTIVES. Currently the "final status" rating of the water body is "LESS THAN GOOD".
- The aim is to achieve GOOD ECOLOGICAL POTENTIAL but the risk of not achieving this is classified as "very high" in the Hydrological Planning documents.
- The goal values set for physico-chemical quality elements, of interest in this project, are as follows: $6 \leq pH \leq 9$; Dissolved $DO \geq 5$ mg/L; $60 \leq \%OD \leq 120$; Ammonium ≤ 0.6 mg/L; Phosphates $\leq 0,5$ mg/L; Nitrates ≤ 25mg/L.

The sewage system in the municipality of Madrid has almost 5,000 kilometers of sewage networks and 8 wastewater treatment plants, and 37 stormwater tanks with a total storage capacity of 1,370,250 m3 (Figure below). The system treats 100% of the wastewater corresponding to more than four million inhabitants of the population of Madrid metropolitan area.

The drainage and sanitation system discharges its treated wastewater, CSO and pluvial stormwater to both the Manzanares and Jarama rivers.

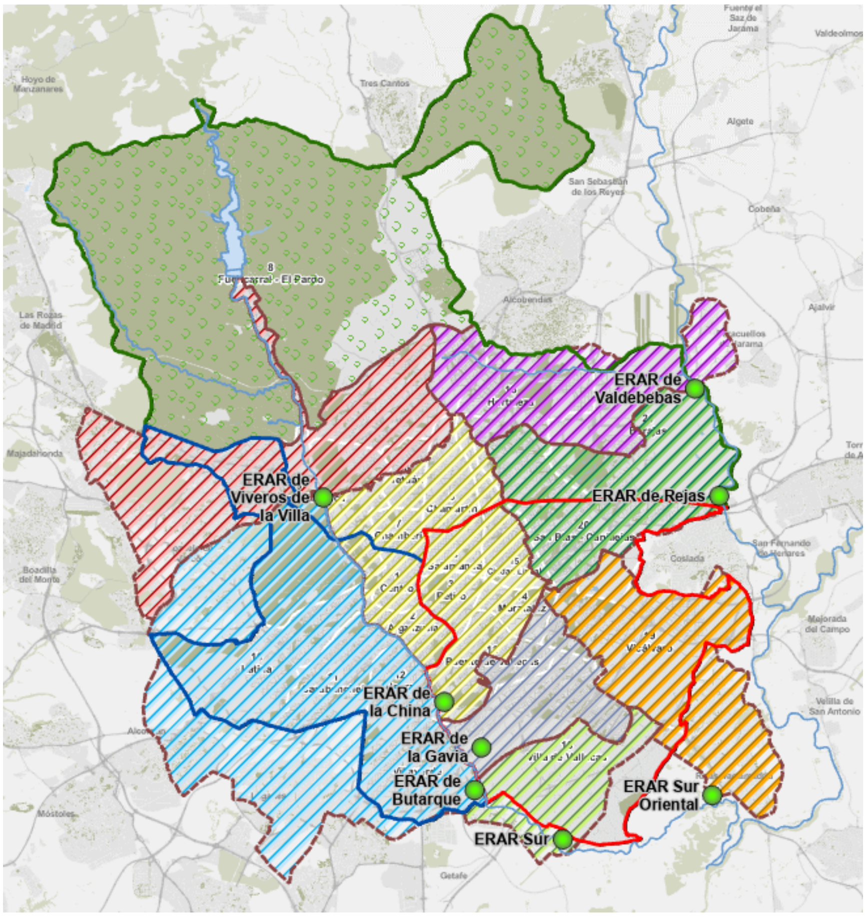

Figure 6 : Sewerage sub-basins of Madrid, linked to its main WWTP

Some of the most important WWTP don't have nutrient removal. These are La China (3.725 m^3/s), Butarque (3.548 m^3/s) and Sur (6.494 m^3/s). The existence or not of biological nutrient removal affects to organic matter and ammonium content in the river. An effluent from a WWTP without nutrient removal implies BOD5 values of the order of 25 mg/L and ammonium values of the order of 20 – 30 mg/L. A WWTP with nutrient removal will have less than 5 mg/L of ammonium in the effluent.

The impact of Madrid area over Manzanares is summarized in these bullet points:

- Ammonium concentrations to classify water body status ranges 0,2 – 0,6 – 1 mg/L. Values above 25 mg/L are recorded as seen in figure below.
- Ammonium concentrations upstream el Pardo reservoir are below 0,1 mg/L and in Rivas monitoring station (downstream) range from 5 to 25 mg/L.

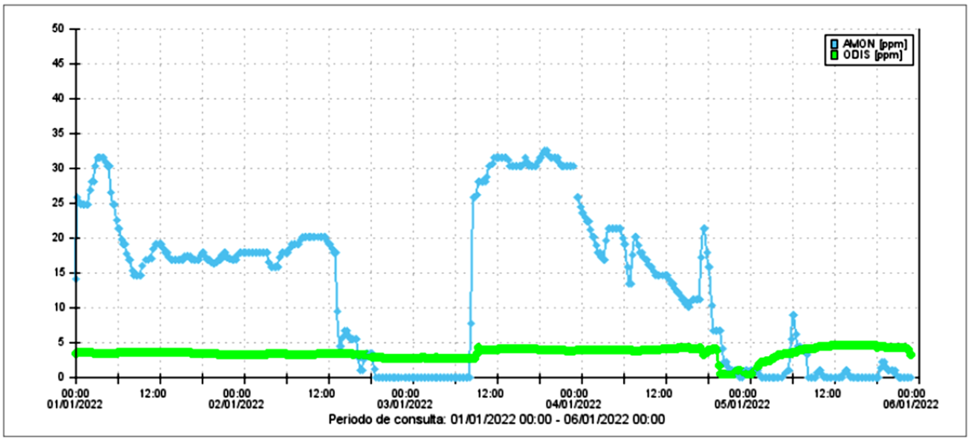

Figure 7 : Example of dissolved oxygen (green) and ammonium (blue) timeseries at Rivas Station downstream the site area (January-June 2022)

So according to this description reaching the GOOD ECOLOGICAL POTENTIAL in Manzanares river is almost impossible in the short and medium term, mainly because the flow rate of the WWTP discharging into the river is around 20 times the low river water level. The river reach is one of the rivers with the poorest water quality in Spain.

The LIFE RUBIES approach is to improve current autonomous operation of each CSO tank and WWTP by integrated management of all these infrastructures, based on RTC optimization algorithms to minimize the pollution loads discharged into the river and thus improving river water quality.

1.1.4. French site of Lille

The receiving body of Lille sewage network consists of:

- The Deûle canal
- The Marque canal (other name : Roubaix canal)

The water bodies concerned are displayed in Figure 8:

- Water body FRAR32: Deûle Canal from the confluence with the Aire Canal to the confluence with the Lys river. This is a heavily modified water body. The objective is to achieve good chemical status and good ecological potential in 2027.
- Water body FRAR34: Marque river. This is a natural water body. The objective is to achieve good chemical status and good ecological potential in 2027.

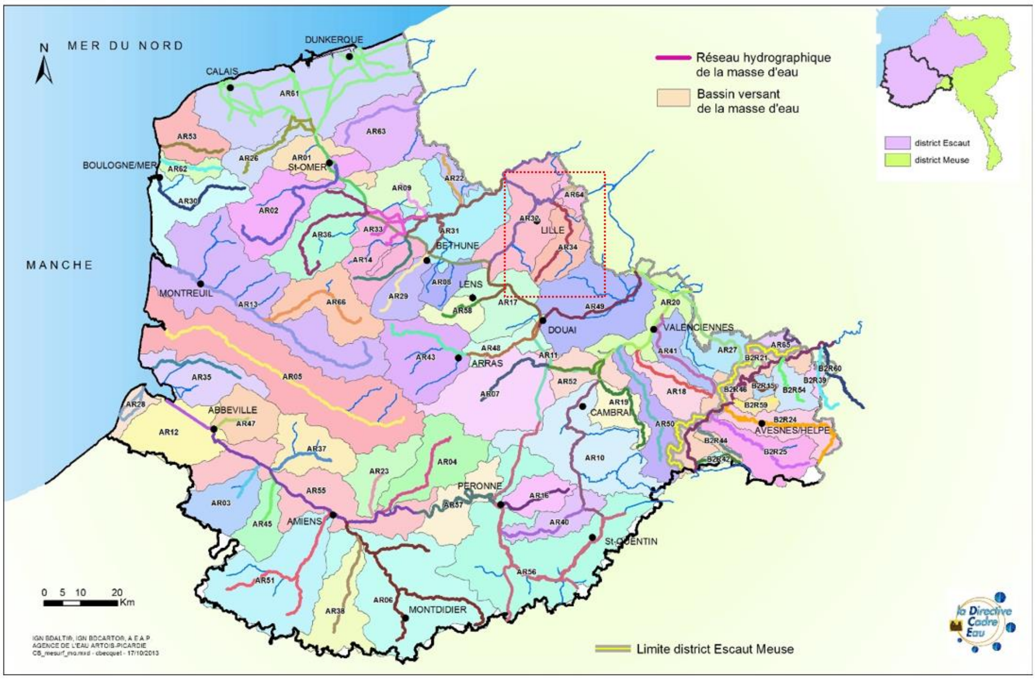

Figure 8 : Inland surface water bodies.

The Lille sewerage agglomeration covers 35 municipalities and 163 km², with a population of 523,466. It is a highly urbanized area with a few agricultural zones to the north and south of the agglomeration

From 2012 to 2020, a long succession of works (rebuilding of WWTP, creation of storage basins, disconnection of stormwater network) have been carried out to reduce discharged flow from the network to these waterbodies (Table 1). These actions allowed to reduce the regulatory compliance criterion (% of discharged volume vs total volume) to currently 7.5% on average over five years.

Table 1 : MEL wastewater systems spillage reduction between 2012 and 2021

	Rain	A1		A2			A3	Regulation	
Name		Global network weir overflow		Global WWTP weir overflow	WWTP security weir	Denis du Péage	WWTP Inflow	Compliance criterion	
Ref						386-006		Annual value	5-year roll average
Year	Rainfall depth mm	A1 Vol m3	A1 Nbre Spilling Day	WWTP overflow Vol m3 (A2)	A2 overflow Vol m3	Overflow Vol m3	Vol m3 (A3)	A1/(A1+A2+A3)	A1/(A1+A2+
2012	857.2	11 383 295	178	110 305		110 305	45 204 268	20.1%	
2013	795.0	10 957 215	174	147 392	0	147 392	43 046 886	20.2%	
2014	805.2	9 740 953	197	18 882	0	18 882	50 088 028	16.3%	
2015	731.9	6 533 399	180	242 421	79 872	162 549	49 149 908	11.7%	
2016	804.8	7 684 507	178	96 527	25 113	71 414	49 235 081	13.5%	16.3%
2017	683.6	4 149 788	137	21 097	965	20 133	46 890 008	8.1%	14.0%
2018	645.5	4 631 593	146	189 823	36 444	153 379	49 757 770	8.5%	11.6%
2019	641.7	2 992 046	148	35 142	6 722	28 421	46 004 588	6.1%	9.6%
2020	631.4	3 204 666	136	67 653	22 259	45 395	45 425 634	6.6%	8.6%
2021	804.0	5 204 851	0	99 989	12 387	87 603	53 001 546	8.9%	7.6%

Nevertheless, the legal limit is 5% and actions remain to be carried out in the agglomeration to reach this threshold. They should consist of the construction of a few storage basins, the disconnection of active surfaces to limit rainfall contributions to the sanitation system, and also optimization through dynamic management of the system. New incentives from states agency tends to reduce the reliance on structural engineering solution such as creation of new storage basin. Indeed, these solutions are often expensive and use of alternative solution such as optimization of existing infrastructure should be prioritized.

The LIFE RUBIES approach to protect the fragile ecological status is to develop integrated management strategies for UDN and WWTP, based on RTC of quantity and quality of water spilled (actions B.1, B.2). Unlike the current independent control of these two systems, the envisaged integrated control makes it possible to minimize the discharged pollutant loads.

2 Monitoring strategy for urban wastewater control

Wastewater quality modelling and management has been limited for a long time by technological aspects such as computational and sensor capacities. During the last decade, these barriers have been pushed back leaving room to quality modelling and management improvement. Recently, models and simulators have been intensively developed (Ledergerber et al., 2019), although such models require a huge amount of data to be well calibrated and reliable. Classical methods only based on punctual sampling campaigns cannot provide this level of requirement both in terms of spatial and temporal scales.

Sensors can fill these two gaps by collecting data at a very high frequency and by being located at various strategic locations in the sewer. Thus, monitoring challenges for wastewater quality management and control can be categorized in three sections: sensor type, maintenance and calibration and proper device installation.

2.1 Parameters to be monitored in the context of wastewater quality-based control

Sensor for hydraulics have been strongly developed through many technologies (pressure sensors, ultrasonic, electromagnetic…) but still remains with some issue to overcome such as reliable continuous measurement of flow rates at Combined Sewer Overflows (CSOs). Indeed, computation of precise flow at lateral storm weir in order to monitor CSOs is a complicated topic that continuously addressed either in the research academic (Crobeddu and Bennis, 2006; Larrarte et al., 2017) or in the industry. Few studies proposing abacuses based on results coupling of measurement and Computational Fluid Dynamics (CFD) simulations sounds promising, especially due to the independency of the methodology regarding sensors (Isenmann et al., 2016).

In order to perform a quality-based control of sewers, it is required to have a first strong layer of hydraulics monitoring. Every site that are used to demonstrate the LIFE RUBIES solution within the project are presented in the Deliverable DA1.2 and DA1.3 that are dedicated to specific pilot description.

Data for wastewater quality has been largely adopted by WWTP operators to optimize biological processes, however their deployment in sewers is still under development. However, the recent efforts put in this direction have seen many improvements regarding sensor development and calibration with sensors for temperature, conductivity, turbidity, UV/vis spectrometers to measure BOD, COD, nitrates, ion selective probes for NH4 (Lepot et al., 2013; Maruejouls et al. 2018). If some issues still need to be studied, some of these sensors are more and more used in wastewater systems.

The benefits in terms of pollutant fluxes estimation precision have been demonstrated to be very important when comparing methodology based on grab samples and sensors. For instance, Mourad (2005) studied a methodology to assess pollutant fluxes in sewers called the Typical

Concentration (TC). It consists in calculating a pollutant concentration, based on in situ measurement of Event Mean Concentration (EMC). In practice, this method is the one selected by the most “advanced cities“ that have built an EMC database while other cities do not even have data on wastewater quality at CSOs. Mourad (2005) concludes that the uncertainty is around ± 25% if the EMC database includes around hundred events. The manpower investment to be provided in order to collect such a number of events can be very important for cities.

Wastewater quality is generally described as being split in two fractions, the soluble and particulate fractions (e.g. Activated Sludge Model suite). Depending on the type of pollutant to be monitored, this fractionation between soluble and particulate can broadly vary. Thus, in order to be able to monitor continuously the main pollutants, it appears quite obvious to monitor Total Suspended Solids and solubles.

Patris et al. (2020) have proven that coupling turbidity and conductivity sensors could be enough to monitor the main classical pollutants (TSS, COD, BOD, TKN and TP). Figure 9 illustrates the correlations between each quality sensor and each parameter. In order to achieve this capacity, the authors emphasis the need the properly calibrate the sensors thanks to in situ water quality analysis. This important step is discussed in the next section.

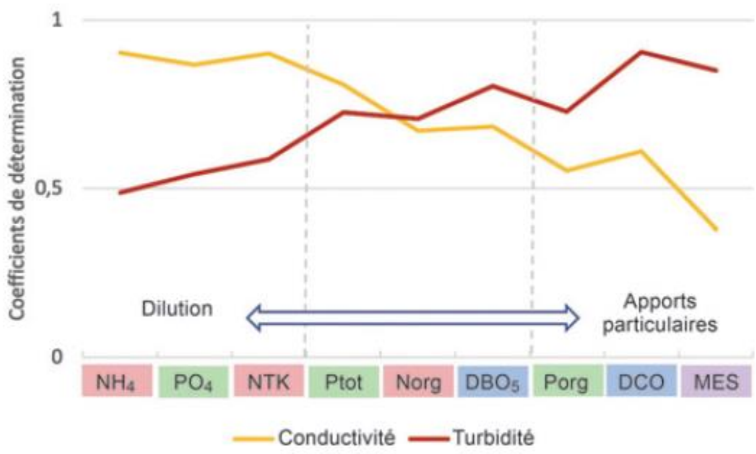

Figure 9 : Correlations between quality sensors (turbidity and conductivity) with classical pollutants (Patris et al., 2020)

2.2 Sensor operation and calibration concepts

The interest of such sensors described in the previous section is mainly due to the robustness and knowledge about them and low energy requirement to be operated. However, the industrialization of such solutions depends on the capacity to remotely collect the data and to store a large amount of data. Nowadays, the main technology used is to first collect data on data loggers to be further sent to a remote database. The approach to be applied in LIFE RUBIES is highly inspired from LIFE EFFIDRAIN previous project that has proven the relevance of the devices and the methodology (Maruéjouls and Montserrat, 2016).

The data quality from such sensors is dependant on three main parameters:

- **the installation set up** – its capacity to reduce debris and floating capture, the set up must ensure not to monitor sediments accumulation and eventually, it should reduce as much as possible the biofilm apparition on the monitoring window
- **The maintenance operation** – Frequency must be adjusted depending on the need of each monitoring point. However, it is anticipated to set a maintenance frequency at once/month. The use of sulfuric acid (3%) is highly recommended for the monitoring window cleaning.
- **The post data treatment** – This post process can be more or less advanced and able to correct different type of wrong data.

Data quality from sensors are known to be highly dependent on the calibration methodology. Indeed, combined wastewater is characterised by heterogeneous composition that highly vary in terms of quantity, quality and composition. This huge variability can result in various sensor signals for the same pollutant concentration from laboratory analysis in the case the sensor is not well calibrated. To avoid bad estimation of the pollutant concentration, it is important to perform precise local calibrations based on samples collected in-situ at the same location where the sensor is placed. Caradot et al. (2014) made several sensor calibration of turbidimeters over five different case studies in the world. Their results suggest that: 1) local calibration significantly increases the measurement quality, and 2) The best compromise between sampling effort and result performance is to obtain a minimum of 15-20 samples per site (Figure 10).

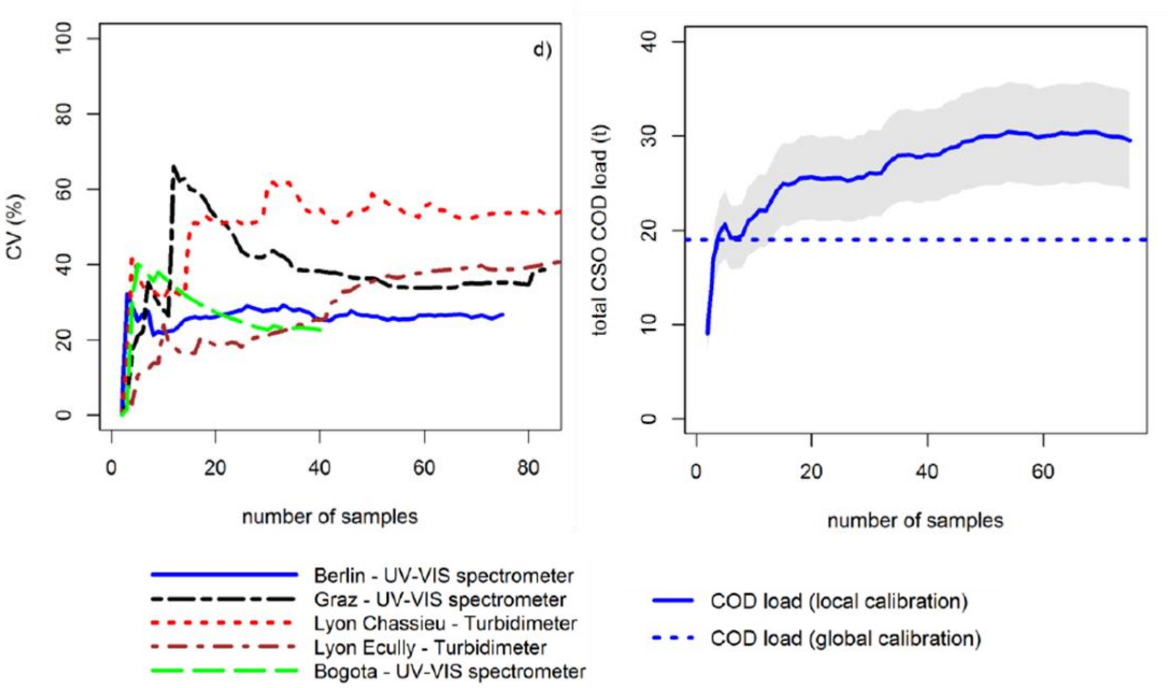

Figure 10 : Results from Caradot et al. (2014). On the left, the required number of samples to stabilise the coefficient of variation of quality sensor calibration. On the right, Comparison of total CSO COD load calculation using global and local calibration

The sampling campaign aims at collecting various samples having the widest possible concentration range during wet weather at each sampling point. Sensors are simultaneously measured to collect the corresponding turbidity/conductivity values. The objective is then to correlate laboratory analysis to sensor signal values during a rain event by putting TSS/COD/BOD/TKN/TP concentration values and corresponding turbidity/conductivity on the same chart as illustrated on Figure 11. The objective is to collect samples during dry weather (at least 10 samples from 2 sampling campaigns) and wet weather (at least 5 samples from 2 sampling campaigns). Following figure illustrates the final results of wastewater quality sensor calibration together with the performance expected for each correlation.

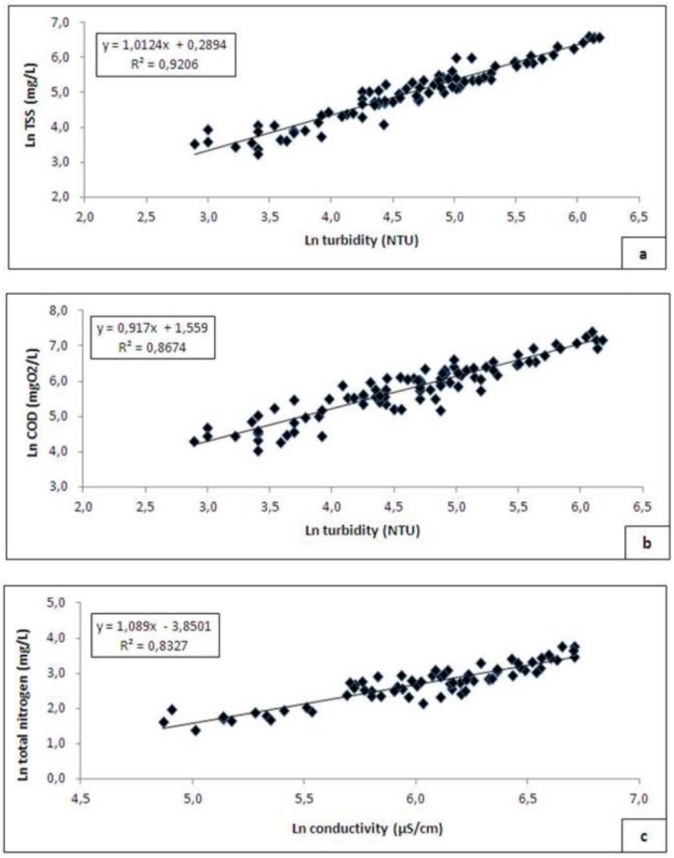

Figure 11 : Correlations between quality sensors (turbidity and conductivity) with classical pollutants (Bersinger et al., 2015)

In order to catch the most important range of wastewater quality, it is important to set a detailed wet weather sampling protocol. Automatic samplers containing 24 bottles of 1 L will be installed on the five sampling points. For dry weather sampling the protocol is quite simple. The automatic sampler is set to collect grab samples each hour of the day. Other the 24 bottles, 10 samples will be selected for lab analysis for each parameter (TSS/COD/BOD/TKN/TP). These steps will be repeated twice for each monitoring point.

Under wet weather conditions, a level detection switch will be connected to the sampler in order to trigger the sampling when the water level rises up to a certain level associated to wet weather conditions. Then, the sampling program starts, collecting samples with a pre-defined variable time step. The time step chronicle will be set based on the theory of having a high flowrate at the beginning of the event going less intense with the time (Figure 12). Then, based on visual interpretation of concentrations, at least 5 samples will be selected to be analysed for each previously cited parameters at the laboratory following COFRAC standard (French standards).

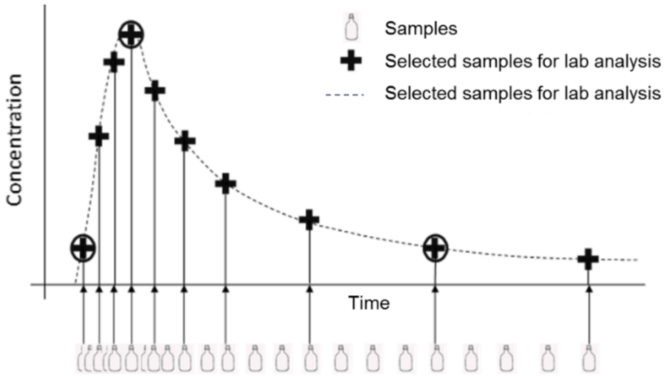

Figure 12 : Illustration of the correlation curve building comparing pollutant curve to wastewater samples

Sensors are autonomous thanks onboard battery and GSM connection. Data are further stored in database that should be able to store many years of data in order to be able to treat historical data. The French guidelines from the *Office National de l'Eau et des Milieux Aquatiques (ONEMA)* (Versini et al., 2015) suggest to set a monitoring timestep smaller than five minutes recommending to be set at one minute or less for data post-treatment purposes. The database can include a data visualization tool in order to make the data analysis easier for the operator. This data visualization is also used as a first level of manual data validation, however automatic validation should be preferred.

2.3 Sensor set-up and location requirements

The objective of the monitoring station is to be able to calibrate models so they would be able to reproduce the wastewater quality but also to compute the wastewater quality fluxes sent to the environment. As a result, the monitoring stations need to be located as close as possible to the CSOs and the actuators in order to rationalise the number of quality sensors required. There can be some distance between them in the case no important branch is joining the main conduit in between that could impact the wastewater quality.

The sampling points must be located upstream the CSO weir in order to be able to keep the sensors immerged in the wastewater sent to the WWTP. As the station has conductivity onboard, the sensors have to be immerged in both the wet weather and dry weather volume, i.e. below the minimum water level that happens during the night. The installation principle is similar for each point. It consists on a PVC pipe that guides a sensor rack to the wastewater. The rack was designed to receive the three sensors and is linked to a chain having a length adjusted to have sensors' window flushing with the end of the pipe. Thus, the PVC pipe protects the cables and the sensors from big debris allowing them to slide on the wall (Figure 13). This installation has proven to be very efficient, avoiding too many intervention, i.e. around once a month per sensor.

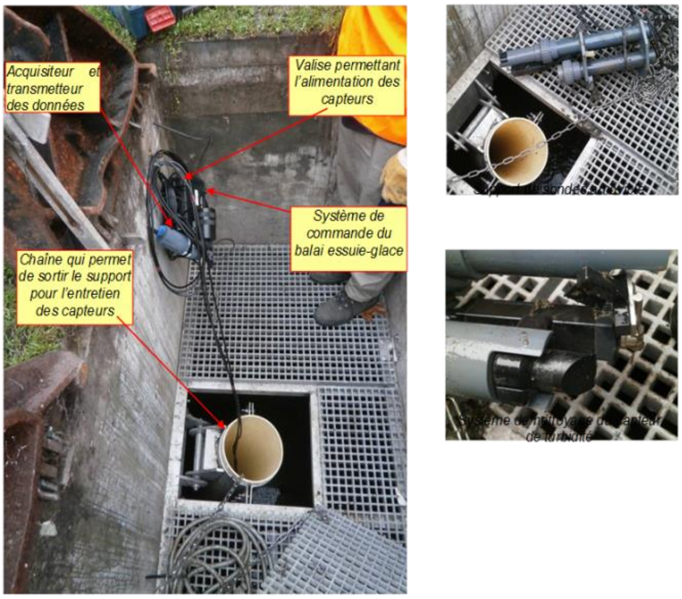

Figure 13 : Pictures illustrating the installation principle to be followed as the generic monitoring station set up (Maruéjouls and Montserrat, 2016).

3 Urban wastewater controllers' concept

3.1 Real-time control of urban wastewater systems

Modern UDNs have included infrastructure to prevent CSO such as tanks, gates and pumps, which can provide storage during the rain events and can release water gradually to the WWTP. The infrastructure operation is performed based on a telemetry and telecontrol systems, which allow considering real-time sensor measurements on the system to decide control actions, achieving real-time control (RTC)

Different types of RTC strategies have been shown to produce efficient management strategies for UDNs. More specifically, a class of RTC strategies is based on pre-established operational decision rules, which may be developed by experience or by extensive studies offline, using simulators. In this case, the rules provide control action decisions in real time, using online sensor readings. Rule-based RTC may consist of simple rules involving the current values of local sensor readings. In other cases, the rules may use more complex reasoning, consider historic series of sensor readings and predictions thereof. This is the case of the M-V curve RTC method to be tested in LIFE RUBIES.

Another class of RTC is also based on using predictions of the external disturbances (e.g. rain) and the effect of control actions on the urban drainage system for a time horizon. In this case, it uses an explicit model of the dynamics in the system and an online optimization process to derive control actions predictively for a time horizon, which minimize CSO. This is the case of the Model Predictive Control (MPC) method to be tested in LIFE RUBIES.

RTC developments have so far usually managed flows, not taking into account the polluting load (quality) of the carried water, which varies considerably throughout the rain events and the storage periods. Similarly, the efficiency of the processes in the WWTP depends on both the quantity and the quality of the incoming water, so that even if flow is within the acceptable limits for a WWTP, its quality may not. Then, untreated water may be refused at different by-pass points producing CSO.

Up to now, UDNs and WWTPs have been managed separately. It is clear that an integrated and coordinated management of quantity and quality in both systems is required to optimize the overall efficiency and protect the quality of the receiving waters, as required by the EU Water Framework Directive (WFD). The recent previous project LIFE EFFIDRAIN developed a Pollution-based RTC (PBRTC) approach whose objective is to minimize the amount of pollutants released to the environment both by means of CSOs and through WWTP effluent, tested in simulation. It is the goal of LIFE RUBIES to take these developments to real urban wastewater systems.

The main elements involved in the RTC of wastewater systems are (Schütze et al., 2004; Camacho and Bordons, 2007):

The control variables in the system: These are the values of control actions that can be taken to manage the system, and correspond to the system actuators. Typically, the following control variables are considered:

- Flows through gates or pumps in the urban drainage system: these may be flow-routing elements, they may control the filling and emptying of detention tanks or boost water to reach a topographic level to be treated or released
- Outlet flows of the WWTP: Different options to release water to the receiving environment, at different stages of the treatment (or bypass before treatment)
- Optionally, pump flows within the WWTP

A sequence of control actions during a certain time horizon is called a control strategy.

The state variables: These define the situation of the system at a certain instant: State variables may be measured directly in real time with sensors or they may be obtained indirectly using a model (observers). In LIFE RUBIES, state variables refer to hydraulic and quality variables. Taking into account previous experience in LIFE EFFIDRAIN, the following state variables will be considered:

- Volumes contained in detention tanks
- Volumes contained in in-line detention sewers
- Water level at strategic locations
- Water flows in main sewers, weirs
- Water quality parameters at strategic locations. Specifically, at least TSS and/or turbidity

The dynamic model of the system: A detailed hydraulic model, including the water quality dynamics is required for offline studies to develop and validate RTC strategies (M-V or MPC). It is especially relevant in LIFE RUBIES as a “virtual reality” in a simulation-based validation phase and it is incorporated in a simulator (SWMM, ICM, etc.).

Furthermore, the detailed dynamic model (simulator) may be used online as a digital twin in the context of RTC, to provide real-time estimations of required state variables which cannot be directly measured.

A simplified dynamic model is also required in the case of MPC. It is an explicit mathematical representation of the system dynamics, including its topology, its physical and operational constraints the effect of the control actions on the system and, in particular the evolution in space and time of the state variables, depending on the control actions.

The predictive control strategy: This is a procedure to compute, ahead in time, the best possible control strategies for a horizon (typically 30 min to 1 hour), so that the operational goals are optimized, taking into account the system dynamics all the physical and operational constraints.

Performance index: A mathematical expression of the operational goals to evaluate the goodness of a control strategy, in terms of the sought operational goals. Some examples of performance indexes are:

- Total volume of water sent by the UDN to the WWTP
- Total CSO volume

- Total volume flooded to the streets
- Total polluting load of CSO
- Total cost of pumping operations

LIFE RUBIES will address three types of predictive RTC, the first one corresponds to the baseline of urban drainage system control by using exclusively hydraulics parameters for control. It means that flowrates and volume are continuously monitored in order to reduce volume spills to the environment. The other predictive RTC to be deployed in LIFE RUBIES for the integrated management of urban wastewater systems are using wastewater quality as input variables to take control decision but also as target variable to assess the cost of decisions. These approaches constitute the most innovative part of LIFE RUBIES, they are the model predictive control (MPC) and the Mass Volume (MV) curve methods, as derived in LIFE EFFIDRAIN project.

3.2 Hydraulics based control rule of Aquadvanced Urban Drainage

At each calculation cycle, AQUADVANCED UD® is in charge of preparing the data input of the models, launching the simulation over the period corresponding to the real time and extracting the results. In order to ensure continuous operation of the calculation chain, the system integrates all hot restart mechanisms (preservation of previous conditions to limit the initialization period).

The hydrological model converts rain into flow by taking into account hydrometeorological conditions and the characteristics of each watershed. The modelling will be carried out using a hydrological model.

The hydraulic model makes it possible to represent, depending on the configuration of the network and hydrometeorological conditions, the flow conditions at all points in the network. This model will be fed by the results of the hydrological model. The configuration of the various equipment that compose it will be updated at each calculation cycle based on the latest observations from the supervision. The operator will also be able to manually constrain the position or functional status of an equipment.

It is also possible to implement connectors that will allow real-time integration of observed and forecasted water level from outlets subject to ocean influences.

This dynamic scheme will be refreshed in sufficiently close (configurable) time steps to ensure a good match between the temporal variability of the input data (weather forecast, equipment functional status, downstream influences) and the results of the simulations.

The results will make it possible to anticipate flow rates and levels at all points in the network over a 1-hour period.

3.3 Pollution-based Model Predictive Control

Model predictive control is an optimization approach which uses the dynamic model of the system and forecasts of external variables to derive future optimal control strategies. Previous examples of the application of MPC in sewer network control to reduce CSO volume may be found in (Cembrano, et al., 2004; Joseph-Duran, et al., 2015).

The more advanced model predictive control approach to integrated management of water quantity and quality of LIFE RUBIES will be based on Sun et al. 2020. In this approach, the dynamic model of the urban drainage system and the performance indexes were built considering both the quantity and quality dynamics of flows in the urban drainage network and the effluents to the receiving environment. The approach uses the total suspended solids concentration (TSS) as a key quality parameter given that TSS is generally correlated with turbidity, which can be measured continuously online. The hydraulics and TSS dynamics were represented by simplified mathematical equations, included in the optimization procedure. In order to integrate the sewer network and the WWTP subsystems during the optimization process, a feedback from the WWTP is considered, in which the WWTP provides, in real time, estimations of its capacity at the inlet and/or at internal points where bypass to the receiving environment.

The integration of the MPC approach in LIFE RUBIES will consider an initial phase of development and validation in a simulation environment and a subsequent phase of online implementation. Virtual testing is used as a support to deploy and validate the PBRTC methods allowing to identify gaps, solve errors or to have an estimation about the performance of the PBRTC in the pilot perimeter in terms of environmental protection. Once PBRTC method is validated virtually, real testing could be carried out avoiding unexpected behaviours and having an estimation about what could be achieved in terms of environmental impacts. For the real / online testing, in LIFE RUBIES, the RTC Closed-loop Simulation Algorithm (CLSA) will be connected to the AQDV platform which is the one connected to the reality through the SCADA system. In this sense, at every time instant, AQDV will provide measurements of the existing sensors to CLSA and will collect the computed control actions.

Figure 14 represents a scheme of the interactions between RTC elements in the off-line validation setup with a detailed model as a virtual reality, to test the management strategies. In the case of an integrated urban drainage model including a UDN and a WWTP, the system simulation further involves the evaluation of the UDN simulation model according to control actions and the evaluation of the WWTP simulation model according to the inflows provided by the UDN simulation model. After the system simulation has been performed the variables corresponding to physical sensors in the real network (also others in hypothetic situations) can be used in the RTC algorithm to compute new control actions. Once control actions are computed, they can be used into the configuration of the UDN simulator to start again the whole procedure.

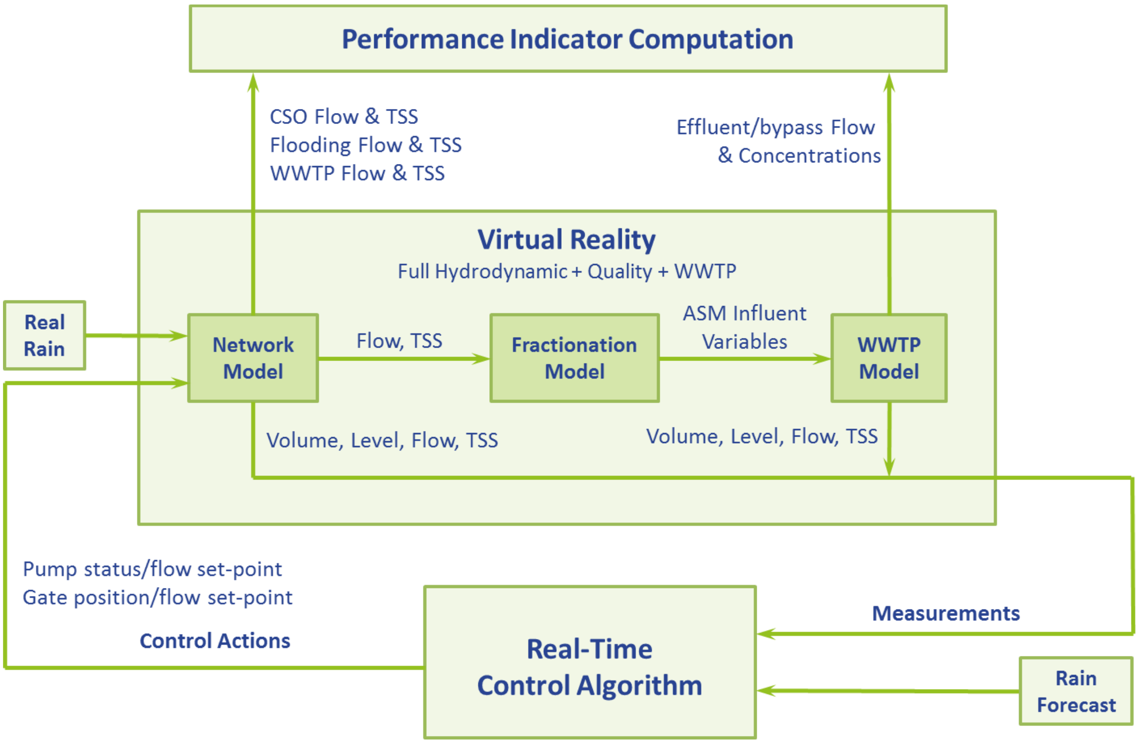

Figure 14 : Elements and variables taking part in a closed-loop simulation of RTC algorithm applied to integrated control of UDN and WWTP

Figure 15 represents a proposed scheme for the implementation of the online MPC RTC of LIFE RUBIES. In order to enable real testing, CLSA implementing PBRTC method will be connected to the reality through AQDV platform as depicted in the figure. AQDV platform is the system able to connect to the SCADA system which registers in real time measurements coming from the existing instrumentation and send computed control actions to the existing local controllers (i.e. PLCs). In this sense, at every time instant (or closed-loop iteration), AQDV retrieve measurements coming from the instrumentation which are sent to the CLSA. Then, CLSA computes control actions which are retrieved by AQDV platform in order to be sent to the SCADA system. In this closed-loop, CLSA is still connected with the virtual reality which is used as a provider of virtual measurements. In this sense, CLSA computes control actions not just considering measurement of existing sensors but also measurement estimations of certain placements where there are no sensors. These virtual measurements are also sent to AQDV platform in order to check if there are major deviations regarding real measurements and trigger adaptation mechanisms of hotstarts used to initialize the virtual reality at every closed-loop iteration.

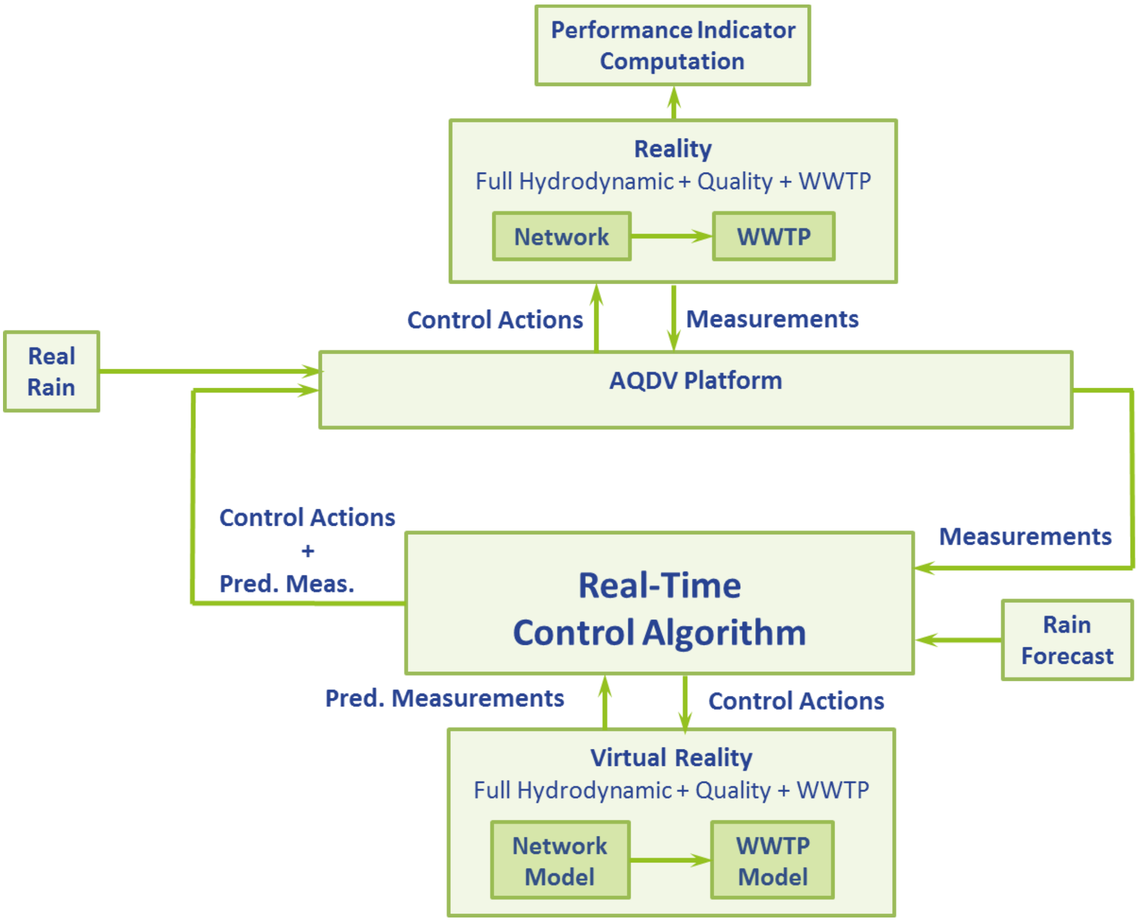

Figure 15 : Connection of the RTC CLSA with the AQDV platform in order to enable real testing to the PBRTC method.

3.4 Mass/Volume curve controller

The MV curve controller is based on the principle the mass/volume (Bertrand-Krajewski *et al.*, 1998) curve is computed. An MV curve, by definition, refers to a dimensionless way of representing the variation of the cumulative pollutant load divided by the total pollutant load with respect to the cumulative volume divided by the total volume during a storm event. This computation allows for anticipating where the most interesting water volume to be caught is located. displays monitored MV curves (Figure 16).

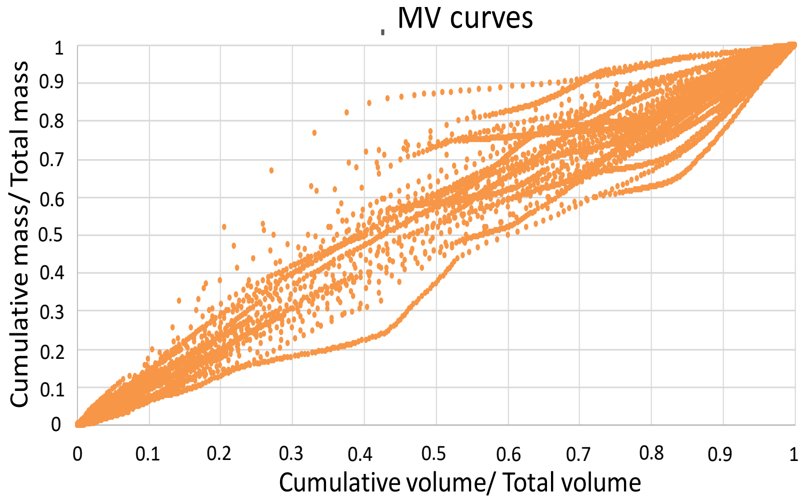

Figure 16 : Mass/Volume curves (Ly, 2019).

The control strategy is mainly based on modelling results. In order to provide the best predictions and control actions, it is important to calibrate as much as we can the urban drainage models. The hydraulics and water quality sensors will be used to calibrate the SWMM-TSS model that will be used to reproduce the reality and anticipate short term flows and fluxes. Thanks to AQDV UD, the model will be connected in short term (1h or 3h) real time to rainfall forecast.

SWMM-TSS is an improved library developed by Suez to reproduce solid transport (Montserrat *et al.* (2017). The processes that were added are illustrated in **Erreur ! Source du renvoi introuvable.** and are listed below:

- Buildup and washoff on catchments
- Distinction of particle size distribution depending on their origin (dry or wet weather)
- Sedimentation and erosion in the sewer
- Settling and solids removal in retention tanks

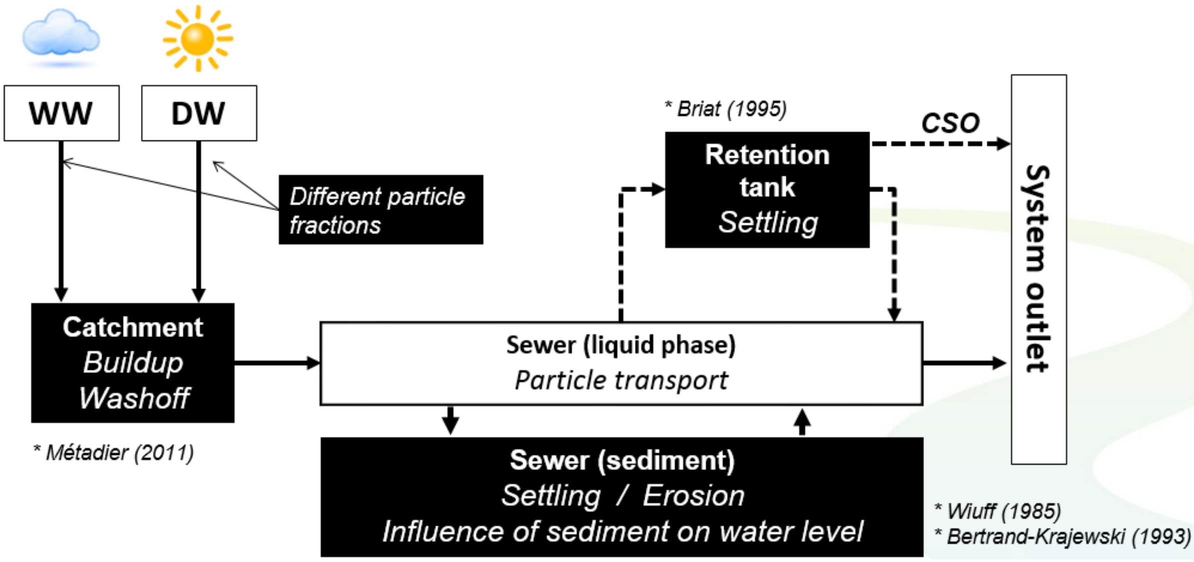

Figure 17 : Water quality processes included in the SWMM-TSS model (after Montserrat et al., (2017)). Black boxes indicate the processes improved by the new library, with given references for the used equations.

The prediction of the event MV curve is key to the control concept. The controller aims to fill the tank during the highest peaks of the TSS flux. To capture such peaks, the controller predicts the MV curve at an upstream pipe of the tank. From this curve, the controller can identify the Control Time Intervals (CTIs) with the highest increases of load versus volume, corresponding to the sharpest gradients of the MV curve.

The MPC involves two fundamental principles: receding horizon control (i.e. recursive repetition of the control actions within a finite CTI) and optimisation (i.e. determination of the optimal sequence of control actions within this CTI). Accordingly, Figure 18 illustrates the closed-loop simulation scheme for QBR in this study. The “MV Curve Controller” block describes the function of the controller. AQDV UD is the main data platform, capable of connecting all components from the whole control chain value. AQDV UD first collects data from the real field (flow and pollutants) along with multi-sources rainfall forecast. Those data are formatted to be given as SWMM-TSS input so it can perform optimisation and generates control rules for the incoming CTI. The control rules generated by the controller are provided to AQDV UD so it can be transformed into real life control rules. The initial length of each CTI is 15 minutes. The routing time step and the reporting time step of the SWMM-TSS models are set at very small values, one second and three seconds respectively, to ensure model convergence and accuracy.

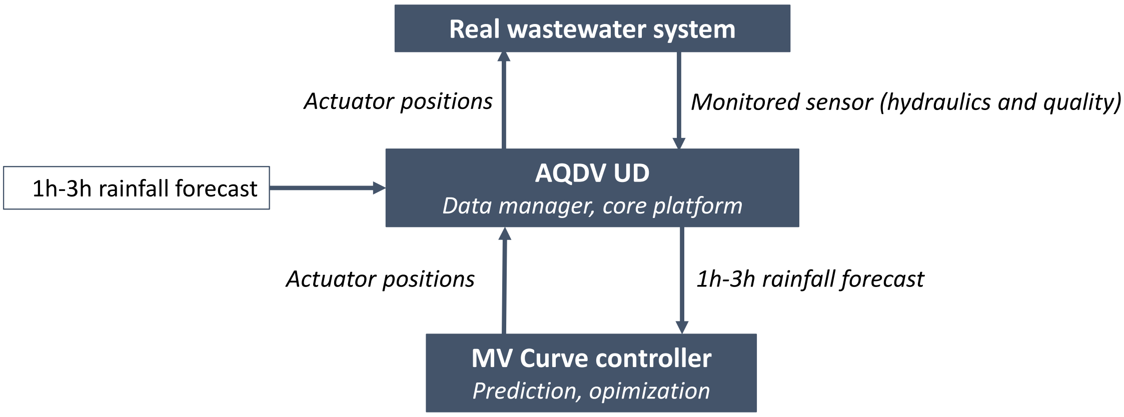

Figure 18 : Block diagram of closed-loop simulation scheme and integration with AQDV UD

The main differences between the MV curve (Quality Based Control, QBR) and more classic hydraulics based strategies (Hydraulics Based Control, HBR) are displayed lower. In particular, **Erreur ! Source du renvoi introuvable.** (a) shows the predicted flow and TSS flux in a pipe right upstream of a retention tank. With HBR, the tank is completely filled right after the first peak of the flow. MV curve only fills the tank during the highest peak of the TSS flux (i.e. the third peak of the flow in this example). Both strategies thus intercept different TSS loads despite utilising the same retention tank volume.

To capture the most appropriate fractions of TSS flux, the MV curve controller needs to derive a mass-volume (MV) curve using information from the predicted flow and TSS flux above. This curve represents the evolution of the pollutant load versus the water volume during a storm event, as presented in Figure 19 (b). From the MV curve, the controller can identify the time window when there is the highest increase of load over volume, corresponding to the sharpest gradient of the MV curve. This time window is then prioritized for filling the tank. Taking a close look at the filling window of QBR versus the one of HBR (red box versus blue box of figure (b)), it is clear that the slope gradient is higher in the filling window of QBR.

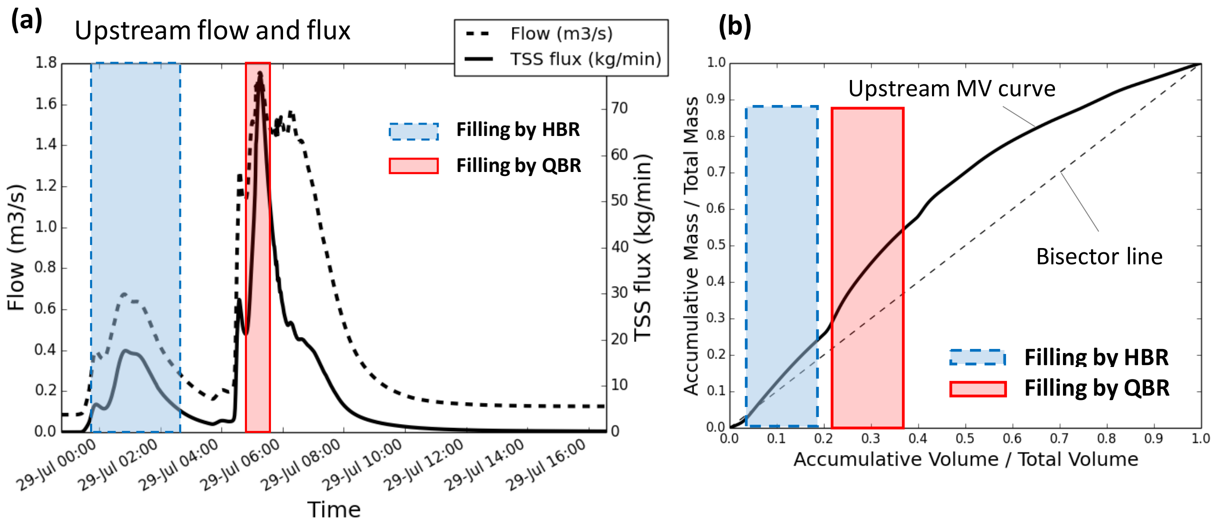

Figure 19 : a) Illustration of filling periods by two strategies overflow and TSS flux plots (upstream of the tank); b) Same illustration over the MV curve plot (upstream of the tank).

4 Definition of environmental performance indicators (Lille - Madrid) – LASIRE / CYII (U. de coruna)

4.1 Emissive Key Performance Indicators – Urban system interface with receiving body

The most common approach to estimate CSOs impacts on the environment, when such assessment is performed, is based on an emissive point of view. The emissive point of view is the approach consisting in monitoring (or assessing) the flow and/or fluxes emitted by the CSOs to the environment, disregarding the behavior or conditions of the receiving body. The very first assessment level is to estimate flows and volumes generated by storm events during a year at each CSO location, the dilution rate is computed with regards to the receiving body current or average flow.

A more advanced approach is to monitor the flow at CSOs or at least the duration the CSO infrastructure was active. In France the Autosurveillance regulation forces the operators to equip with online and continuous monitoring CSO flows of at least 70¨% of the most important CSO infrastructures (>=600 kgBOD_5/d) and to monitor the time of spillage for CSO infrastructures with an upstream subcatchment generating between 120 kgBOD_5/d and 600 kgBOD_5/d.

For example on the French pilot, as the main CSO infrastuctures of MEL are already equipped with hydraulics measurement and LIFE RBIES aims at deploying quality monitoring sensors on same locations, the KPIs to be computed will be volumes emitted per year at each CSO and at the catchment scale. In addition, as LIFE RUBIES focuses on wastewater quality, the mass fluxes emitted through CSOs over the year will be also computed. The goal is to reduce by at least 15 % the CSO volume and 25 % of TSS masses on French pilot; and 50 % the CSO volume and 45 % the TSS masses on Spanish pilot after implementation of the full LIFE RUBIES solution.

4.2 Immissive Key Performance Indicators - Environmental impact assessment

4.2.1 Exacts parameters (hydraulics – quality)

Voies Navigables de France (VNF) measures at high frequency the flows at the Deûle in Wambrechies and the DREAL has a station at Don. These data will thus be uploaded and integrated into LIFE RUBIES measurement sets. In the Marque River, the flows is only measured at Bouvines by the DREAL but this station is very upstream of our study site.

Several water quality parameters will be measured using various techniques. These are summarized in following Table 2.

Table 2 : Forecast of measured parameters

Parameters	Procedure	Technique	Frequency	station
O_2, Turbidity	**On line**	**multi. probes**	**1/10 min**	**D1, D2, D3**
Conductivity, T	**On line**	**multi. probes**	**1/10 min**	**D1, D2, D3**
pH	**On line**	**multi. probes**	**1/10 min**	**D1, D2, D3**
Ammonium	**On line**	**NH_4^+ analyser**	**~ 1/heure**	**D1, D2, D3**
anions	**Spot sampling**	**chromatography**	**Variable**	**All**
Major elements	**Spot sampling**	**ICP-AES**	**Variable**	**All**
Trace elements	**Spot sampling**	**ICP-MS**	**Variable**	**All**
Labile metals	**DGT (~ 4 days)**	**ICP-MS**	**~ 5 times/year**	**All**
drugs	**Chemcatcher (~ 4 days)**	**LC-MS/MS**	**~ 5 times/year**	**All**

For the Madrid, in Manzanares river there already exist several river water quality monitoring stations and river flow gauging stations upstream and downstream the pilot site. Again this information will be analized and used in the LIFE RUBIES project. Then in 3 control sections a probe for continuous quality measurement will be installed.The parameters to be measured are ammonium, dissolved oxygen, turbidity/SS, EC (conductivity), temperature and pH. Two probes will be bought and installed with the aim to continue measuring the river quality even beyond the project duration, and a third one will be rented and installed to asses the river quality during the monitoring period of the Rubies project.

4.2.2 Sensors location requirements

For the monitoring of the Lille pilot site, several active and passive systems will be deployed. On sites D1, D2 and D3, a power supply is required. In D1, an aluminium cabin will be bought, customized and installed on the site of the Grand Carré lock (VNF accommodation). In D2, the mobile laboratory of LASIRE will be hosted on a site of the MEL (clos de l'Abbaye) (a hosting agreement with the MEL is being drafted). In D3, a VNF cabin used for flow measurement will be used to deploy the equipment. In M1 and M2, only water samples will be taken and passive samplers (PS) will be deployed. No particular structure is therefore necessary. However, for the PS, discrete anchoring systems will be installed at the 5 stations to maintain the PS in the water at about 50 cm below the surface. Finally, in M1 and M2, autonomous temperature sensors

(Aquatic 2, Tinytag) will be deployed to allow the correction of diffusion coefficient values (especially for Diffusive Gradient in Thin films (DGT) samplers).

For the Madrid pilot site 3 river monitoring control sections (RMCS) to install the probes are planned in the main interest reach:

- **RMCS1**: Upstream of the river reach to be analyzed.
  - Existing monitoring point ICA Villaverde - Station 66 upstream Oliva CSO tank.
- **RMCS2:** Near downstream control section
  - Downstream Butarque WWTP effluent
- **RMCS3:** Far field downstream control section
  - In Sur WWTP upstream of its effluent.

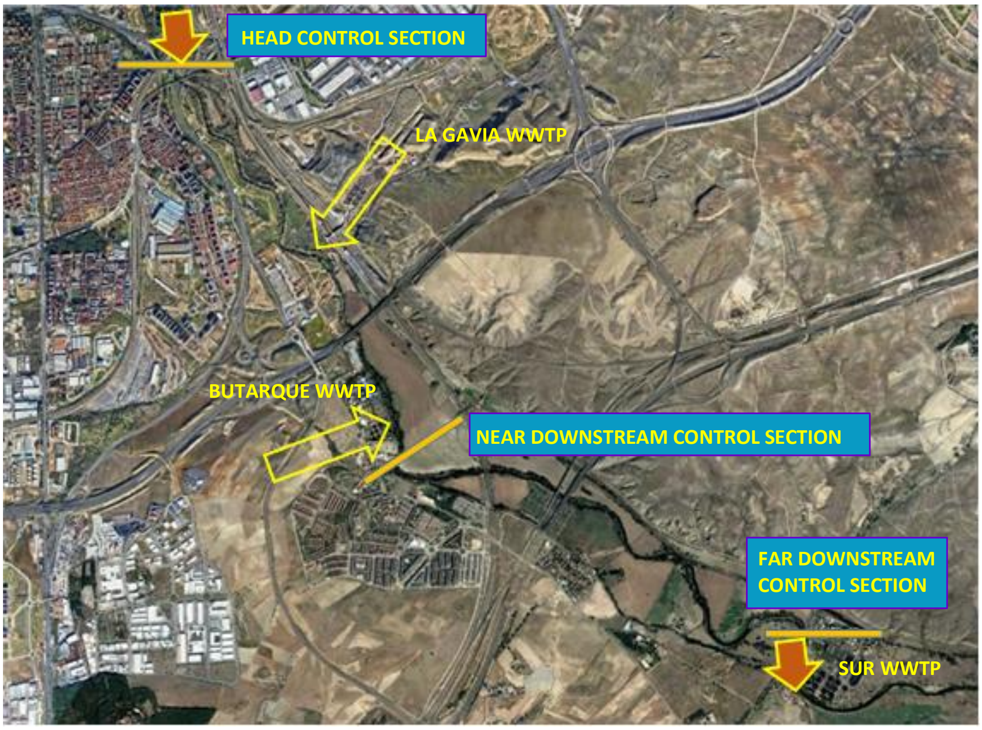

Figure 20 : Planned river quality control sections in Manzanares river

4.2.3 Sensor technology and light calibration methodology

Several apparatus will be deployed during this project. Some instruments have already been acquired during previous projects and will be used for this environmental monitoring. Others will be acquired as complements.

3 multiparameter probes will be set up in the Deûle River (stations D1, D2 and D3). They will measure conductivity electrically, turbidity by light scattering, dissolved oxygen with an optical sensor and pH with an Ionic Sensitive Electrode (ISE) made of a glass membrane (Table 3). For this measurement, a reference electrode Ag/AgCl, [KCl] = 3M is also used. These probes can work autonomously on battery. However, since some samplers and ammonium analysers require power, these probes will be connected to power supply in the cabin, which is supplied

with water by a high flow pump (about 10 m^3/h). In D2, the multiparameter probe is a Manta (Eureka) already acquired and used for 1 year on another site (SUMO project). However, this probe has several shortcomings, in particular the fact that it is difficult to change the probes in the laboratory and that it is not very convenient to program it on demand. Consequently, for D1 and D3, two Exo 2 probes (YSI) have been recently ordered with the same sensors. Note that each probe is equipped with a central brush allowing to clean the sensors (except for the pH) before each measurement. The calibration protocol of the probe is done in the classical way with external standards. For long-term monitoring, a current study proposes: (i) a manual cleaning of the probe every week; and (ii) a measurement also every week of a standard solution. If this measurement exceeds an acceptable limit, the sensor is recalibrated with one or 2 standards. In order to get a traceability of these measurements, all interventions on the probe will be recorded as they occur.

Table 3 : Threshold values for triggering new calibrations

Parameter	pH	Conductivity	Turbidity	O2 saturation
unit	**-**	**µs cm^{-1}**	**FNU**	**%**
Standard tested	**7**	**1413**	**50**	**100**
Acceptable range	**± 0.1**	**± 50**	**± 5**	**± 5**

The monitoring of ammonium will be done with a colorimetric analyser (model Icon, Metrohm) whose operation is summarized in Figure 21. The electrodes to measure this parameter are indeed neither sensitive nor accurate enough for most natural environments. 3 analysers (1 of them has been bought during the SUMO project) will be deployed on the 3 sites of the Deûle and the reagents will be recovered. The calibration will be done with 1 standard, probably at 1 mg L^{-1}. As it is a new apparatus, the acceptable drift range will be further estimated.

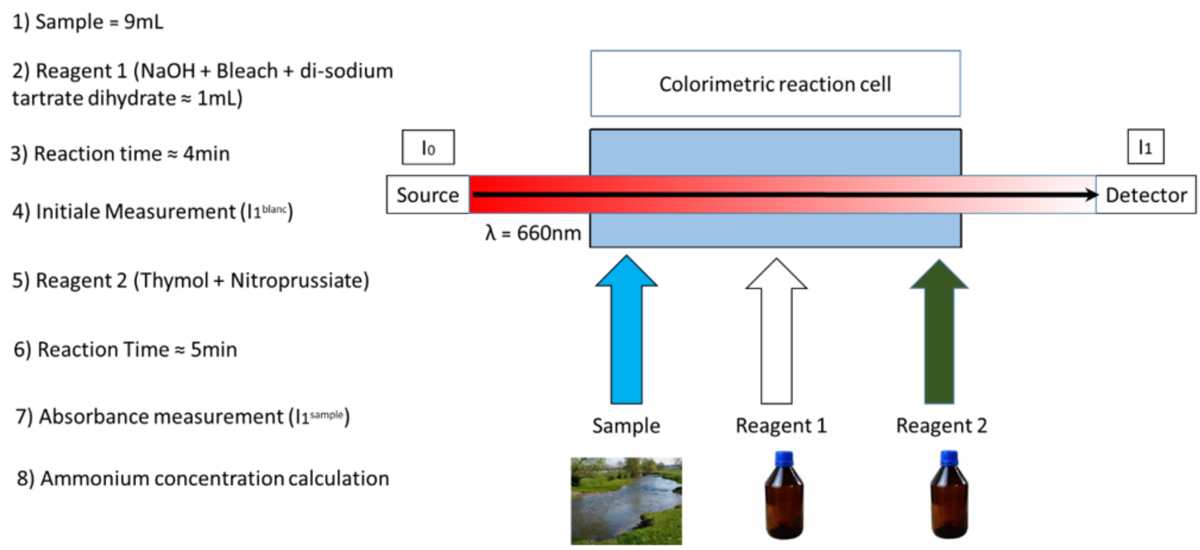

Figure 21 :Summary of ammonium analyses. The filtration procedure of the sample before the analysis is not yet completely defined

Regarding passive samplers, DGT have already been used many times in our laboratory. It could be interesting to calibrate the Diffusive Boundary Layer (DBL) of these PS in the deployement conditions to be more accurate in terms of labile concentration. In this case, we will have to deploy several DGT simultaneously with diffusive gel layers of different thicknesses, at least once during the project (Warnken et al., 2006). The temperature will also be taken into account by correcting the values of the diffusive coefficients. Finally, during the ICP-MS analysis of the DGT eluates, external standards are used to calibrate the apparatus and certified waters are also analysed to validate the calibrations. The laboratory has no specific certification but participates in intercalibration exercises [see for instance Yeghicheyan et al. (2021)].

Chemcatchers (used for polar organic compounds such as some pesticides and drugs) are probably less accurate than DGT but will at least give relative information by comparing results from different sites. These sensors will be calibrated directly in the waters of the Deûle in D2 by taking an average water sample with the refrigerated automatic sampler. We will then be able to determine the sampling rate of the Chemcatcher for each molecule of interest and compare it to the one present in the literature if existing (Criquet et al., 2017). At least two of such calibrations will be necessary (one in summer and one in winter). The analyses will then be done at the Lille University Hospital where the analytical procedures are very strict and meet the requirements of the norm “NF EN ISO 15189”.

Finally, for spot sampling, the water will be immediately filtered in the field. The analysis of anions will be done by ion chromatography (ICS-5000, Thermo-Scientific) with external calibration and the analysis of major and trace elements will be done with an ICP-AES (ICP-OES 5110 VDV, Agilent Technologies) and ICP-MS (ICP-MS 7850, Agilent Technologies), also by external calibration and with reference waters as control points. For ICP-MS analyses, internal standards are also added to take into account possible drifts of the spectrometer on certain masses. Finally, for the elemental analysis, the samples will be acidified with ultrapure nitric acid (to reach an acid content of 2%). For Pt, the stabilization will be done using a HCl/thiourea mixture as previously specified (Trommetter et al., 2021).

4.2.4 Key Performance Indicator computation

As for the Emissive point of view, the immissive point view will be computed to assess yearly benefits of the LIFE RUBIES solution. These KPIs will rely on the previously described monitoring strategy performed on the environment. Contrary to the emissive point of view, the immissive approach takes into account the receiving body characteristics and best reflects the real impact of human activities on the environment. However, this quality result of such approach is highly dependent on the environment characteristics where the complexity to assess the real water system quality can vary tremendously.

As CSOs have main impacts during a storm, the objective of these KPIs are to assess the water quality during storm events mainly. Storm events impact is most of the time strong and intense leading short but very intense pollution peaks. Fauna and flora can be very sensitive to these acute pollution events. According to this, the suggested KPIs are to compute the yearly time where Dissolved Oxygen is less than 3 mg/l and the time where ammonia is higher than 5 mg/l. Those indicators are anticipated to be reduced respectively by 30 % and 20 % on both pilots.

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