Report for Spanish pilot configuration definition, requirements and preparation

Deliverable DA1.2

LIFE RUBIES

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

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1 Introduction

As commented in deliverable D1.1, one of the sites selected as a demonstrative pilot in LIFE RUBIES project is Madrid. This case-study will complement the demonstration carried out in the Lille pilot.

This deliverable corresponds to the sub-action A.1.2 (preparatory action A1) and its main goal is to describe in detail the existing infrastructure and information available in the Madrid pilot, and detail the required tasks to implement the new control strategy envisaged in LIFE RUBIES project and assess the current river quality status and the improvements achieved thanks to the new control strategy.

The specific objectives for the deliverable are:

- To present and understand the existing pilot infrastructure by describing the pilot site drainage system (including sewer system and WWTPs) and how it is operated nowadays. This includes describing the available GIS information (regarding sewer dimensions, slopes, manholes floor level and ground level, and special structures such as CSO discharging points, detention tanks, pumps, gates, etc.), the sensors location and the dynamic data available, the existing models, the current IT architecture in Canal Isabel II (CYII) and finally describing the considered control perimeter to operate in the project.
- To define the monitoring strategy describing the sensors needed in the project (mainly rain gauges, water level sensors and turbidity sensors) and also the quality campaigns necessary to correlate the turbidity real time measurements with other quality parameters such as TSS, BOD5, etc.
- To list the AQDV UD IT requirements regarding the needed IT infrastructure, the connection with CYII current IT architecture, the corresponding configuration and the weather data needed to be operated correctly.
- To describe the needed models and its purpose including the required developments or adaptations to be carried out during the project considering also the simulation software that will be used and associated developments.
- To detail the necessary tasks to carry out the environmental impact assessment in Manzanares river.
- To specify main phases and associated activities/tasks identified in Madrid pilot site and the deployment schedule to reach the automatic control of the selected actuators in the pilot site and to assess the improvement/benefits in the environment (Manzanares river).

2 Madrid pilot description

2.1 General pilot description

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 1 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 m3 for each one and a total detention volume of 77000 m3
- The 6 main detention tanks.
    - Valdemarín (28000 m3)
    - Pozuelo (30000 m3)
    - Arroyofresno (400000 m3)
    - La China (130000 m3)

- Abroñigales (200000 m3)
- Butarque (359000 m3)

➢ The 5 WWTP:

- Viveros: 2.2 m3/s (approx. 1 million p.e.)
- La China: 3.3 m3/s (approx. 1.5 million p.e.)
- La Gavia: 2 m3/s (approx. 1 million p.e.)
- Butarque: 3.5 m3/s (approx. 1.8 million p.e.)
- Sur: 6 m3/s. (approx. 3 million p.e.)

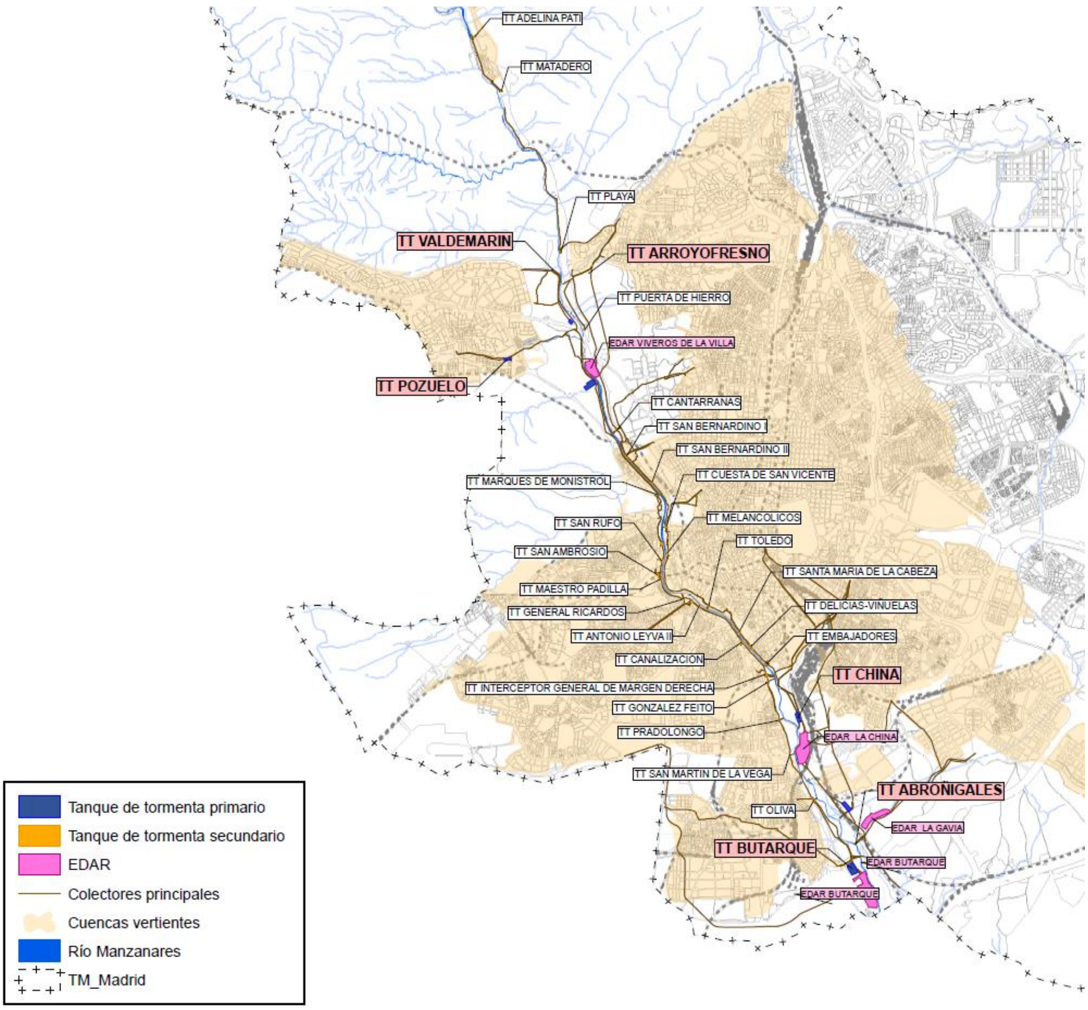

Figure 1.- Manzanares system overview with the location of the main sewers, main and secondary detention tanks and WWTP. Marked in red there is the selected pilot site for the LIFE RUBIES project in the southern part of the system.

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 (see the red square in Figure 1 and a zoom in Figure 2). 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.

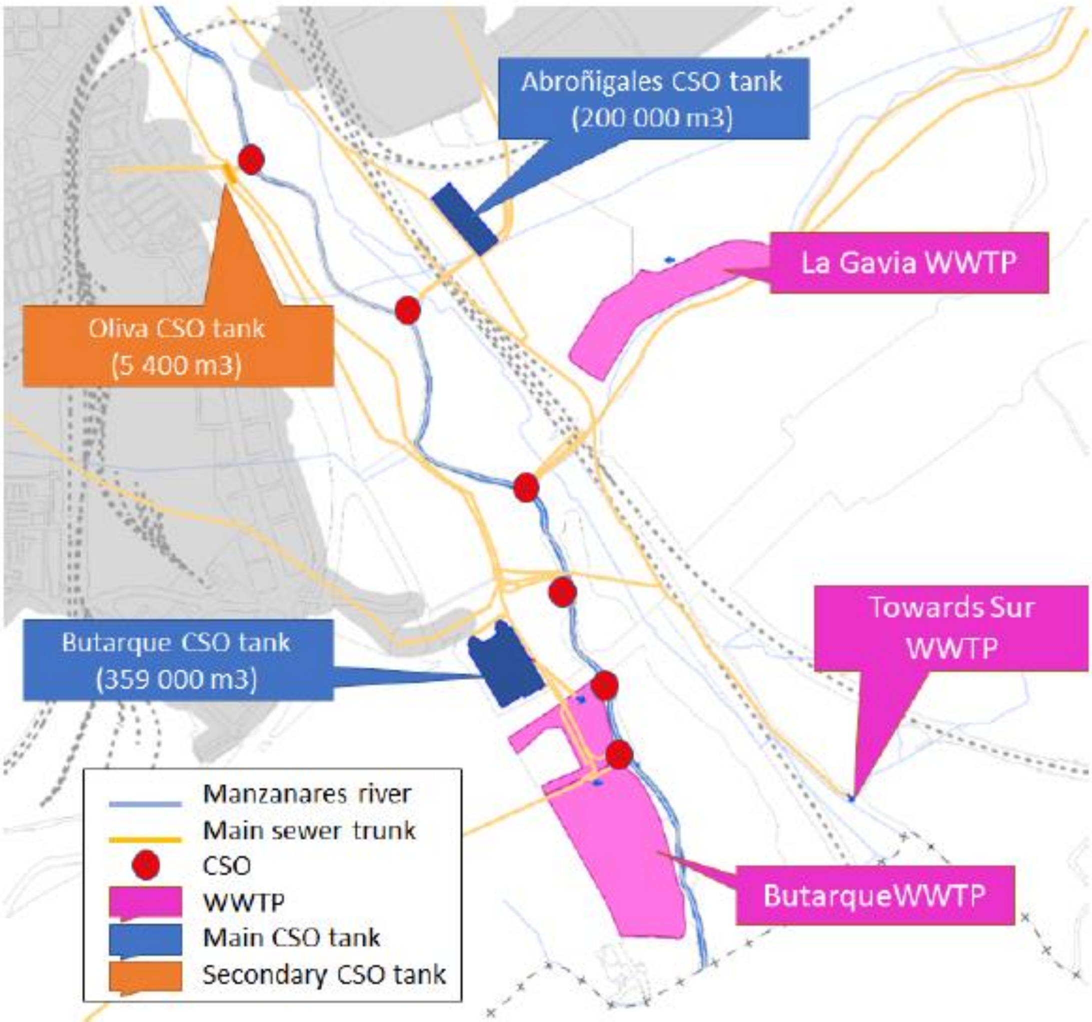

Figure 2.- Detail of the Rubies project pilot site in Manzanares system

The pilot site includes (Figure 3):

- 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.

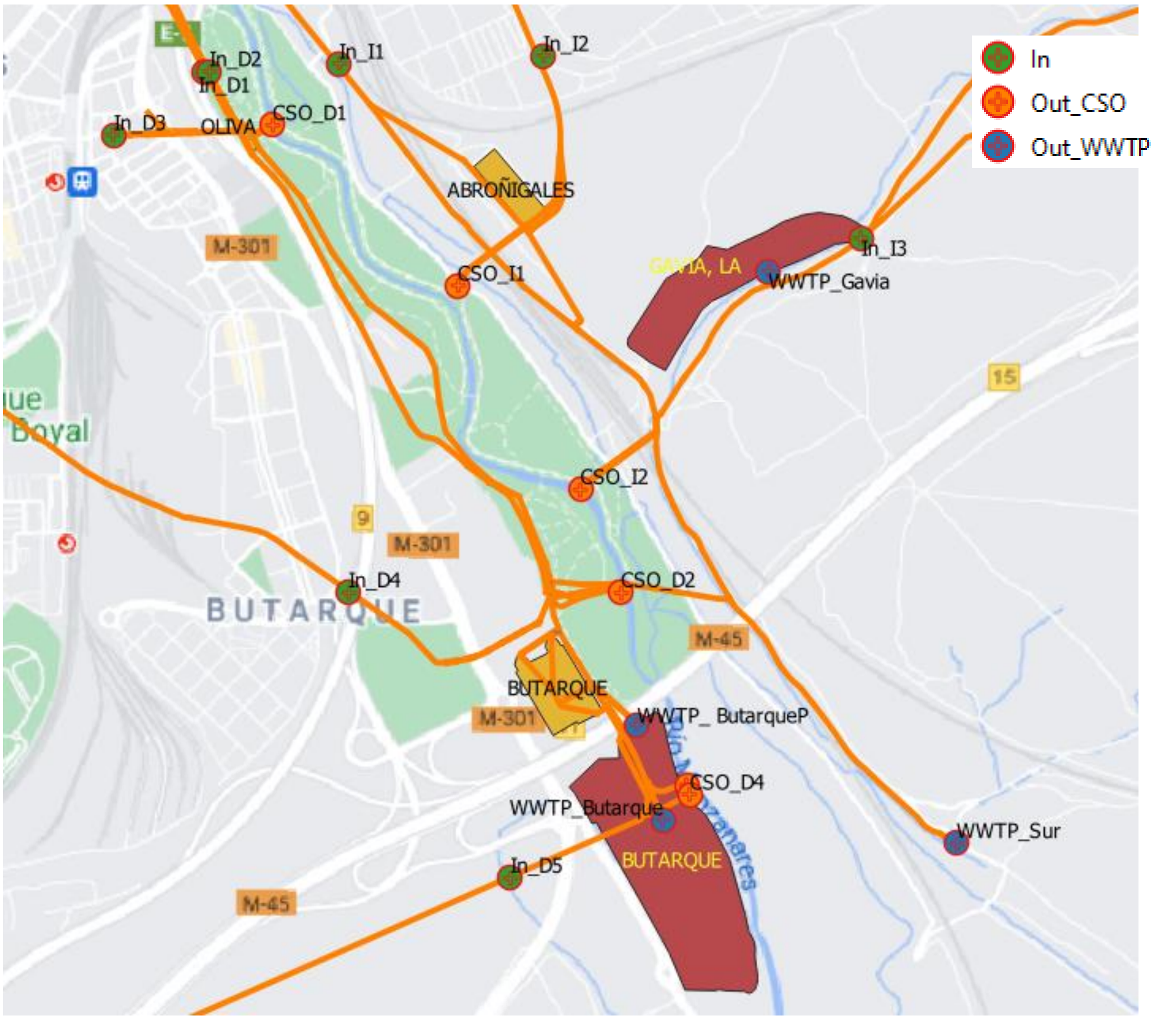

Figure 3.- Location of the flow inputs and output points in the pilot site

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.

In the following subchapters the main infrastructures that can be met in the pilot site are described, starting from the right margin upstream and going downstream, and then doing the same for the left margin.

2.1.1 Oliva CSO tank

This is the only secondary CSO tank located in the pilot site and gets water from a tributary sewer. It has a total volume of 5400 m3, an automatic gate located in the tank outlet to control the flow diverted to the interceptor, and an 18 m long weir discharging to the Manzanares river once the tank is full.

The gate is operated automatically to allow a maximum flow of 17 times the peak dry weather flow. This flow is estimated in 2.6 m3/s. This means that only when the flow is higher than this value the tank starts storing water volume.

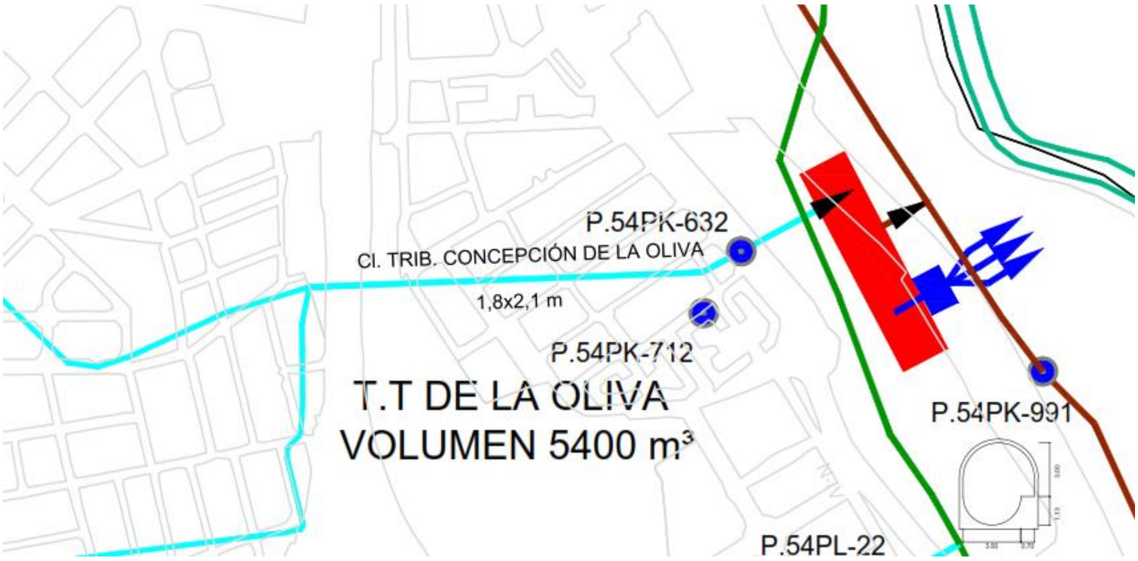

Figure 4.- Location of the Oliva Tank

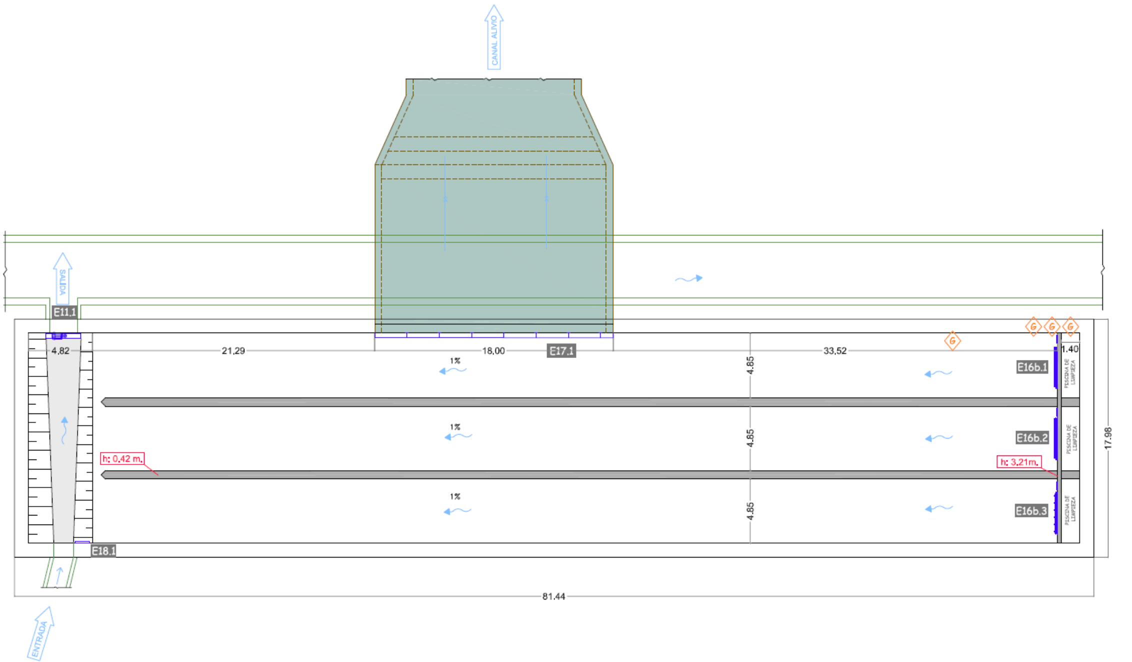

Figure 5.- Horizontal plan and dimensions of the Oliva tank and the location of the gate connecting the tank with the right margin interceptor.

2.1.2 By-pass between right margin and left margin interceptor

Two sewers that before crossing the river, they join into one as seen in Figure 6 driving water from the right margin interceptor to the left margin interceptor and later to the Sur WWTP.

In one of the sewers there is a gate usually open so that when water level in the right margin interceptor reaches 55 cm the water starts flowing to the left margin.

Figure 6.- By pass sewer driving waters from the right margin interceptor to the left one.

2.1.3 Butarque tank

Butarque CSO tank is located at the end of the right margin interceptor before the Butarque WWTP (see Figure 2). It has 359.000 m3 capacity (although in some references the volume is mentioned to be 375.000 or even 400.000 m3). The water gets into the tank through two entrances, the main one which connects the right margin interceptor with the tank, and a secondary entrance from the opposite side of the tank that connects the sewer called Butarque II with the tank. Both entrances have a by-pass so that in DWF or whenever the entrance gates are closed, the water bypasses the tank and gets into Butarque WWTP as long as its capacity is not exceeded. In the case the WWTP capacity is exceeded, the extra water is discharged directly to Manzanares river without being treated but this only happens in rainy events. The tank is emptied by two pumping stations one driving the flows back to the right margin interceptor downstream the tank, and another one driving the flows directly to the WWTP primary treatment line.

As seen in Figure 7,. the tank is divided in two identical modules with independent operation each one (so the filling of the tank can be controlled for energy and cleaning savings). Also, each sub-tank is divided in 4 compartments which are also filled successively thanks to spillway separation walls.

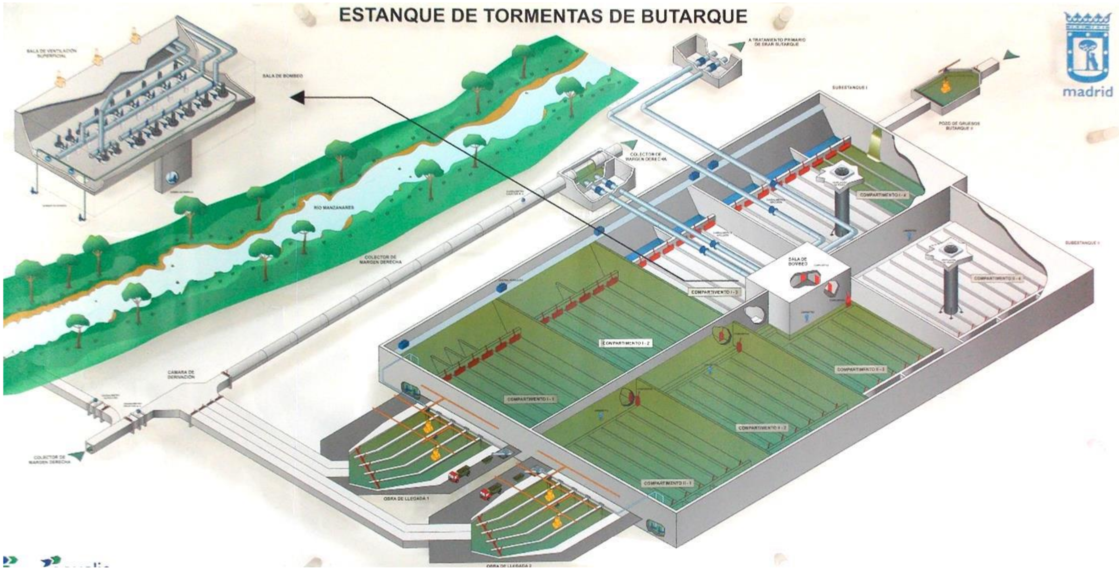

Figure 7.- General scheme of Butarque CSO tank.

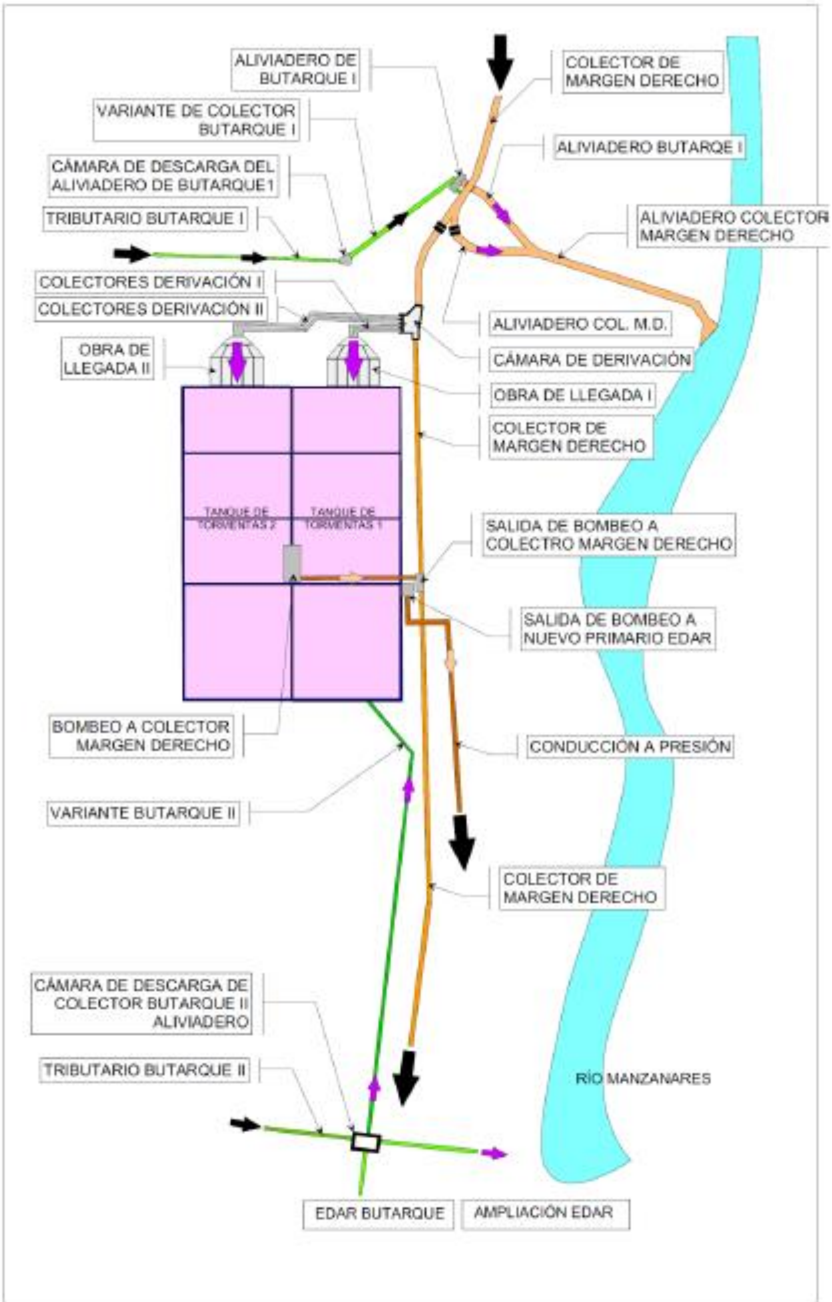

Figure 8.- Main sewers and infrastructures around Butarque tank

Figure 8 also shows the main sewers and infrastructures linked with the tank. They are described below:

- Butarque I tributary sewer and its CSO weir: This is a tributary sewer that has a CSO discharging point before connecting to the right margin interceptor.
- Right margin interceptor and its CSO weir with a gate: The interceptor receives the input from Butarque I and downstream it has a CSO discharging point with a gate of 3 m height. If water level in the interceptor is below 3 m there is no CSO, if the water level is between 3 and 3.3 m the water flows from a weir above the top of the gate, and when water level is above 3.3 m the gate gets opened.

- Right margin interceptor divertion chamber to the tank: This chamber has a by passing gate that allows DWF to by pass the tank and flow directly to Butarque WWTP. When the water level rises above 2.75 m there are 4 entrance gates (two for each subtank) that get opened one after the other to let the flow get into the tank
- Butarque II tributary sewer, divertion chamber to the tank with a gate and connection to the WWTP and river CSO (Figure 9). From this tributary sewer there is the second entrance to the tank controlled by a gate that only gets opened when the WWTP capacity is exceeded. Also from the divertion chamber there is CSO weir that connects directly to the river.
- Pumping station to the right margin interceptor: It has (3+1) pumps of 1050 l/s for each subtank and the total pumping capacity is 6.5 m3/s
- Pumping station to the WWTP primary treatment line: It has (5+1) pumps of 1082 l/s for each subtank and the total pumping capacity is 10.5 m3/s

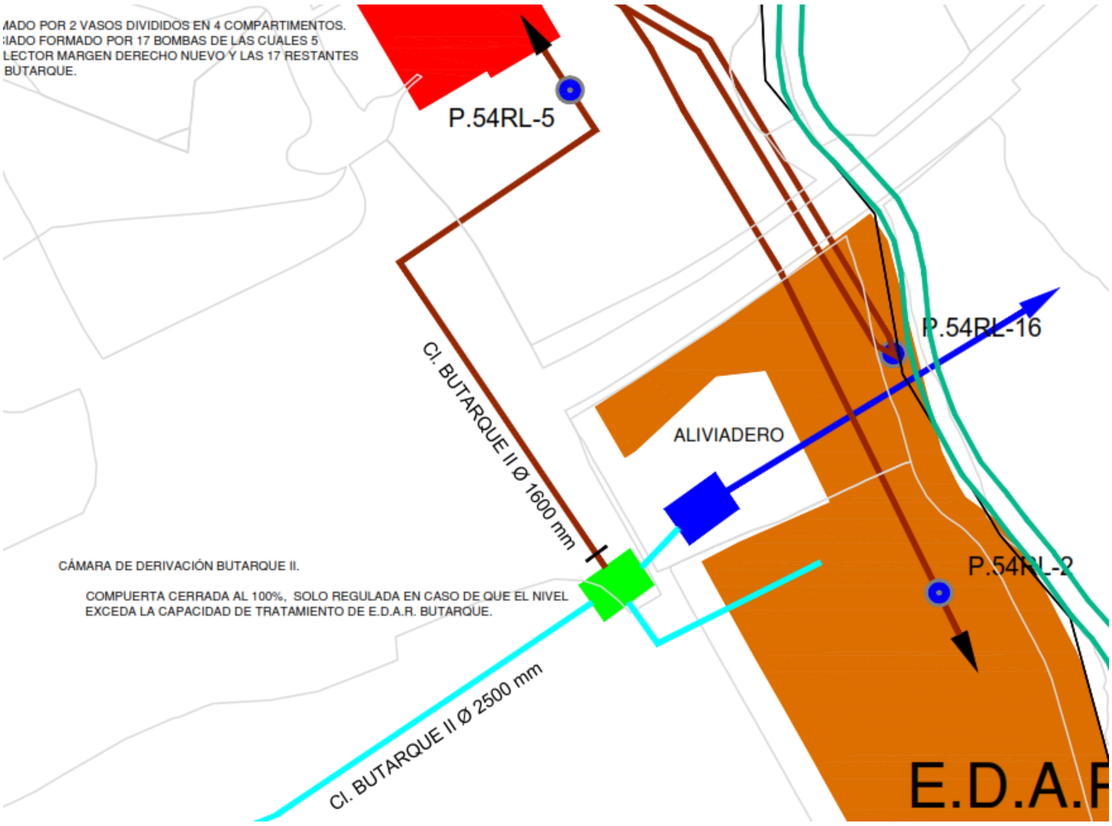

Figure 9.- Butarque II tributary sewer and its connection to the tank, WWTP and CSO discharging point

2.1.4 Butarque WWTP

As stated, Butarque WWTP receives water collected by the right margin interceptor as well as by the tributary sewer Butarque II. In addition, water coming from the Butarque Tank can also be pumped directly to the WWTP "new" primary treatment unit.

The inflow of water coming from the right margin interceptor is controlled by a gate and a weir, which enable the possibility of diverting flow to the river in case of risk of flooding. In addition, water coming from the Butarque II tributary sewer can be diverted from the WWTP coarse debris wet well either to the river, or to Butarque stormwater tank in case the WWTP capacity is exceeded.

The treatment plant comprises the following process phases: pretreatment and primary treatment (divided in two lines, referred as “new” and “old”), biological treatment, sludge thickening, digestion, sludge dewatering, chlorination, electrical energy recovery, airline (odour treatment) and internal reuse of treated water.

The reason for the existence of two different pretreatment and primary treatment lines is due to the construction of the Butarque storm tank. After this new infrastructure was commissioned, a new primary treatment line was implemented in Butarque WWTP in order to increase the plant capacity and thus, allow that water retained in the tank could be processed at a pretreatment and primary treatment level. These existing facilities are currently fully operational.

The “old” pretreatment and treatment process consists of:

- thick separation lines with 70-mm-span bars
- 6 fine separation lines with 20 mm sieves
- 6 aerated grit chambers
- 12 sand suction pumps
- Separation of sand and organic matter in vortex deposit
- 8 primary sedimentation tanks
- Purging of sludge by pneumatic valves

The “new” pretreatment process comprises the following elements:

- Coarse wet well
- Pumping station to send water derived from the right margin interceptor
- Inlet chamber to receive water coming from the Butarque stormwater tank pumping station.
- Grids and Sieves
- Desanders

The design flow of the coarse debris wet well is 7,5 m^3/s, while that of the set of bars, screens and grit traps is 10,5 m^3/s in order to be able to receive in this point water coming from Butarque tank. Flow limitation for the further physical-chemical treatment and new primary settling, for the current eight-line design is 7 m3/s of maximum flow, relieving the excess, up to 3,5 m3/s, through the by-pass spillway located at the grit removal outlet. This relief is measured by means of an ultrasonic flowmeter. In addition, after the primary treatment, and before the secondary (biological) treatment, water can be derived to the Manzanares river.

Lastly, secondary treatment consists of:

- 4 aeration ponds with a total volume of 55,000 m3.
- Phosphorus reduction by adding ferric chloride in the biological treatment ponds.
- 11 secondary clarifiers.
- 1 lamellar settler.

Figure 10, presented below, summarizes the overall layout of Butarque WWTP, together with the existing water level and flow sensors, including those corresponding to the outflow weirs.

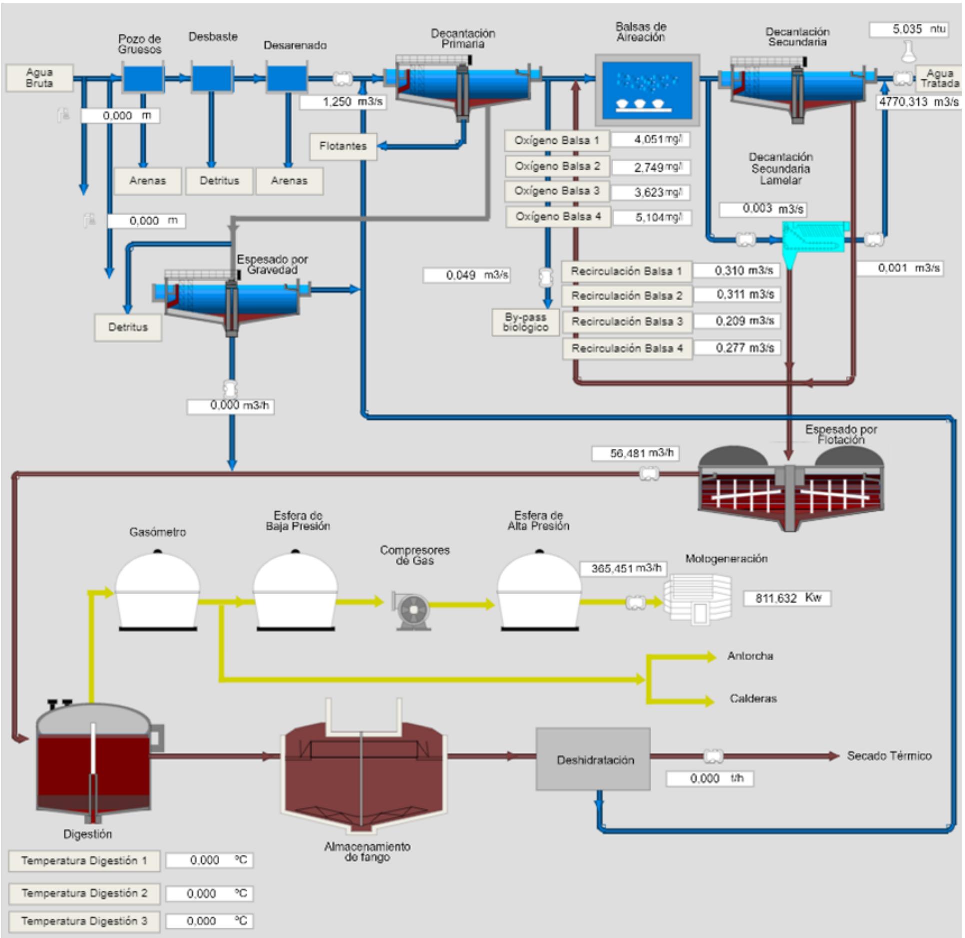

Figure 10.- Overall layout of Butarque WWTP

2.1.5 Abroñigales tank

Abroñigales CSO tank is located in the left margin of Manzanares river upstream of the pilot area (see Figure 2). It has 200000 m3 volume capacity and its dimensions are 85 x 255 m. The water gets into the tank through the new Abroñigales tributary sewer by-pass. This means that in DWF this sewer is empty and only during rain events water flows will be driven in this sewer. When these flows are lower than 12 m3/s they can be conducted directly to the left margin interceptor through a divertion chamber and therefore, by-passing the tank. When the flows exceed the by-pass capacity (or when the by-pass gate is close) the water gets into the tank through a channel. At the end of the channel there are two CSO gates connecting directly to the Manzanares river, so when these gates are open the flow goes through the tank without filling it and are being directly discharged into the river, but when these gates are closed the water level in the channel rises above the channel walls acting as weirs and the water fills the tank. Once the rain event is finished, the tank is emptied by opening a gate that discharges the flow into the left margin interceptor (see Figure 11).

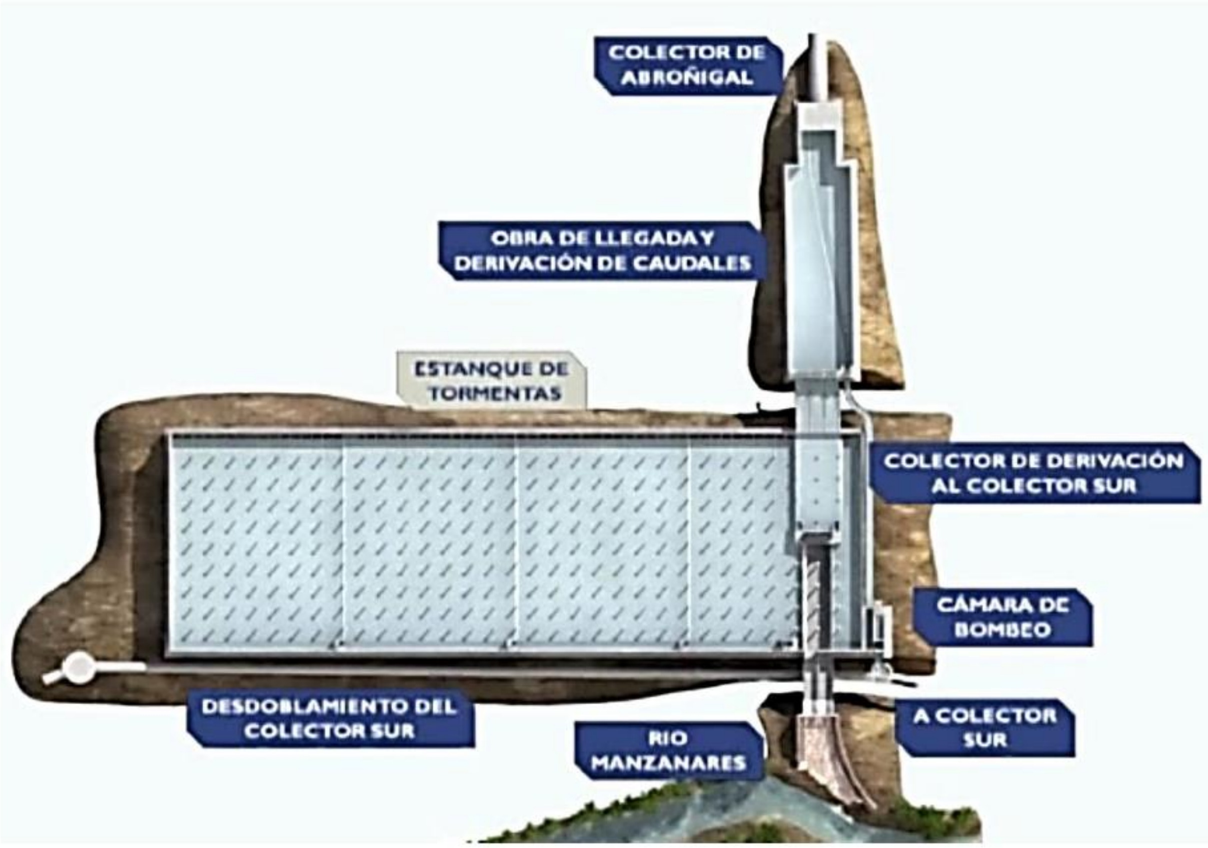

Figure 11.- General scheme of Butarque tank

The tank is divided in 4 different compartments that are filled successively with weir separation walls and anti-floating debris screens as seen in Figure 12.

Figure 12.- Weir wall and anti- floating debris screen between the first and the second chamber of the tank.

The main infrastructures linked with the tank are:

- Entrance divertion chamber (Figure 13): This chamber takes water from Abroñigales tributary sewer and with the help of 4 gates (1 by-pass gate and 3 gates one in each of the entrance sewers to the tank) and an interior weir, it drives the water to the tank or it bypasses it.

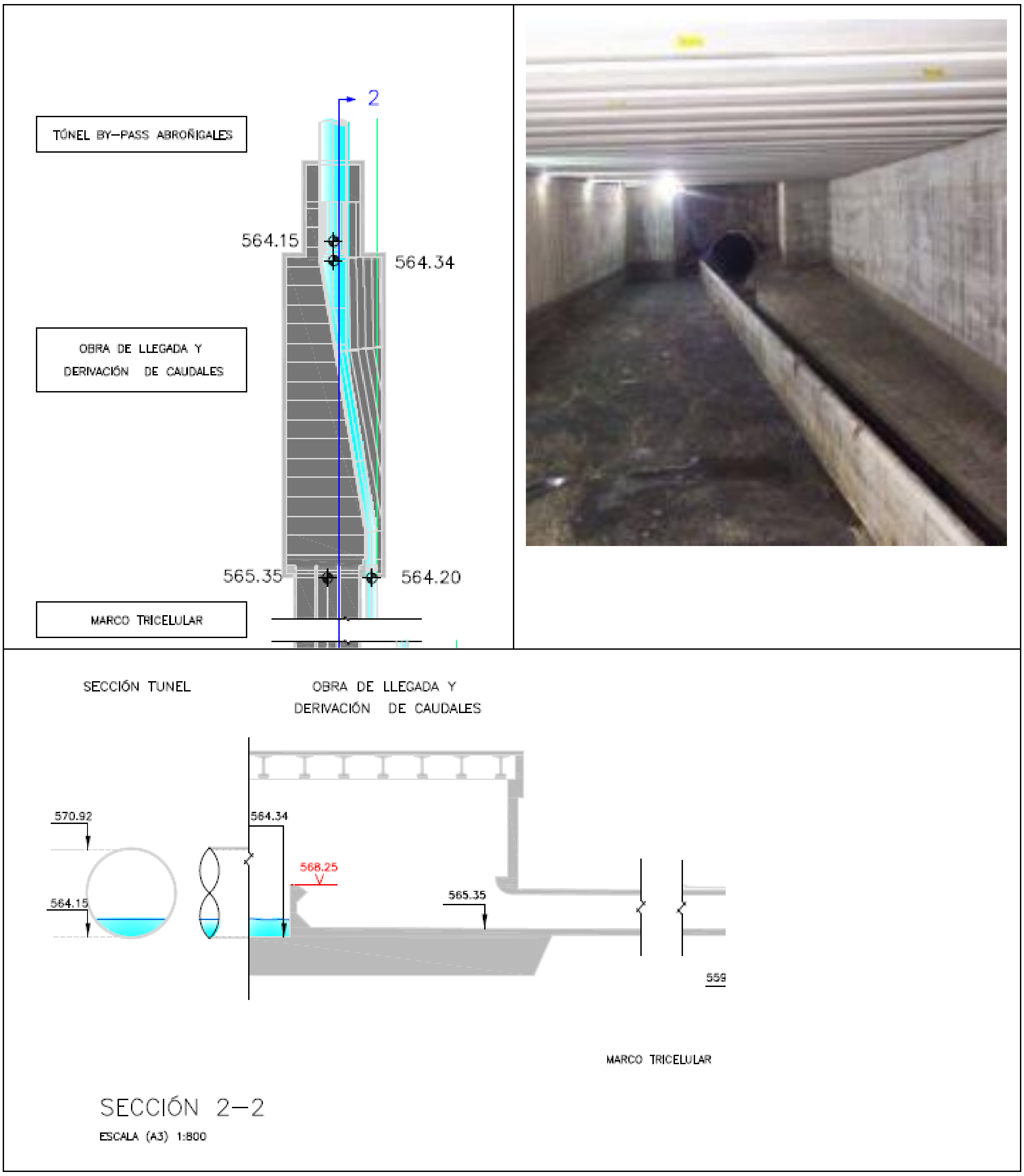

Figure 13.- Scheme and photo of the entrance divertion chamber to Abroñigales tank

- Entrance and CSO channel: This channel goes through the interior of the tank and it has two main parts divided by two gates. The first part until the gates, has a weir so with the gates closed the water level reaches the weir and the water goes into the tank. If these gates are opened, the flow does not go into the tank and flows directly to the river without getting into the tank. Only when the tank is full the emergency weir located in the same channel but downstream the gates is reached and there is CSO flow discharging into the river.

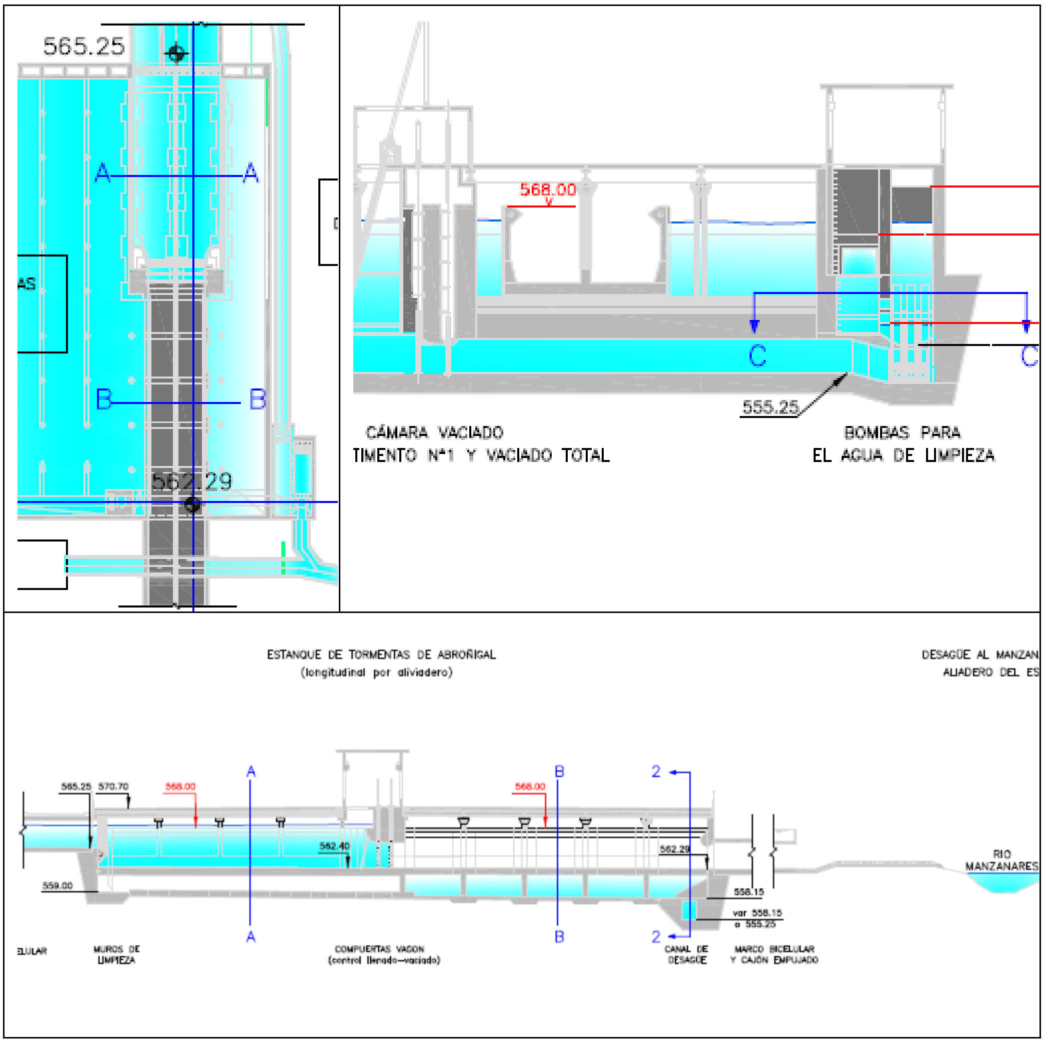

Figure 14.- Horizontal plan longitudinal and cross section of the channel

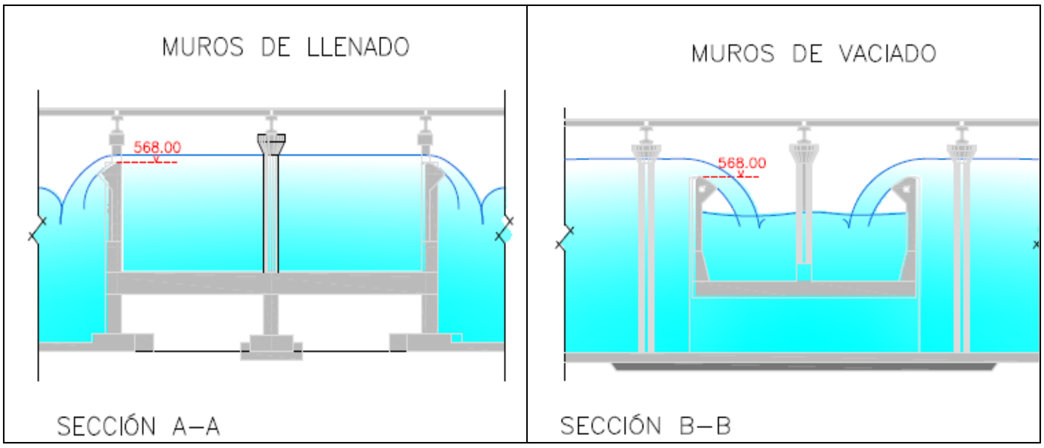

Figure 15.- Filling the tank with the channel gates closed (left). Emptying the tank through the emergency weirs once the tank is full (right).

- Emptying chamber and pumping station to the left margin interceptor: Finally through a gate the tank is emptied connecting first with the by-pass sewer (coming from the divertion chamber upstream) and later both connecting to the left margin interceptor.

Most of the tank volume is emptied by gravity but to fully empty the tank, there is a remaining 5 % volume that must be emptied by pumps.

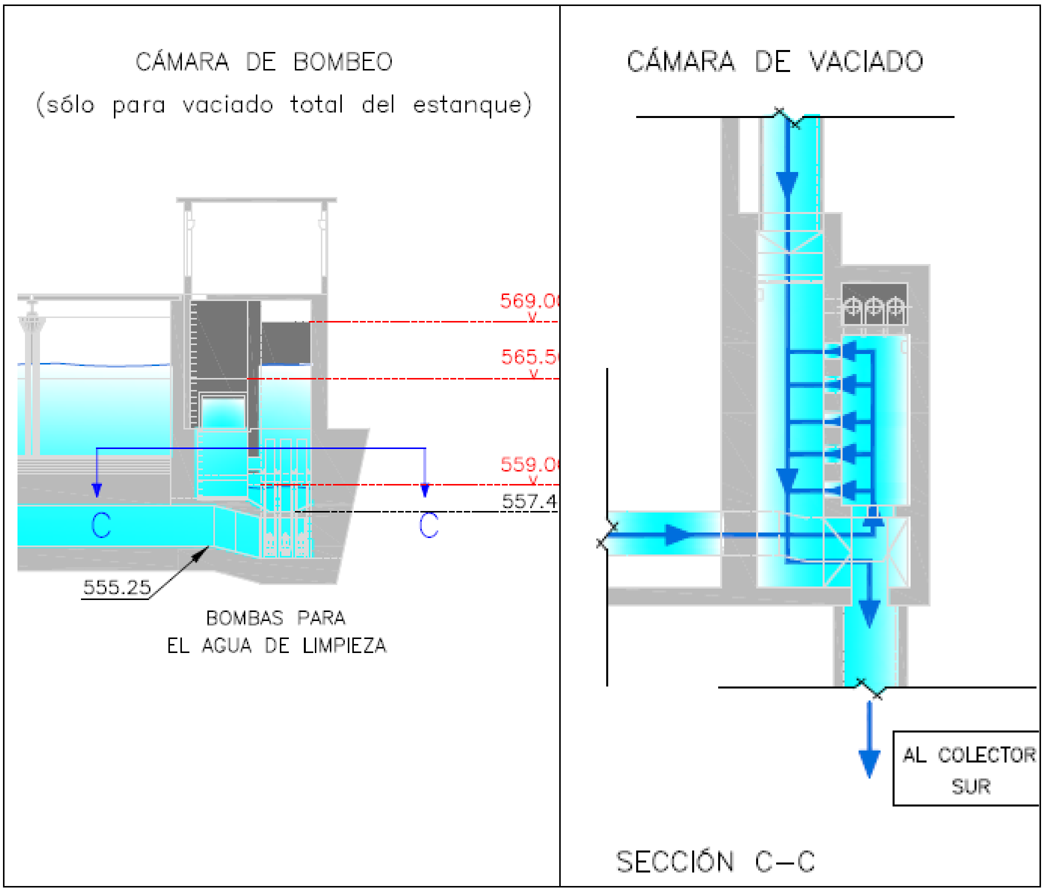

Figure 16.- Cross section (left) and horizontal map (right) of the emptying chamber and the the pumping station

The tank operation can be summarized in:

- Case 1: Entrance flow is lower than 12 m3/s. The flow through the divertion chamber by passes the tank and goes directly into the left margin interceptor (see Figure 17).
- Case 2: Entrance flow is below 80 m3/s. Then part of the flow by passes the tank and the other gets in starting filling the tank (see Figure 18).
- Case 3: Entrance flow is below 80 m3/s and the tank is full with the channel gates opened. In this case part of the flow is by passed as usual to the left margin interceptor, and the rest of the flow crosses the tank through the channel and is being discharged directly to the river causing CSO (see Figure 19).
- Case 4: Entrance flow is below 80 m3/s and the tank is full with the channel gates closed. As in the previous cases some flow is by passed to the left margin interceptor, and the rest of the flow gets into the tank through the channel weir located upstream the gates, but then this rises the tank level and it is emptied by flowing through the emergency weir to the channel downstream the channel gated and discharging CSO to the river (see Figure 20).

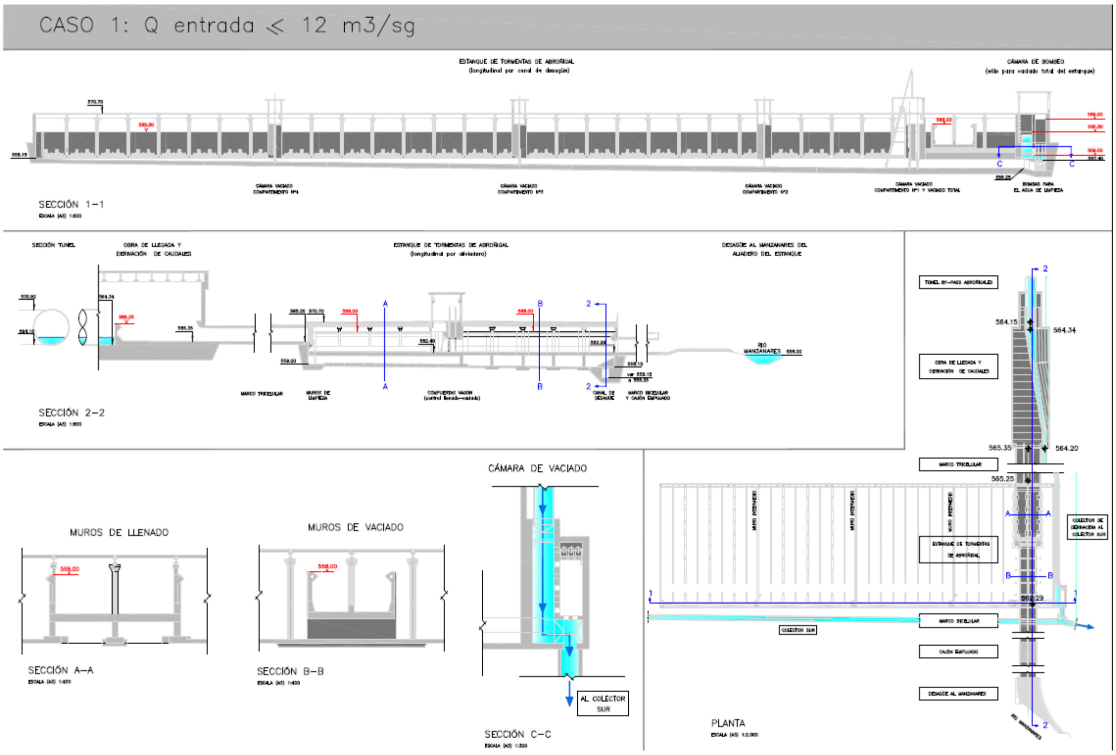

Figure 17.- Abroñigales operation model for case 1

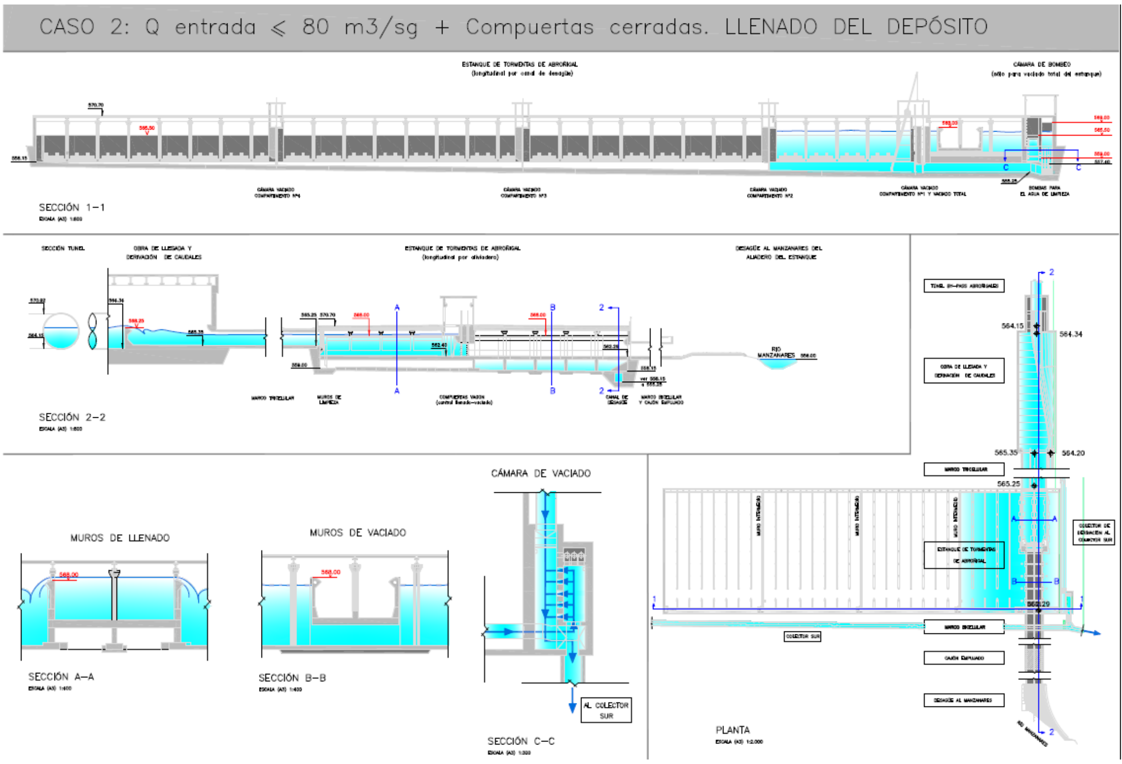

Figure 18.- Abroñigales operation model for case 2

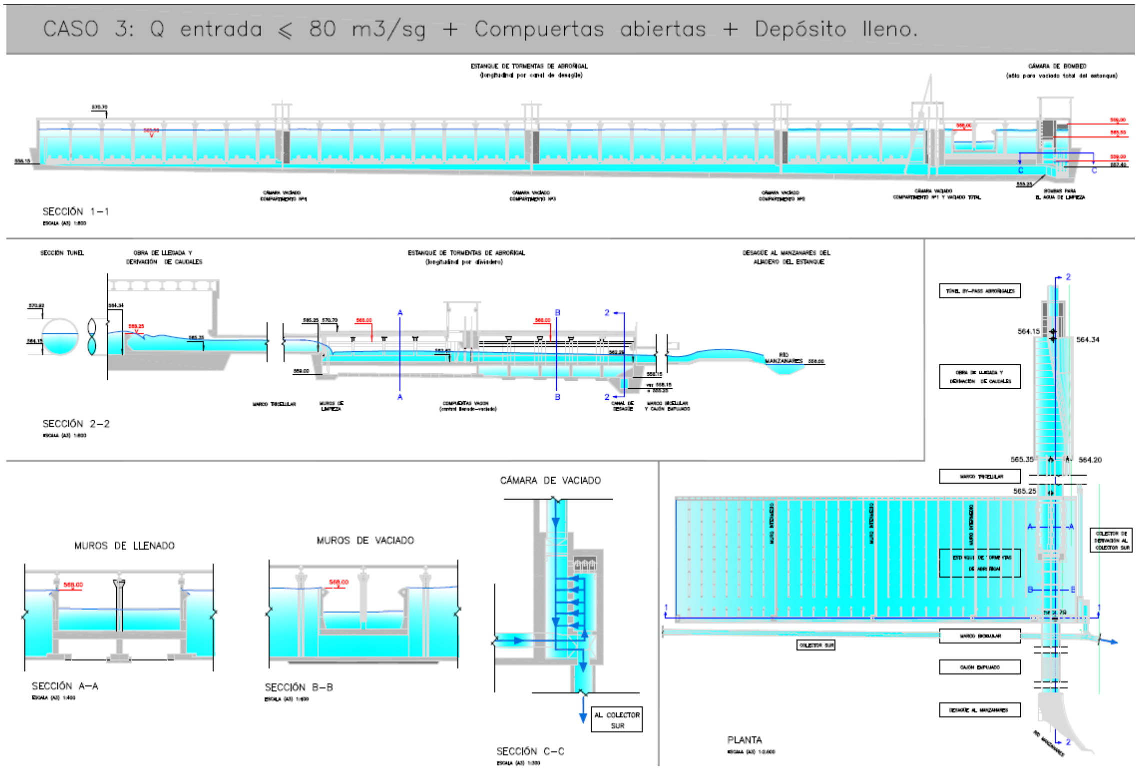

Figure 19.- Abroñigales operation model for case 3

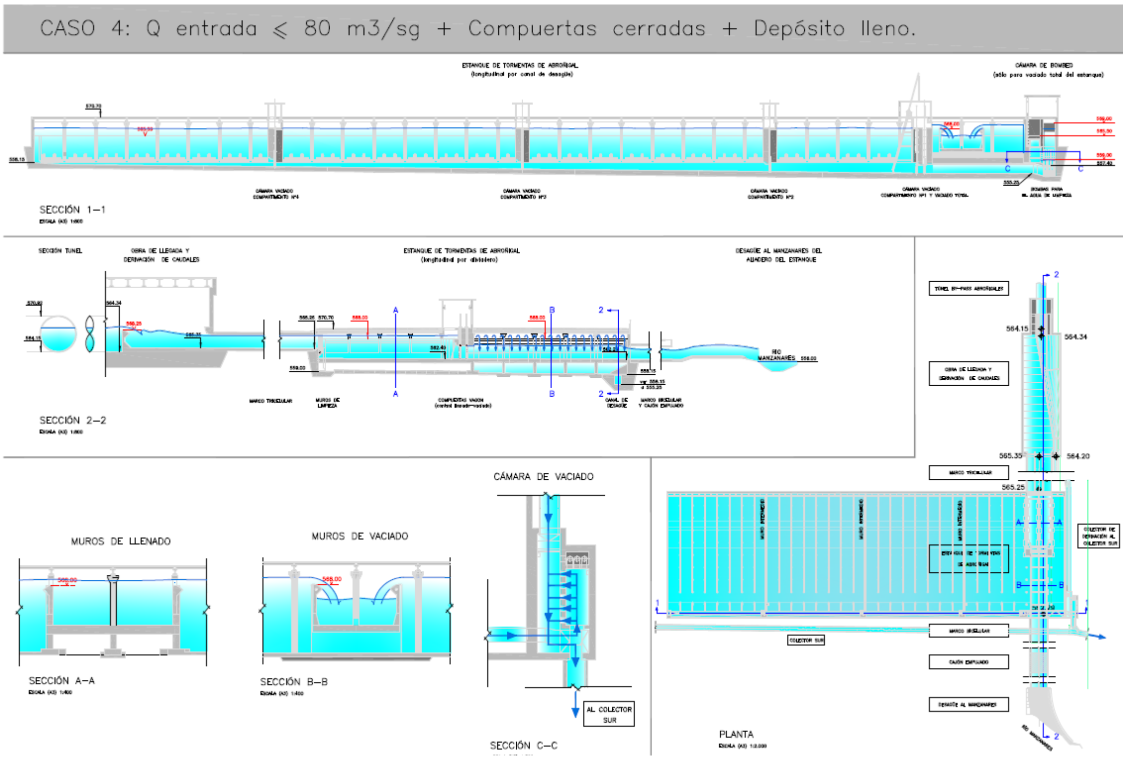

Figure 20.- Abroñigales operation model for case 4

2.1.6 La Gavia WWTP

La Gavia WWTP has an average treatment capacity of 2 m3/s. This plant receives water coming from the two La Gavia tributary sewers (Gavia I and Gavia II). The intake to the WWTP at this point consists of a coarse debris wet well. The capacity of the pumps installed is of 6 m3/s.

Besides, La Gavia WWTP can also receive intakes coming from the left margin interceptor. Connection at this point is made by means of a second coarse debris wet well. The pumping capacity in this intake is of 1,5 m3/s.

Pretreatment process includes coarse and fine screens and aerated grid chambers. Primary treatment consists of 6 lamellar type clarifiers. At the outlet of this primary decantation treatment, the flow that passes to the biological treatment is regulated. In case of high flow rate, certain amount of wastewater is bypassed after the primary treatment, extracting the surplus through the by-pass CSO. The flow measurement at this point is carried out in the DN 1800 pipe that feeds the biological treatment, by means of an electromagnetic flowmeter. The outlet of this DN 1800 pipeline is equipped with a servo-motorized gate that regulates the flow rate based on the reading of the flow meter. The surplus goes to the DN 2000 by-pass collector through a 24 m long spillway, located at the outlet of the primary settling. This by-pass connects with the treated water discharge line.

Secondary treatment in the La Gavia WWTP comprises an advanced biological nutrient removal reactor (BNR), which contains four zones connected in series (preanoxic-anaerobic-anoxic-aerobic). Each zone plays a different role in the removal of nutrients. The distribution to the biological treatment is carried out by symmetry through a distribution channel and isolation gates at the entrance to each biological reactor. After the biological process, water enters into 6 sludge suction clarifiers.

Additionally, La Gavia WWTP has a tertiary treatment, facility designed to treat an average flow of 1 m3/s and a maximum flow, in exceptional cases, of 1,5 m3/s. Tertiary treatment comprises the following processes:

- Coagulation-flocculation
- Filtration
- Advanced oxidation by means of combined ozone and hydrogen peroxide system
- Ultraviolet desinfection

2.1.7 Aliviadero SUR CSO discharging point (CSO_I2)

At this point two discharging flows are met, the one coming from the effluent (and the non treated waters by-passed in rain events) from La Gavia WWTP, and the flow exceedance from the left margin interceptor.

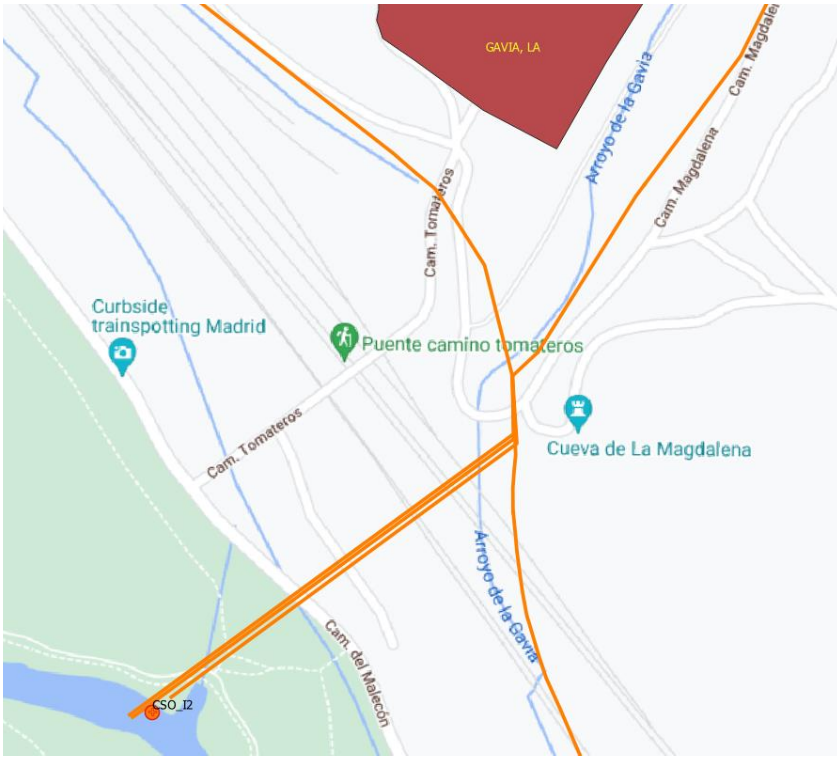

Figure 21.- Aliviadero Sur discharging point to the river and the location of the weir chamber between

Figure 22.- Weir chamber from the left margin interceptor (right channel) with the wall weir and the window are the flows coming from La Gavia WWTP. When the water level in the left margin interceptor raises above the wall these flows join the ones from La Gavia and are discharged in the river.

2.2 GIS information

Canal Isabel II has Geographic information system of the infrastructures of the Manzanares sanitation system in ArcGis support. This includes detailed information on the characteristics of the network with precision topographic data. A list of the most important elements of the existing elements in the GIS with a short description and the most important information available is provided here:

- Sanitation connection:
    - Description: It is the conduit that connects the different discharges from homes, industries, and other services to the sewage network.
    - Information: material, length, start and end invert level, etc.
- Weir:
    - Description: element that diverts the excess flow produced by rainwater, avoiding direct discharges when there is no adequate dilution.
    - Information: Height and length of the weir, and invert level from the chamber or manhole floor, etc.
- Pressure breaking chamber:
    - Description: Chamber where a pipe coming from a pumping station gets connected and from that point water flows by gravity
    - Information: Depth, dimensions, material, etc.
- Sewer:
    - Description: -
    - Information: Type of water (separative rain water, separative DWF or combined) cross section information such as shape (circular, rectangular, egg-shape…) and dimensions, type of floor (with or without shape for DWF) and its dimensions, material, length, start and end invert level, etc.
- Pumping station:
    - Description: Infrastructure for lifting wastewater.
    - Information: Chamber dimensions, depth and floor invert level, number of pumping lines and pumps, pump capacity, weir dimensions, etc.
- WWTP:
    - Description: Waste water treatment plant
    - Information: Name, date when it started the operation, design capacity, etc.
- Inlet:

  - Description: opening through which surface water (rain or street cleaning waters) is conducted to the sewerage system.
  - Information: type, depth, material, shape, dimensions, invert level, etc.

- Sensor:
  - Description: measure instrument
  - Information: type (water level sensor, rain gauge, quality sensor, flow meter…)
- Node
  - Description: connection points of the sewer network
  - Information: type (it means what infrastructures it connects sewers without manhole, , WWTP, storm tank, pumping station…)
- Manhole:
  - Description: -
  - Information: type (meaning it is special access point, or connects to a visitable sewer, or a small circular sewer) material, floor invert level, dimensions, cover ((type, material, dimensions…)
- Discharging point:
  - Description: It represents an outlet point of the sewerage system.
  - Information: Floor invert level, with or without screen, etc.
- Hydraulic jump:
  - Description: Built to connect two sewers with important depth differences, or when the slope of the sewer is less than that of the terrain.
  - Information: width, number and dimensions of the steps (in case it is chair type)
- Storm tank
  - Description: tanks allowing to regulate the flow being driven by storing the excess water in it.
  - Information: name, volume, dimensions (length, width, depth) cleaning system, with or without pumping station and pump capacity, number of tank compartments, etc.

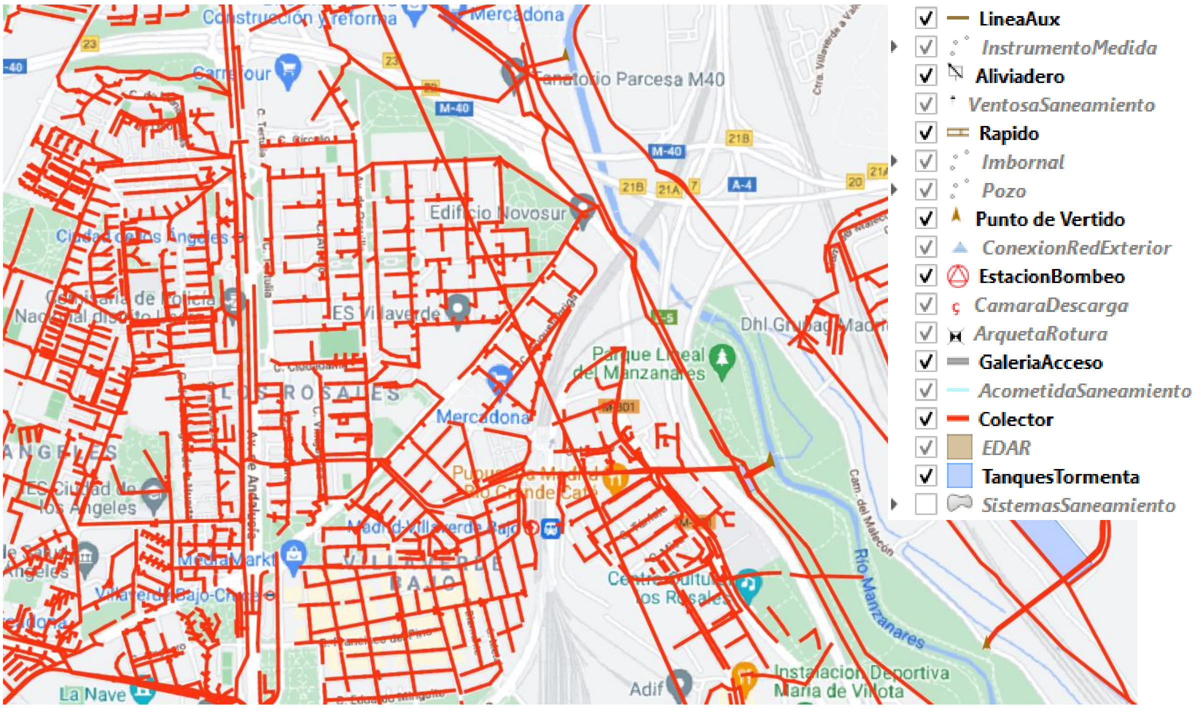

Figure 23.- General view of the GIS information available

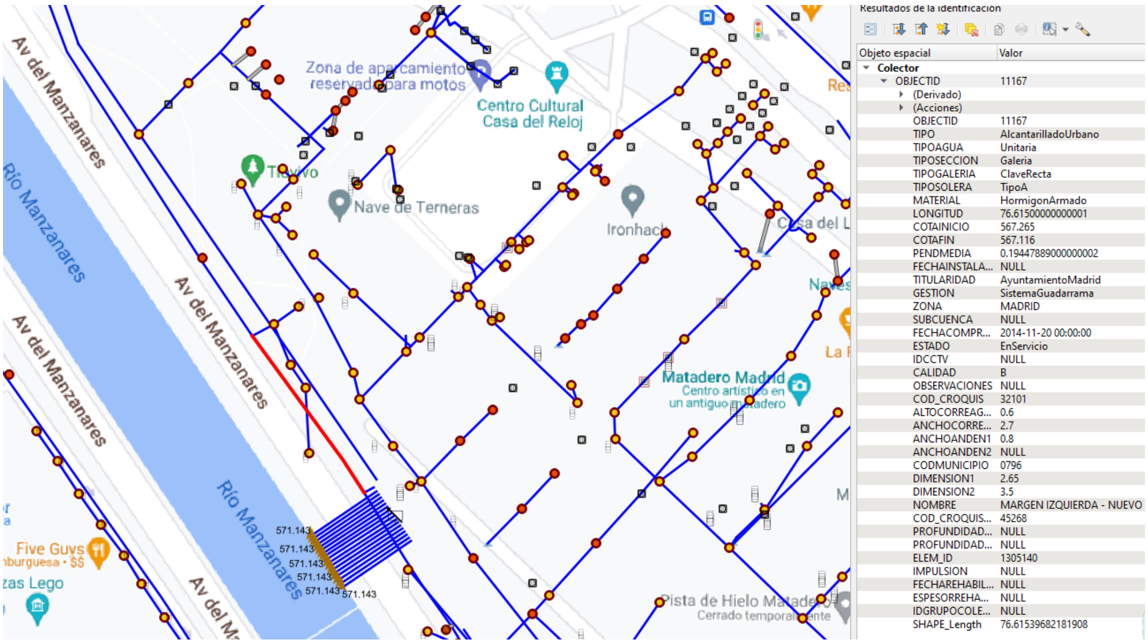

Figure 24.- Detailed view of the GIS with information from a sewer element.

Apart from all the specific information described for each GIS element there is some general information that all the elements has, such as quality of the information, status (if it is in operation, planned to be built, or not in use any more…), management proprietary, and there is always a field to add comments, sketch, date of the last visit, etc.

The information available is enough to understand the general sewer system behaviour for the Manzanares system and specifically in the pilot area, and to build and update the system model to fulfil the project requirements

Also, there are some specific locations where some more information or a detailed inspection to obtain a sketch with dimensions would be necessary to fully understand the flow behaviour. The list of these points is defined here and it could be increased during the project:

- First connection chamber between right margin interceptor and left margin interceptor where a gate is located. Information about this connection, gate dimensions, connection levels ,sewer dimensions and gate operation is required (see Figure 25).

Figure 25.- General and detailed view of the first connection chamber.

- Second connection chamber between right margin interceptor and left margin interceptor and CSO discharging point with gate. Connection levels, sewer and gate dimensions, and gate operation is necessary (seeFigure 26)

Figure 26.- General and detailed view of the second connection chamber.

- Upstream Butarque WWTP CSO discharging point. Same information is required here: connection levels, weir width, etc. (see **Erreur ! Source du renvoi introuvable.**)

- Upstream Butarque II tributary sewer connection to the WWTP and CSO point. Connection levels, sewer dimensions, connection to the WWTP, CSO discharge sewer and levels, etc.

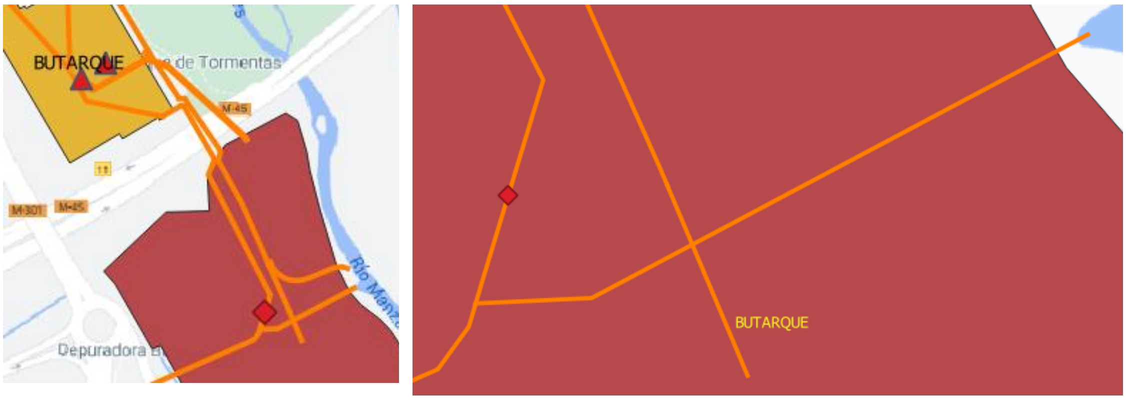

Figure 27.- General and detailed view of Upstream Butarque II and CSO discharging point

2.3 Dynamic data

2.3.1 General description of Dynamic data sensors

The function of the dynamic remote sensor system is to establish a control in real time of the state of all facilities comprised in the integral water cycle. To achieve this purpose, Canal de Isabel II has implemented a modern remote control system which, thanks to 200,000 sensors and more than 2,500 remote stations, guarantees the possibility of having real time knowledge of the status of its infrastructures and the quality of the water served.

This system performs the capture, transmission and reception of all the different kind of data measured. Roughly, the main elements which comprise this infrastructure are the following:

- Instrumentation system: including data sensors and remote stations consisting of a PLC with communications processor. There is a wide variety of sensors installed, involving different manufacturers and technologies. Integration within the corporate system is achieved through standard protocols, as described in the IT Architecture chapter (2.5)
- Communication system: Canal de Isabel has a proprietary communication network, based on optical fibre and/or wireless radio communication.
- SCADA: developed in a widespread commercial software, its structure is based on the real-time data measured by the sensors, the drivers for communication with the PLC's and the graphic package for the workstations.
- Control Center, from where it is possible to monitor the status of the facilities and the efficiency of operations, guaranteeing a prompt response to any incident which may arise.

The Control Centre manages integrated telecontrol and geographic information systems. At this location, data received is consolidated and stored in Oracle database. Information can be further sent to different functional areas such as intranet, the corporative geographic information system, or data-warehouses.

2.3.2 Rain gauge and Rainfall radar description

Within the context of this project, the installation of 2 rain gauges in the study area is foreseen, as stated in chapter 3. Information provided by these new sensors will be cross-checked with that obtained from the existing rainfall radar network which Canal de Isabel II currently manages. It consists of 3 X-Band radars from the manufacturer ELDES, (model WR10X). Radars have volumetric capacity, in order, to be able to vary the height of the scanning volume instead of obtaining information only at a fixed elevation. These instruments do not have polarimetric capacity (possibility of measuring reflectivity in different polarimetric orientations), nor Doppler capacity (possibility of measuring, in addition to precipitation, the radial velocity with respect to the radar).

The current location of the radars is in the municipal districts of: Colmenar Viejo, Loeches and Valdemorillo. The coverage of the radars has a defined range of 72 km radius, so the study area is broadly covered. The data recorded by each radar is processed locally using the software provided by the manufacturer (WR-10X Server-Suite) where products are generated for local viewing and processing RAW files that are sent via FTP protocol. On the server, and through the software also provided by the manufacturer (WR-10X Client-Suite), products are generated again for individual radars and products involving the entire network (composition, Nowcasting, etc.)

The following figure presents the location of the above described rainfall radars together with the rain-gauges network of Canal de Isabel as well as those rain gauges managed by AEMET (Meteorology Spanish Agency). The red rectangle corresponds to the study area. Unfortunately, none of the rain gauges located close to the study area can provide rainfall intensity information, as they only give hourly data, but the three closest ones will be used to validate / correct radar measurements.

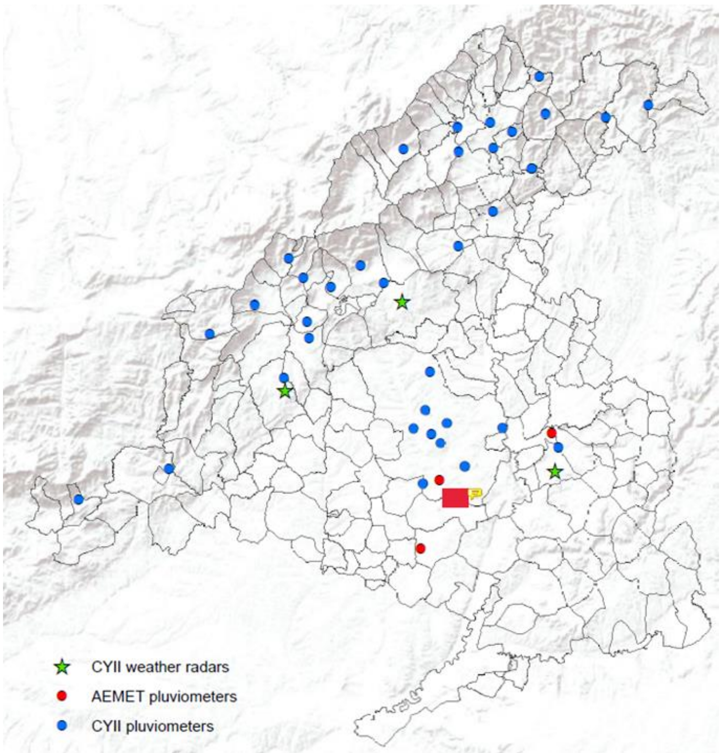

Figure 28.- Location of CYII weather radars and rain gauges (including the ones from AEMET)

2.3.3 Sensors around Oliva tank

At the time being there is no control regarding inflows or outflows in Oliva tank. There neither is sensor information about water level height inside the tank, so when it is filled or emptied can only be estimated from the gate manouvering. The overflow weir for the discharges to the Manzanares river is neither monitorized.

2.3.4 Sensors in Left Margin and right margin Interceptor

The figure below represents the existing water level monitoring points located along the left and right margin interceptor within the study area. Those monitoring points related to CSO and outlet discharges of WWTP and storm tanks are described in the following paragraphs. In addition, there are some water level sensors in the left interceptor which can be useful for defining the hydraulic boundary conditions of the system. They are highlighted in the referred figure below represented.

These are:

- Left margin interceptor upstream Abroñigales outlet connection
- Left margin interceptor downstream the pilot site before reaching Sur WWTP

With regards to the right margin interceptor, there are no water level sensors upstream the existing by pass which connects the right and left margin interceptors, so there is no possibility of defining the hydraulic inputs in this margin with the existing monitoring points.

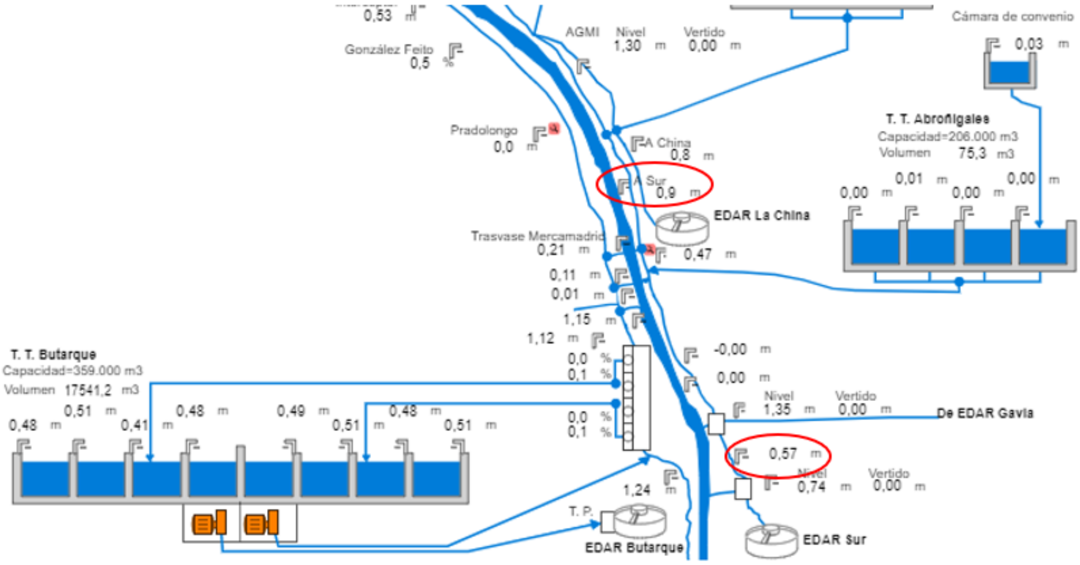

Figure 29.- Water level sensors located within the study area

2.3.5 Sensors in Butarque tank diversion

As stated above, the function of Butarque tank is to release the amount of discharge in a controlled way so that the capacity of Butarque WWTP is not exceeded. The right margin interceptor ends at the Butarque WWTP, so if water coming from this element exceeds the capacity that the tank and the WWTP can handle, the excess is sent through 2 pipes which cross the Manzanares river to the left margin interceptor. If the capacity of this structure is also surpassed, a weir enables to divert flow to the Manzanares river. The following figure corresponds to Canal de Isabel II SCADA system and represents the sensors and devices under control in this diversion.

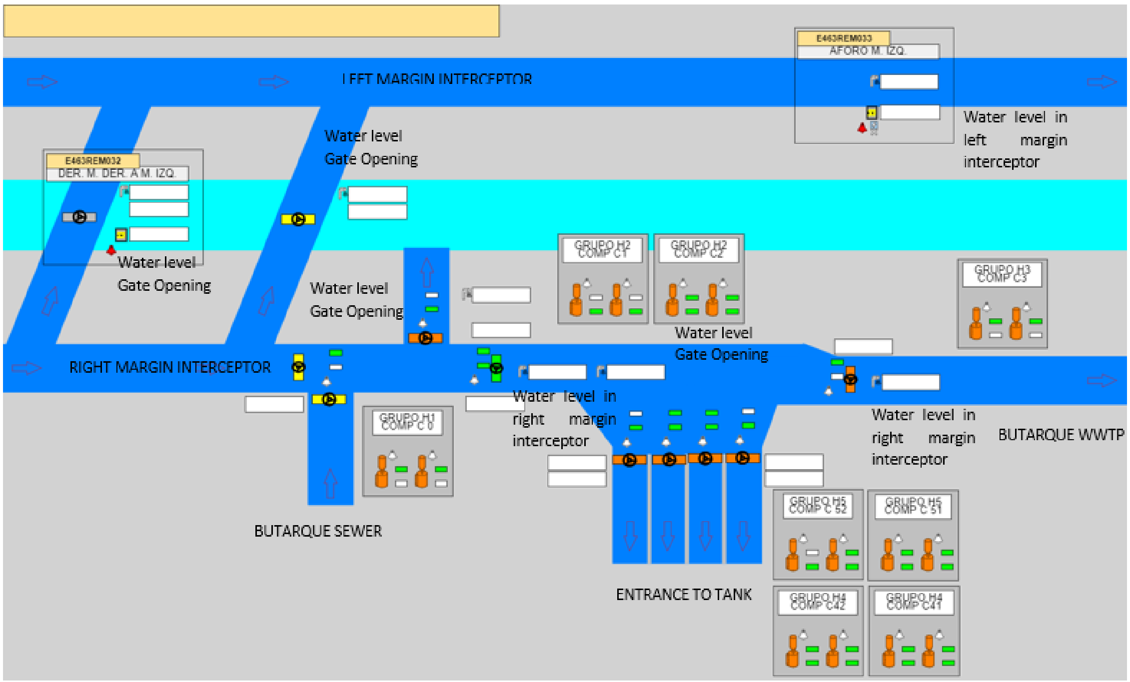

Figure 30.- Connections between left and right bank interceptors and diversion to Butarque tank

Information related to flows and discharges can be indirectly obtained by means of the weir gates opening and water level measurement. The dynamics of the tank can be derived from the level sensors located inside, which allow to estimate the flow of filling and emptying (by pumping) towards the WWTP.

2.3.6 Sensors in Butarque II tributary sewer

Butarque II tributary sewer ends in a water distribution chamber. At this point there is a weir which allows the outflow to the river if water level reaches a certain level. In dry weather conditions, all flow enters the WWTP. During wet periods, by opening an existing gate, water can be diverted from this point to the Butarque tank, filling compartments I-4 and I-3. When the tank´s capacity is full, the gate closes and the excess of water is directly sent to the river.

By means of a water level sensor located in the weir leading to the river, the CSO flow evacuated may be estimated. The other existing sensor corresponds to the water level of the distribution chamber. The flow diverted to the tank may be indirectly estimated from the evolution of the water level as the compartments are filled.

The following figure corresponds to a schematic view of the existing diversion at the end of Butarque II tributary sewer, together with the signal sensors received in the SCADA:

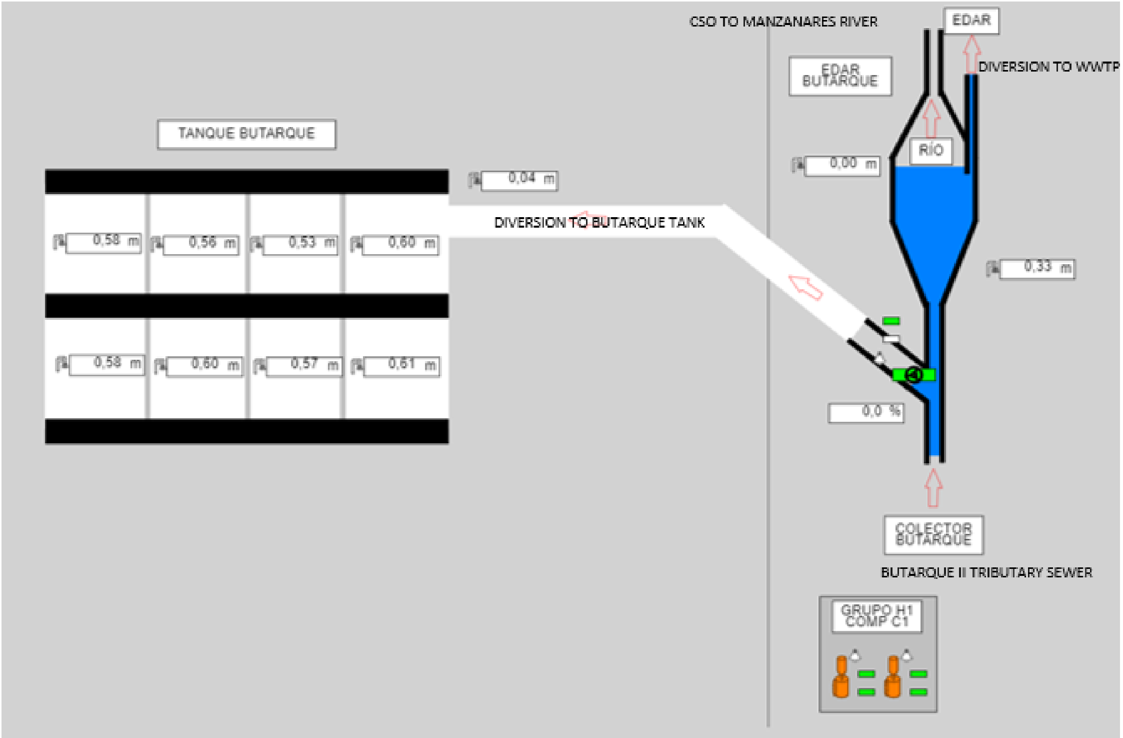

Figure 31.- Diversion point at the end of Butarque II tributary sewer

2.3.7 Sensors in Butarque tank

Butarque tank is divided in two identical modules which can be independently operated, as they have separate entrances. Each module is subdivided into 4 enclosures by means of spillway separation walls. The following figure schematically outlines this description:

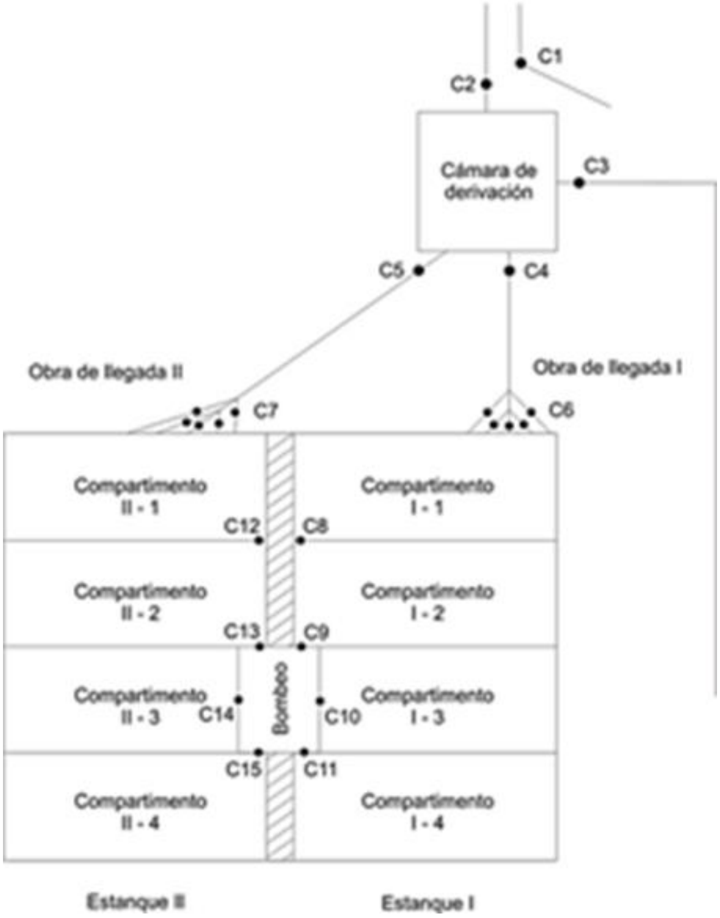

Figure 32.- Schematic view of Butarque tank partioning

The inlet configurations for each module are very similar. Flow is diverted into 5 channels and each of them has its own gates (see figure below). Sensor monitoring at this point consists of water level elevation, in order to estimate the inflow, and gate opening.

Figure 33.- Sensor monitoring of the intakes to Butarque tank

However, a more precise estimation of the inflows and discharges in the tank can be obtained from the monitoring of the evolution of the water level inside the tank. There is instrumentation implemented in order to control the water level of each enclosure and, derived from them, the filling and emptying flows, based on the geometry of each of the enclosures. The following figure represents the existing monitoring.

Apart from the water level, there is also information about the flow evacuated by the pumping system, both the ouflows sent to the WWTP and to the right margin interceptor

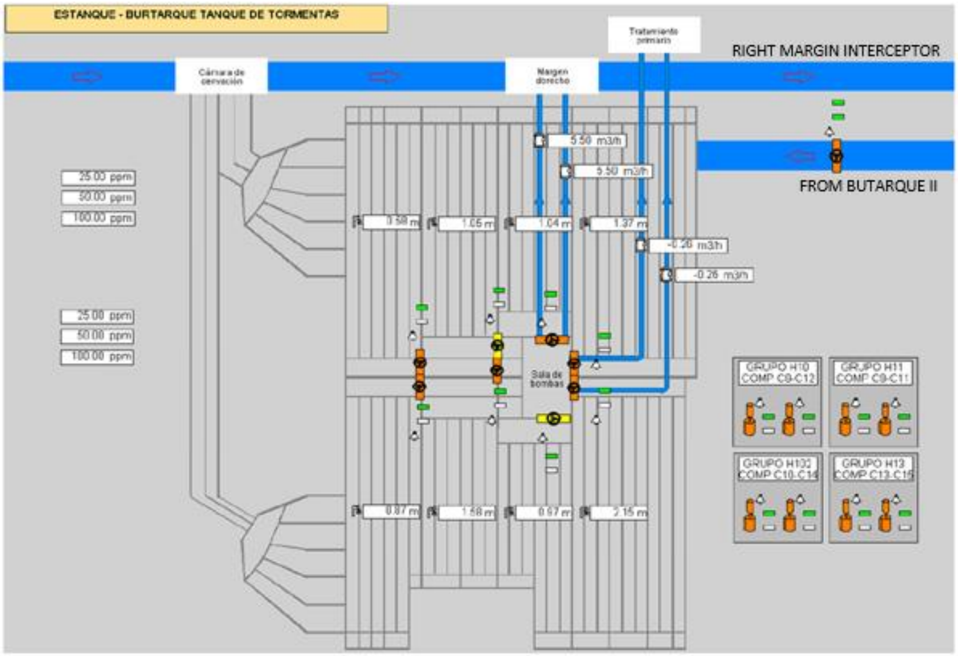

Figure 34.- Sensor monitoring in the tank´s compartments and pumping station

The separation walls between these compartments have a height which may vary between 7.20 m and 7.30 m high. The capacity of the sub-tanks, up to the discharge threshold to the neighbouring compartment and up to their ultimate capacity, is indicated in the following table:

Table 1.- Butarque tank compartment capacity

Compartment code	Compartment capacity (m3)	
	Up to the discharge threshold	**Full capacity**
I-1 / I-2	**30.000**	**41.000**
I-1 / I-2	**30.000**	**41.000**
I-1 / I-2	**28.000**	**39.000**
I- / I-2	**60.000**	**82.000**

2.3.8 Sensors and data existing in Butarque WWTP

It is of great interest for this project to be able to monitor all outlflows derived from Butarque WWTP. At the time being, the following discharge weirs are monitored by means of level sensors:

- Point A: weir for discharge of raw water flow
- Point B: weir for discharge of water after grit removal in the “new” pretreatment.

- Point C: weir for discharge of raw water coming from Butarque II tributary sewer
- Point D: weir for discharge after the “old” primary treatment and prior to the biological treatment
- Point E: Discharge point of treated water to the river

It is to be highlighted that there are two gauge stations within the WWTP, (points F and G, shaded in yellow). Point F corresponds to a Parshall flume located after the old primary pretratment and point G corresponds to an electromagnetic flow meter located after the biological treatment. As these measurements are much more precise than those which can be obtained from the estimation of flow from weir D, the difference between flow in G and flow in F is considered to be a more accurate estimation of discharges in D. The only inconvenience is that sensor G is not incorporated to the global SCADA system of Canal, and can only be monitored by the local WWTP SCADA.

Figure 35.- Plan view of Butarque WWTP with reference to the existing gauges and weirs

Lastly, considering quality parameters, a turbidimeter sensor is located at the discharge point of treated water in Butarque.

2.3.9 Sensors in Abroñigales tank and left margin interceptor

The operation of Abroñigales tank is described in chapter 2.1.5. The Abroñigal tributary sewer which collects the tank inflows ends in a diversion chamber from where flow can be by-passed to the left margin interceptor or, if the flow exceeds the by-pass capacity, it can be sent to the tank through a channel with lateral spillways. The discharge is carried out laterally to the first enclosure of the tank. When water level in this compartment reaches a certain level, the spillway walls able the possibility of filling the enclosure located next. The end of the inflow channel is blocked by gates which, if opened, generate a discharge into the Manzanares River. This operation is not usual, being more frequent the diversion to the left margin interceptor when the tank is close to its full capacity. The following figure represents a schematic plan view of the tank connections within the left margin interceptor, in which the existing sensors related to water level monitoring are represented. All these signals are controlled in the SCADA system.

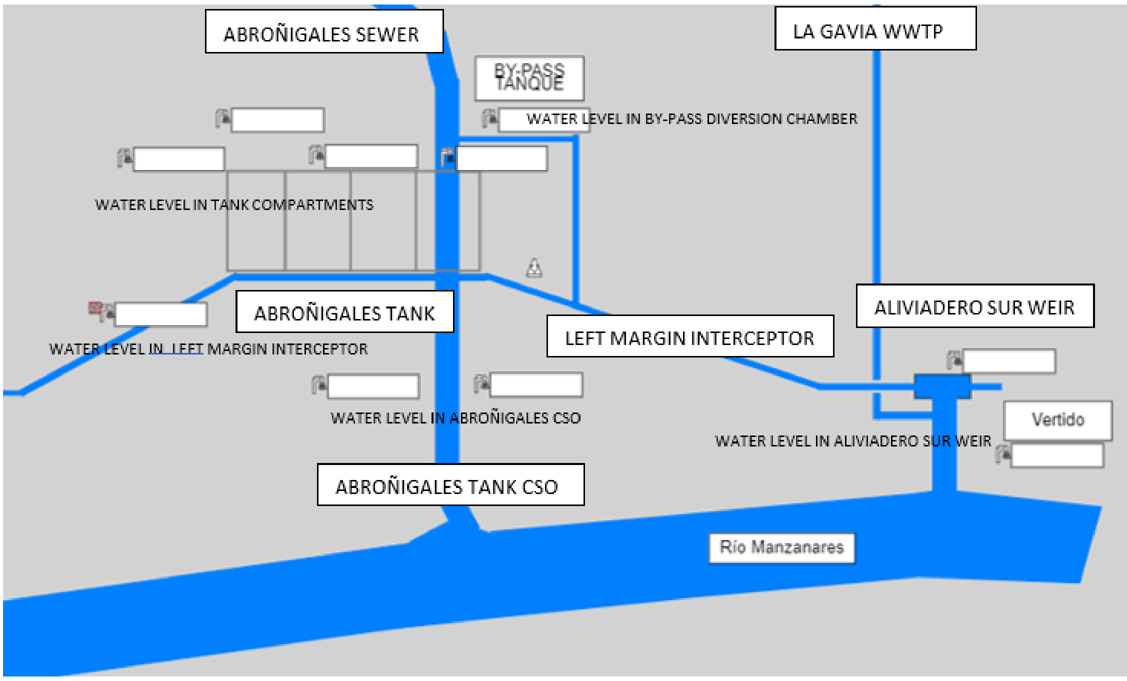

Figure 36.-Schematic view of the Abroñigales system with reference to the existing sensors in gauges and weirs

Regarding the tank operation, it is controlled by means of different sensors monitored at Canal de Isabel II SCADA system. The following figures represent the existing monitoring signals inside the tank:

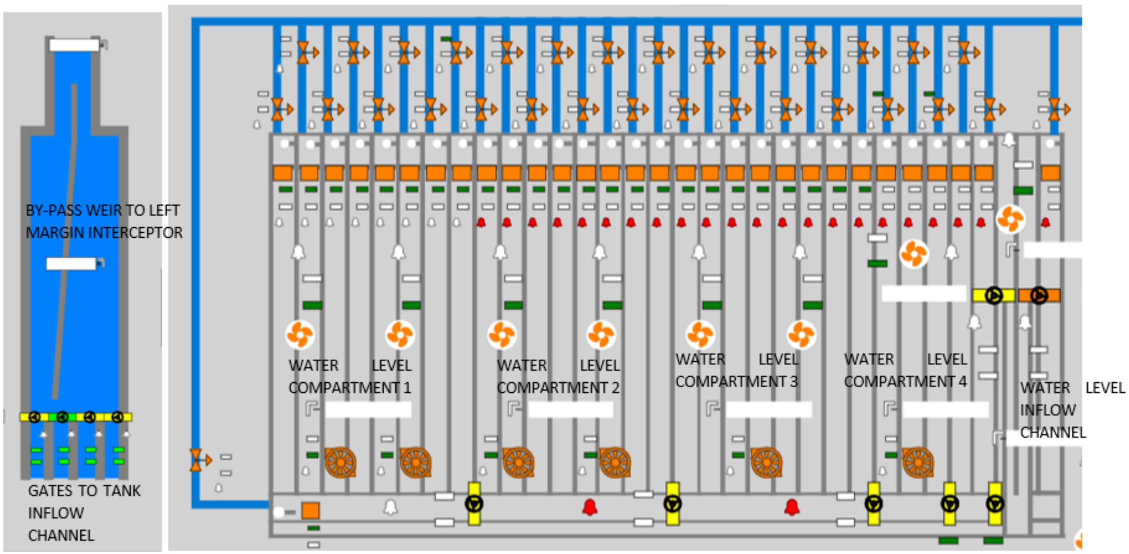

Figure 37.- Existing monitoring signals inside Abroñigales tank

The filling and emptying of the tank can be estimated from the evolution of the water level in each compartment, as the surface of each compartment is known:

- Surface Compartment nº1: 4513.5 m2

- Surface Compartment nº1: 5729 m2
- Surface Compartment nº1: 5729 m2
- Surface Compartment nº1: 5729 m2

The average height of the separation walls between compartments is 6.42 m. Above this height, water is diverted to the following compartment. The full filling height of the tank is 9.8 m (walkway height); when the level inside the tank reaches that height, the wagon gates in the inlet chamber are forced to open to force the bypass towards the left margin interceptor.

2.3.10Sensors and data existing in La Gavia WWTP

The figure below corresponds to a plan view of La Gavia WWTP in which the existing gauging points are highlighted:

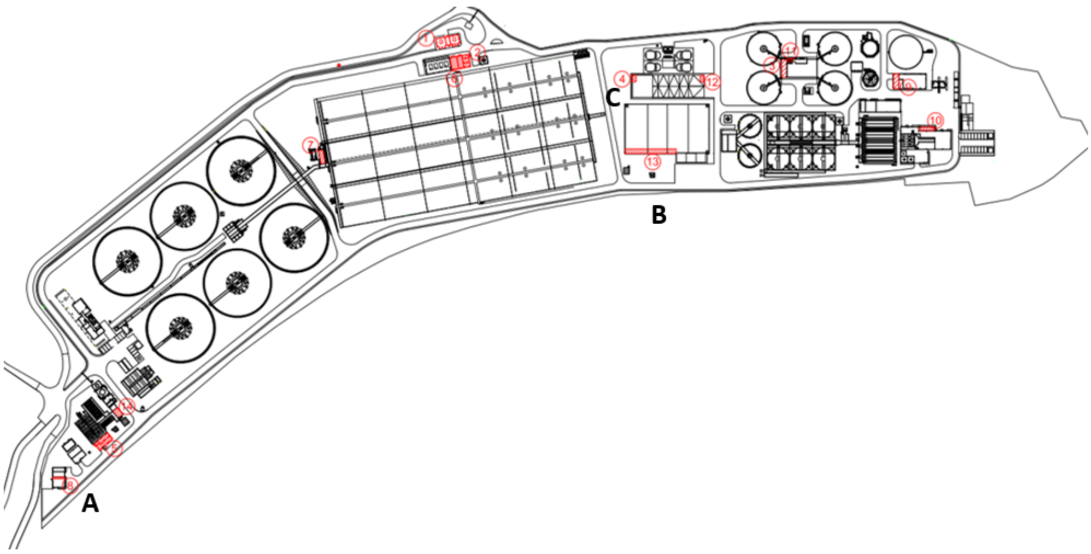

Figure 38.- Plan view of La Gavia WWTP with reference to the existing gauges and weirs

The referred control points are the following:

- Point A: gauging station for the control of flow pumped to the WWTP from the wet well located at the left margin interceptor.
- Point B: flow is measured in a weir is located at this point, after the lamellar clarifier and prior to the biological treatment. If the capacity of the secondary treatment is close to be surpassed, the excess of flow coming from the primary treatment can be by-passed. This outflow connects with the WWTP treated water outlet, from where the combination of both discharges is sent to the river.
- Point C: electromagnetic flow meter located at the entrance of the biological treatment.

Therefore, total inflow in La Gavia WWTP corresponds to the aggregation of flow measured at point C plus flow measured at point B.

With regards to the quality parameters, at the outlet of the WWTP, there is a turbidimeter sensor which controls the effluent.

2.3.11 Sensors in aliviadero Sur

The left margin interceptor connects at this point with the discharges coming from La Gavia WWTP (both treated flow coming from the WWTP effluent, and non treated flow which is diverted at the WWTP weir). Discharge from the left margin interceptor to the flow coming from La Gavia is done through a broad crested weir which separates both collectors, as they run side by side along 21 m. The height of this separation wall is 2,47 m. When flow in the left margin interceptor reaches that height, it overflows the relief wall and this spillover reaches, together with the La Gavia discharge, to the Manzanares River.

Monitoring at this point is made by means of a level sensor, which controls the height of water surface above the crest of the weir.

2.4 Existing model

Between 2016 and 2020 a model of the main sewers of the Manzanares drainage system was developed to evaluate the current operation management of the system and assess potential operation improvements to take advantage of the great storage and management capacity of the system tanks to reduce CSO discharges to the Manzanares river.

This model was created in Infoworks ICM software, which allows modelling:

- Hydrology. Both in 1D and 2D
- River hydraulics in 1D or 2D
- Sewer systems
- Water Quality
- Real Time Control of Structures

The model included the left and right margin interceptors and the main tributary sewers, as well as all the system detention tanks and actuators. The secondary sewers far away of these main ones were simplified and modelled as big catchments as seen in Figure 39.

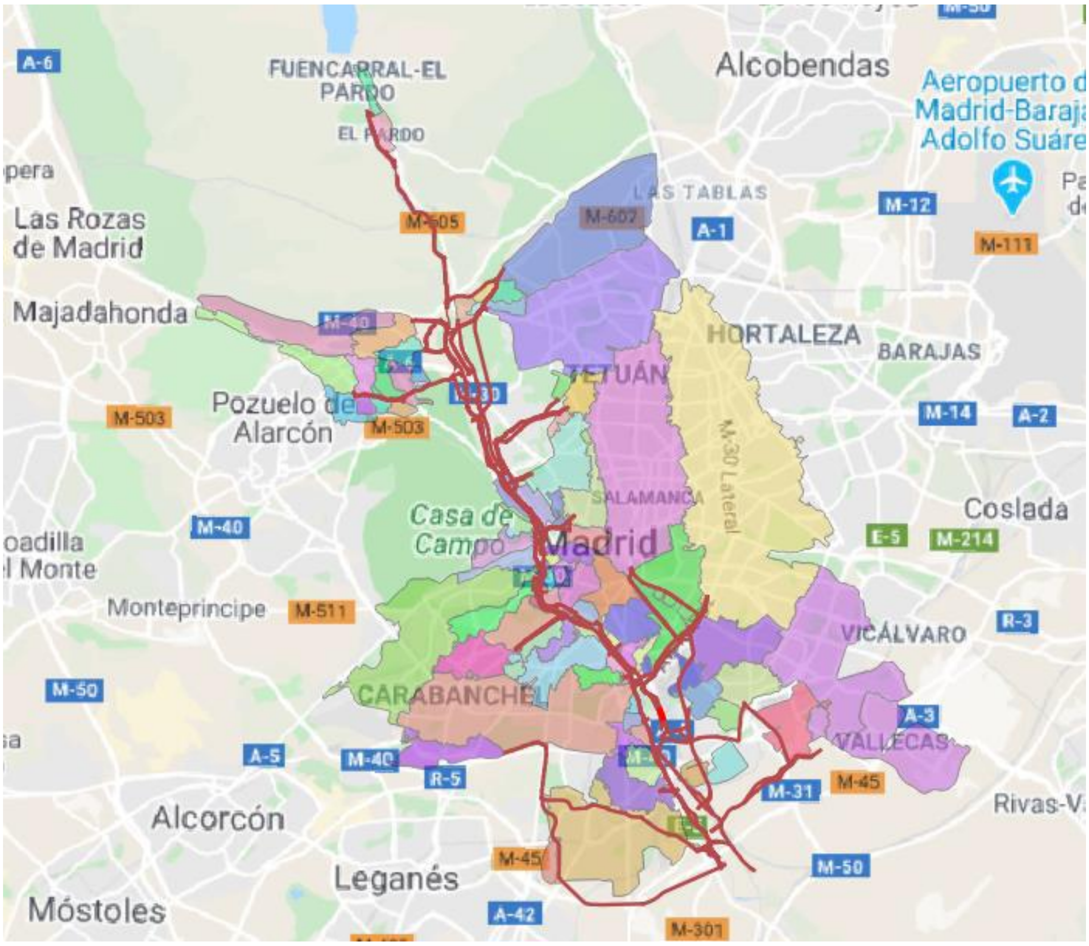

Figure 39.- General view of the model with good detail around the river interceptors while the secondary network far away of these interceptors was simplified and modelled as catchments.

In some cases, this model required important assumptions because of the lack of data at that moment. The most important assumptions of this model were:

- Several manholes and sewers had no information about their floor level (for manholes) or upstream and downstream levels (for sewers) and in those cases these levels were obtained from interpolation of nearest manholes or assuming constant slope from other connected sewers.
- Also, some sewers had no information about its cross section, so it was assumed that the section was the same as the one of the closest upstream or downstream sewer.
- All the tanks had information about their volume and their dimensions in plant (width and length), but some of them had no information about its height or floor levels, so this was computed according to levels of the connecting sewers, so that the tank volume was consistent with the reported volumes of the tanks.
- Gates dimensions. Similarly, for some gates we had no information about their dimensions, in this case they were assumed to be the same as the dimensions of the sewer where it was located.

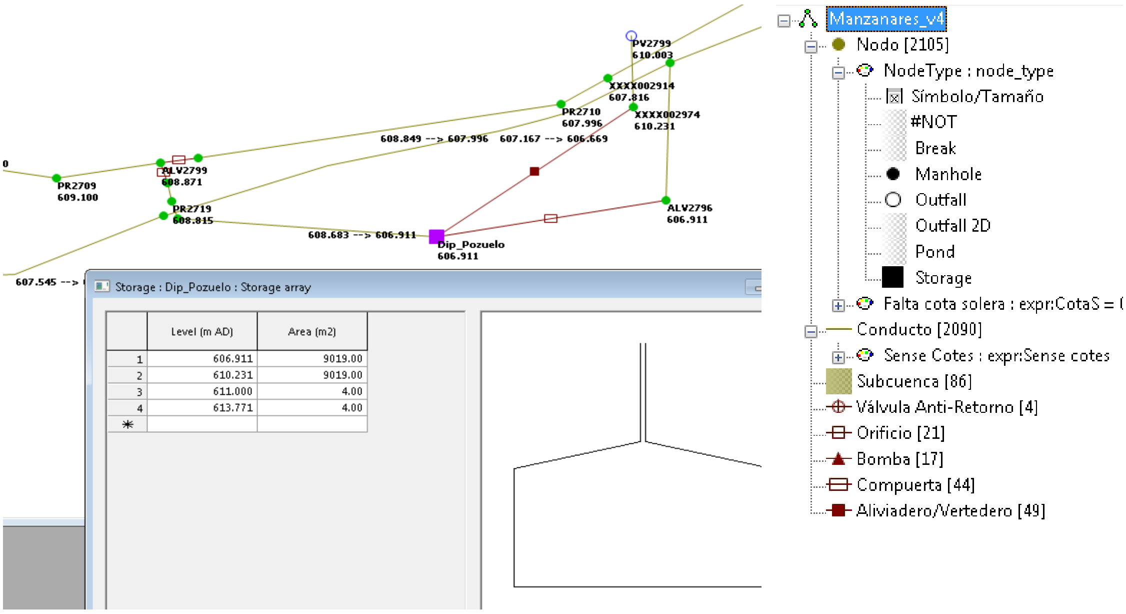

Figure 40.- Example of detention tank model configuration

This is the model that will be used as a starting point for the Rubies project and which will be updated with the most recent and updated information Canal Isabel II has, specially concerning the case study area.

2.5 Current IT Architecture

Canal de Isabel II supervises and controls its infrastructures by means of a remote control system based on a set of strategically located sensors which measure and control the most significant variables and which, through various networks, collect the data in a central system, providing high added value to the management, supervision and control of the infrastructure processes operated.

Remote control and monitoring at Canal de Isabel II is carried out by inserting different concentrator PLC located in its facilities. These elements act as a signal hub and are responsible for collecting all the variables monitored and sending this information to the front-ends of the Control Center. There is, at least, one PLC for each facility. In case there are several PLC in a same location, one acts as the principal and the rest of them are considered as peripherals, thus sending their measurements to the principal PLC. The remote control system database reads the data from the front end in service via OPC server, which in turn feeds the remote control system SCADA. All the measurements are integrated to SCADA through OPC Server. The measurements are refreshed approximately every minute.

Canal de isabel II has mostly PLC automation equipment installed from two different technologies, Siemens and Rockwell, with specific front-end characteristics for each type, under industrial design standards and Canal de Isabel II programming criteria.

For those locations which are isolated and therefore lack from electric supply and/or optical fiber for data transmission, Canal has developed its own technology, called TESEO. which records measurements every 15 minutes and sends them to TESEO Server. TESEO Server gives the measurements to SCADA through another OPC Server every 15 minutes.

Real time data received by the SCADA system is processed and stored in Oracle Database for time series analysis of the historic records. The highest frequency of the stored data is 2 minutes.

Canal´s SCADA is located on the IT network. It is possible to exchange and share data. It is foreseen that AQDV solution will in first instance communicate with Canal de Isabel II server by means of FTP.

2.6 Control perimeter (What actuators will be controlled)

In the pilot site there are a total of 18 actuators (16 gates and 2 pumping stations) which can be seen in Figure 41 classified in monitored (green triangles or diamonds) meaning that within RUBIES project, AQUDV will only monitor its position to take into account its impact on the drainage system but these will not be controlled by the RUBIES algorithms (they will be managed according to their local current operational rules), and fully controlled (red triangles or diamonds) which will be the actuators that will be fully controlled by Rubies project.

Figure 41.- General view of the actuators in the pilot site. Triangles are the pumps while diamonds are the gates. Also green ones are the ones that wil be monitored in the project, while the red ones are the ones that will be fully controlled by Rubies algorithms

These actuators are mainly linked to the main infrastructures of the pilot site:

- Oliva Tank: This secondary tank has one gate that controls the way it gets filled and emptied and this one will be monitored only.
- Butarque tank: The by-pass (1 gate) and entrance gates (5 gates) will be fully controlled by Rubies algorithms to fill the tank in rain events while it avoids the WWTP capacity is exceeded so no CSO is being discharged upstream the WWTP without the tank being full. Also the tank pumps (2 pumping stations) will be controlled to empty the tank as soon as the WWTP has capacity to treat this water (see Figure 42).

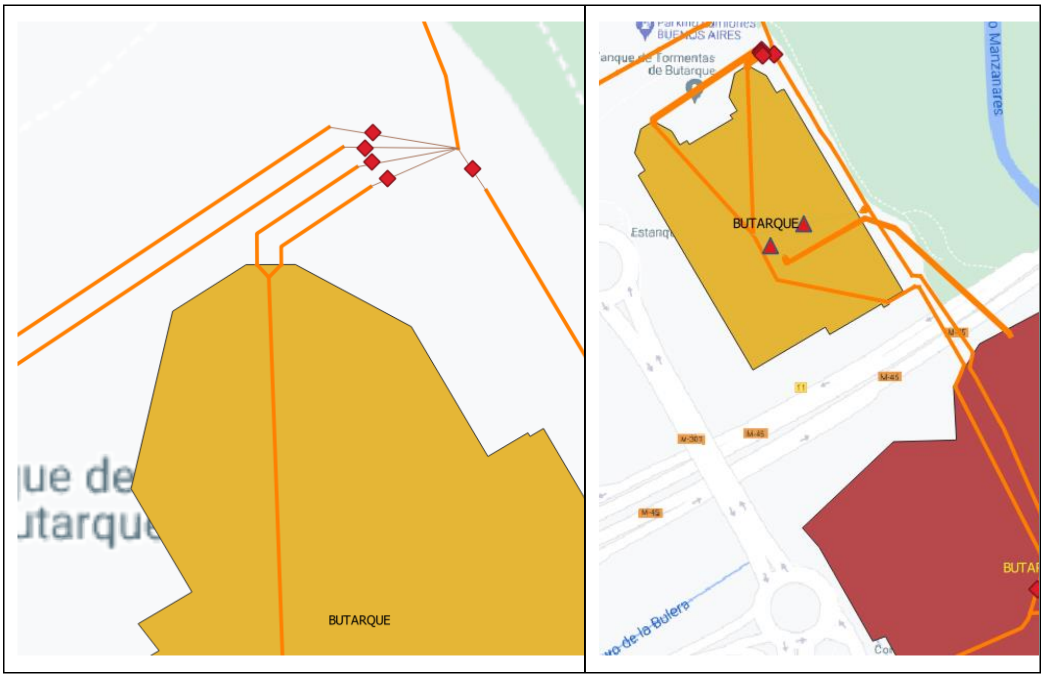

Figure 42.- Actuators controlled in Butarque tank (left zoom to the entrance and by pass gates from the right margin interceptor)

- Abroñigales tank: The by-pass gate and outlet gate will be fully controlled by RUBIES algorithms to avoid having CSO in the downstream Aliviadero Sur while flow is by-passing the tank or the tank is being emptied. The entrance gates (3 gates) and CSO gates (2 gates) will only be monitored and thus controlled by the current operational strategy (see Figure 43)

Figure 43.- Gates controlled (red) and monitored (green) in Abroñigales tank.

Finally all other actuators in the pilot site as well as Butarque and La Gavia WWTPs will be monitored.

3 Monitoring strategy

3.1 Sensor installation

The new sensors required to correctly implement AQDV UD in the pilot case must complement the already available sensors existing in the pilot area which are described in chapter 2.3.

In this chapter the type, location and purpose of the potential new sensors is described. The section is divided in 3 parts depending of the sensors types:

- Rain gauges
- Water level / Flow sensors
- Turbidimeters

3.1.1 Rain Gauges

Rain data is the main input on the system and it will be important to have good and reliable rain measures in the pilot site to correctly understand other sensor data (water levels, flows or water quality parameters), modelling results and also, as input for the online operation of AQUDV.

In this sense, the project will also use radar rain data and radar rain predictions (see chapter 4.3), but rain gauge information will be used to compare and calibrate radar measurements and as a secondary rain input to AQUD in case radar data is not received correctly.

Two rain gauges will be installed in the scope of the project inside the pilot area (see Figure 44):

- RG1: Rain gauge installed inside the installation of the WWTP of Butarque.
- RG2: Rain gauge installed inside the installation of the WWTP of La Gavia.

Figure 44.- Rain gauges locations to be installed.

3.1.2 Water level or flow sensors

Water level or flow sensors are important to correctly estimate water balances in the pilot area, so they will be important to identify how much water gets into the pilot area and where this water gets in, and how much water gets out of the pilot area and at which points.

Ideally all the input and output points of the pilot area should be monitored by flowmeters, but this would require an important budget and also an important result of the pilot case and of this project in general, should be that these type of real time solutions can be implemented obtaining good results with limited number of sensors. In this sense, the new sensors to be installed will be kept to a minimum number applying these principles:

- Already existing sensors in the pilot area, installed and maintained by Canal Isabel II will be used as much as possible avoiding sensor redundancy. Only when a historic review of the measurements data of these sensors show that they are not valid for the project purpose (the main reasons for that could be bad measurements quality and not availability of the measurements in real time or an important delay in receiving the data). This historic data review will be done in a future task, so in this chapter these existing sensors will be identified and listed as possible new sensors to be installed if necessary.

- The required measure for the project is flow, but flow sensors are much expensive to buy, install and maintain, so the sensors to install will be water level sensors and later on flows will be correlated with the water level measurements. This correlation is not perfect and even in some cases (where backwater effects happen often) it is impossible. In this case online model results can help to obtain the required flows. Also, in some very specific cases flow sensors installation might be considered.
- Linked with the previous point, in some locations, although a real sensor data would be advisable, these flows can be estimated thanks to the correlation with other measurements points or thanks to the online models. These points will also be listed here as possible future secondary locations to install water level sensors.
- Finally, according to the information collected, inflow and outflow flows and quality is monitored at both WWTP (Butarque, and La Gavia), so no new sensors are considered for these points. Again in a future task historic data will be reviewed to confirm the available data sensor is valid for the project requirements, and in case it is not some more sensors might be necessary in these points.

In the following general figure the water level sensors have been classified in:

- Water level sensor – basic: These are the ones that have been identified as important and necessary for the project implementation. Six sensors have been identified here
- Water level sensors – existing: These are the sensors already existing and installed by Canal Isabel II that are also basic for the project implementation. As mentioned, in a future task, the historic sensor data available will be analysed to confirm they work properly and that they can be used according to the project requirements. Depending on the result of this analysis, it might be necessary to install new sensors at these points if some of them don’t meet the project requirements. 12 existing water level sensors have been identified here, in future tasks when analysing more deeply the available data, some more sensor could be included here, but at least these ones will be important.
- Water level sensor – secondary: Finally these points could be interesting for a future installation of a water level sensor, but they are not basic for the current project implementation since these flows can be obtained from online modelling. 3 sensors are identified here.

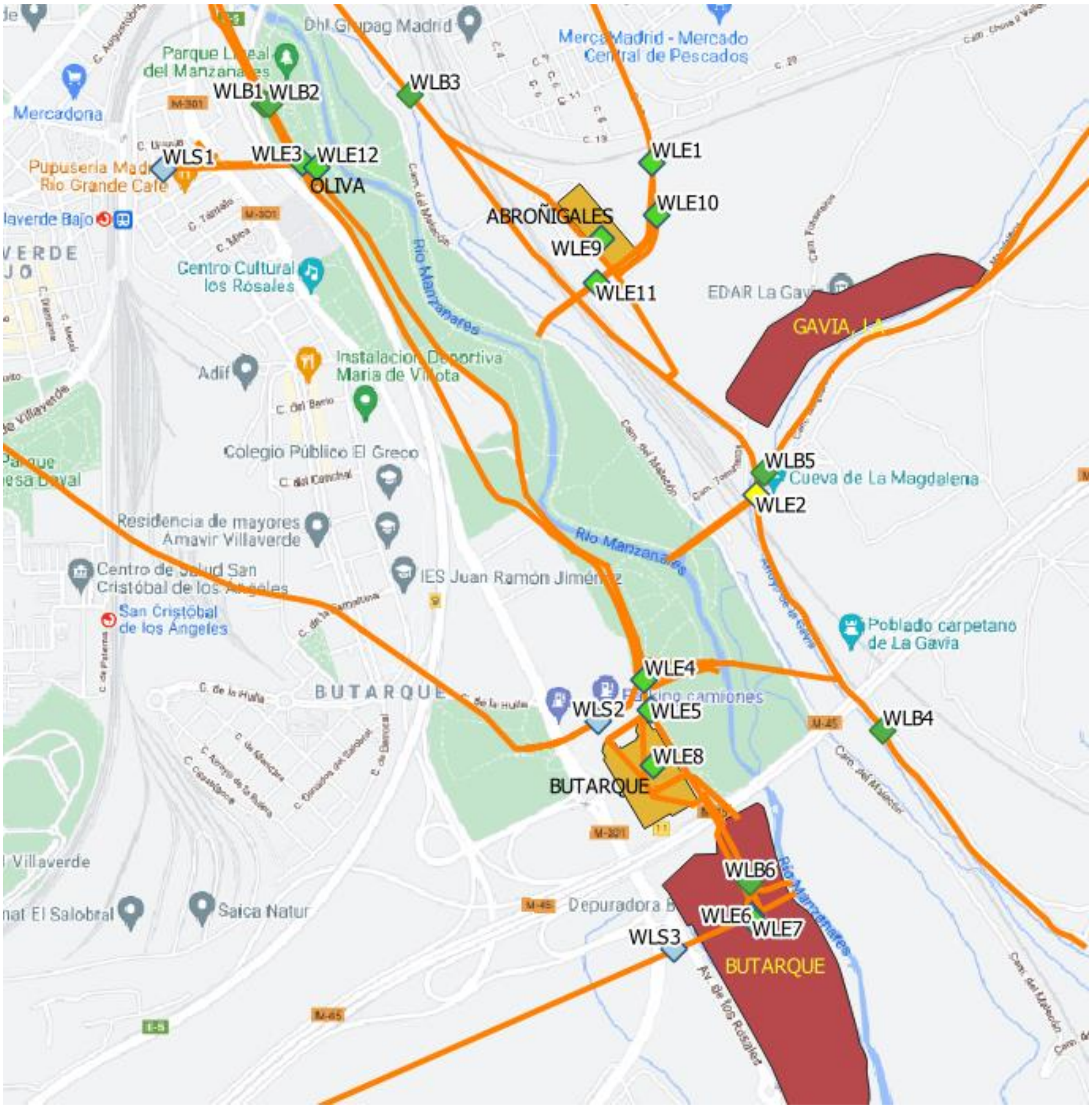

Figure 45.- Water level sensor localtions

The detailed sensor location and goal is explained here for the identified basic sensors:

- WLB1 and WLB2: They are necessary to measure flow getting into the pilot area coming from the right margin interceptors upstream. These flows cannot be correctly estimated by online modelling because they are highly dependent of the upstream tanks operation.
- WLB3: This sensor goal is similar to the ones WLB1 and WLB2 but for the left margin interceptor. Again these flows cannot be estimated by models because they are highly dependent on the China tank and China WWTP operation and by pass actions they do.

Figure 46.- Location of WLB1, 2 and 3

- WLB4: This sensor is required to measure how much water gets out of the pilot area by the left margin interceptor and is driven to the Sur WWTP located downstream.
- WLB5: This sensor goal is to measure the flow coming from La Gavia catchment and discharged to the river. In dry weather period the measured flow will be consistent with the measured WWTP treated flow, but in wet weather the measured flow will be a mixture of treated flow and non-treated flow (flow that by passes the WWTP when its capacity is surpassed). The part corresponding to non-treated one will be estimated by subtracting the measured flow here from the influent flow to the WWTP.
- WLB6: This is the last basic sensor identified. It is located at the by-pass weir before the entrance of the Butarque WWTP so whenever the right margin interceptor flows are higher than the WWTP maximum capacity the excedent flow is bypassed directly to the river by this point.

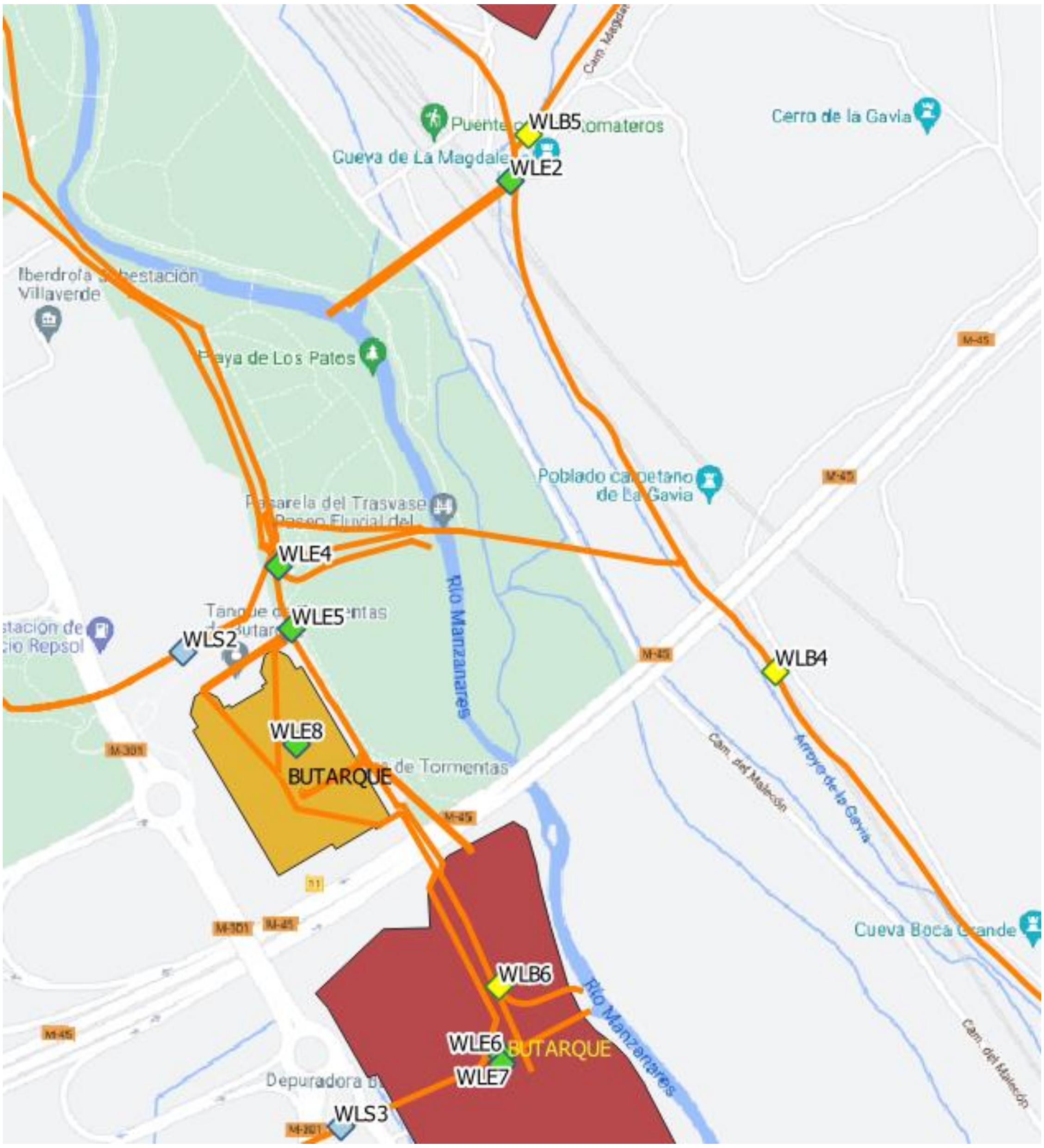

Figure 47.- WLB4, 5 and 6 location

- Abroñigales tank sensors: Around this tanks Canal has several sensors which will be very useful for the project. At least these ones have been identified:
  - WLE1: Measures water level at the collector bringing water at the entrance of the tank
  - WLE10: Measures water level at the collector by passing the tank.
  - WLE9: There exist several water level sensors measuring levels at the different tank compartments.
  - WLE11: Measures water level at the CSO discharge point to the river

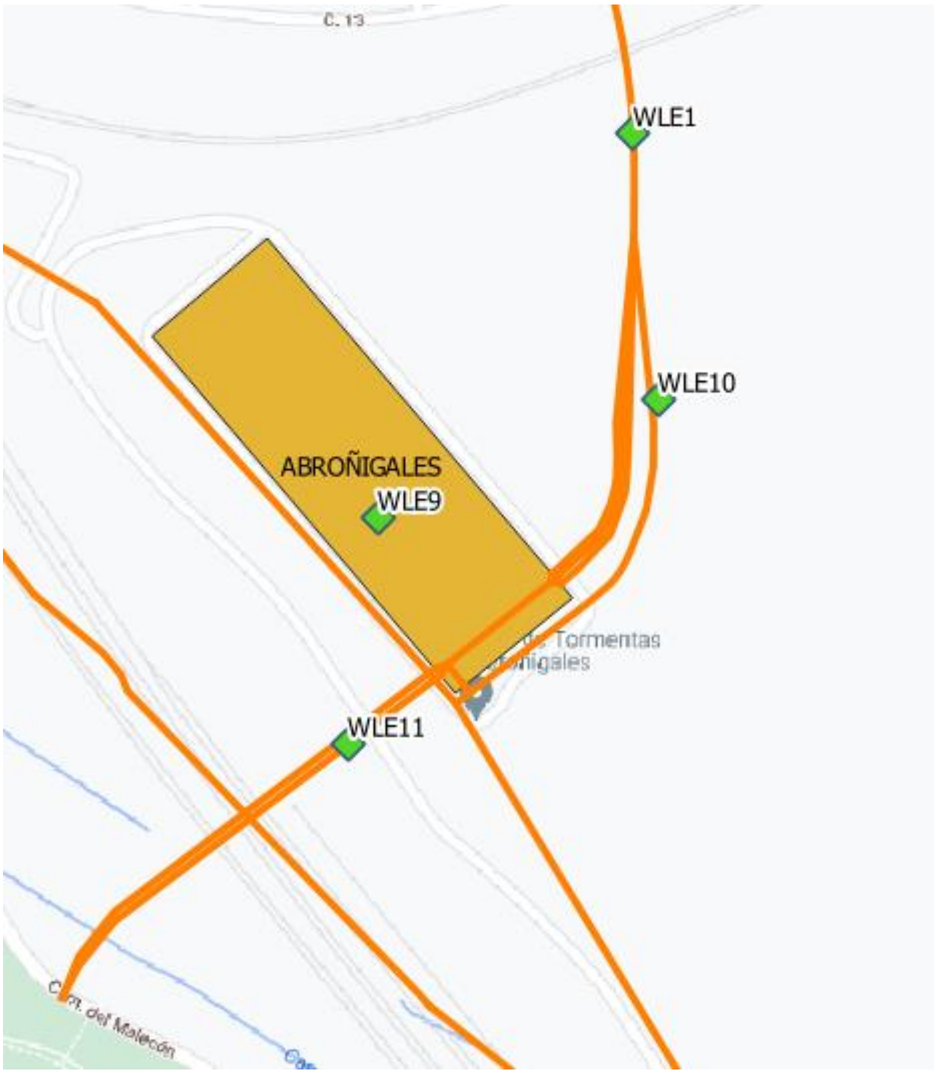

Figure 48.- Existing sensors around Abroñigales tank required for the project: WLE1, 9, 10 and 11.

- Sur CSO point: WLE2 measures water level from the left margin interceptor so when measures above the weir crest level it means CSOs are being discharged to the river through this point.

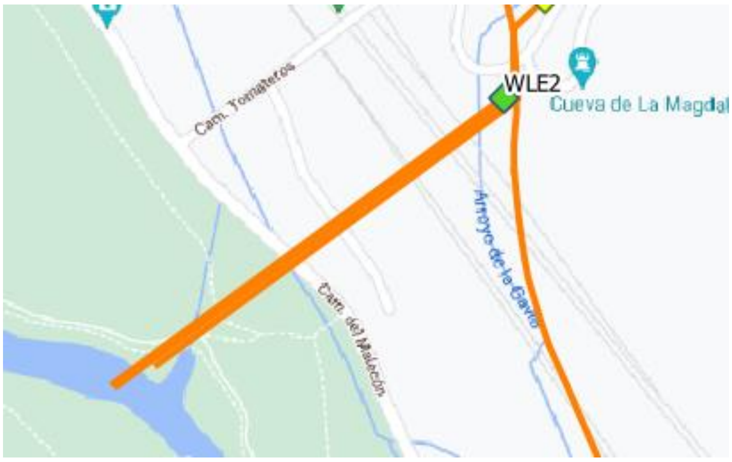

Figure 49.- Existing WLE2 sensor located at Sur CSO discharge point.

- Butarque tank sensors: Again several sensors already existing around this tank will be important for the project. The already identified ones are:
  - WLE4: It measures water level in the collector discharging to the river upstream from the Butarque tank.
  - WLE5: It measures water level in the right margin interceptor in the by-pass chamber of the tank.
  - WLE6: It measures the water level reaching the WWTP from the south tank entrance.
  - WLE7: It measures the water level being discharged directly to the river from the south tank entrance.
  - WLE8: Inside the tank there are several water level sensors measuring the water levels of the different tank compartments.

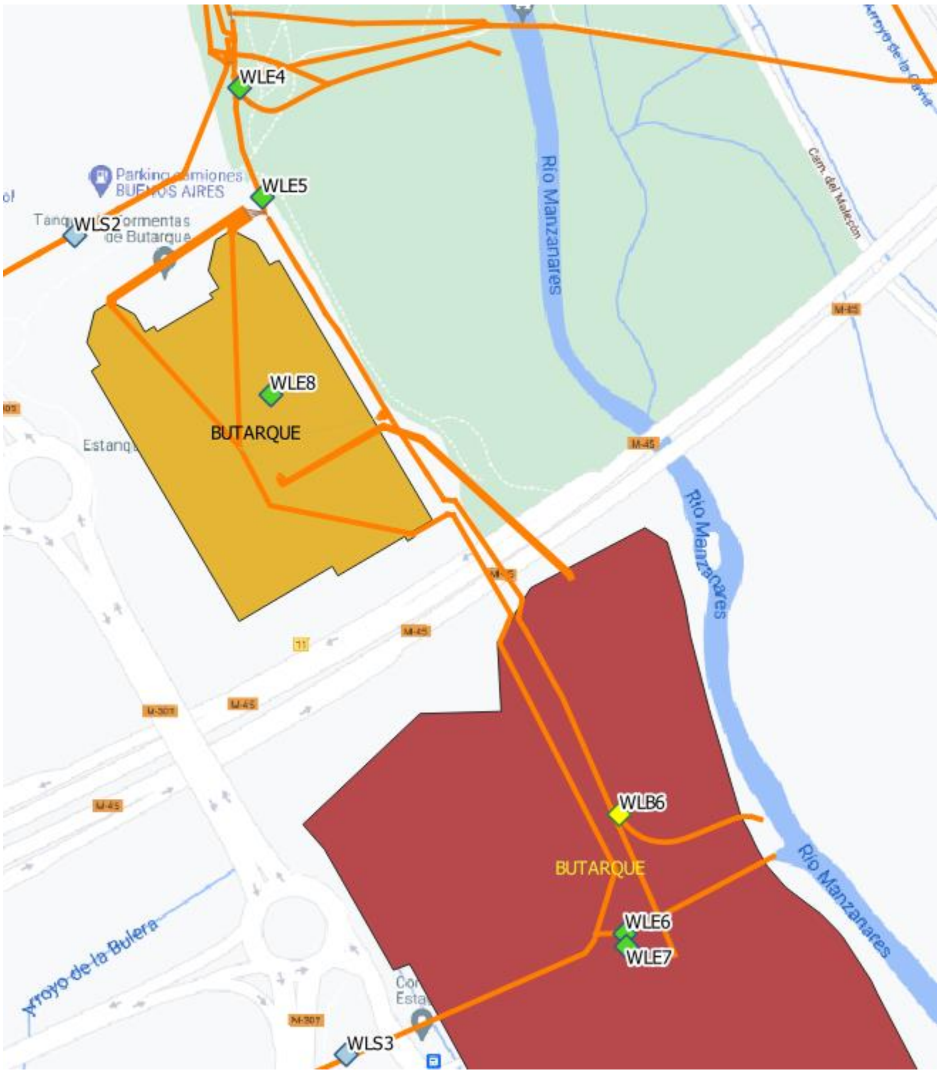

Figure 50.- Existing sensors around Butarque tank required for the project: WLE4, 5, 6, 7 and 8.

Finally, a list and location of the secondary water level sensors is provided. As mentioned previously, these points could be interesting for a future installation of a water level sensor, but they are not basic for the current project implementation since these flows can be obtained from online modelling. These are:

- WLS1: It will measure water from the main collector of the catchment upstream Oliva tank.

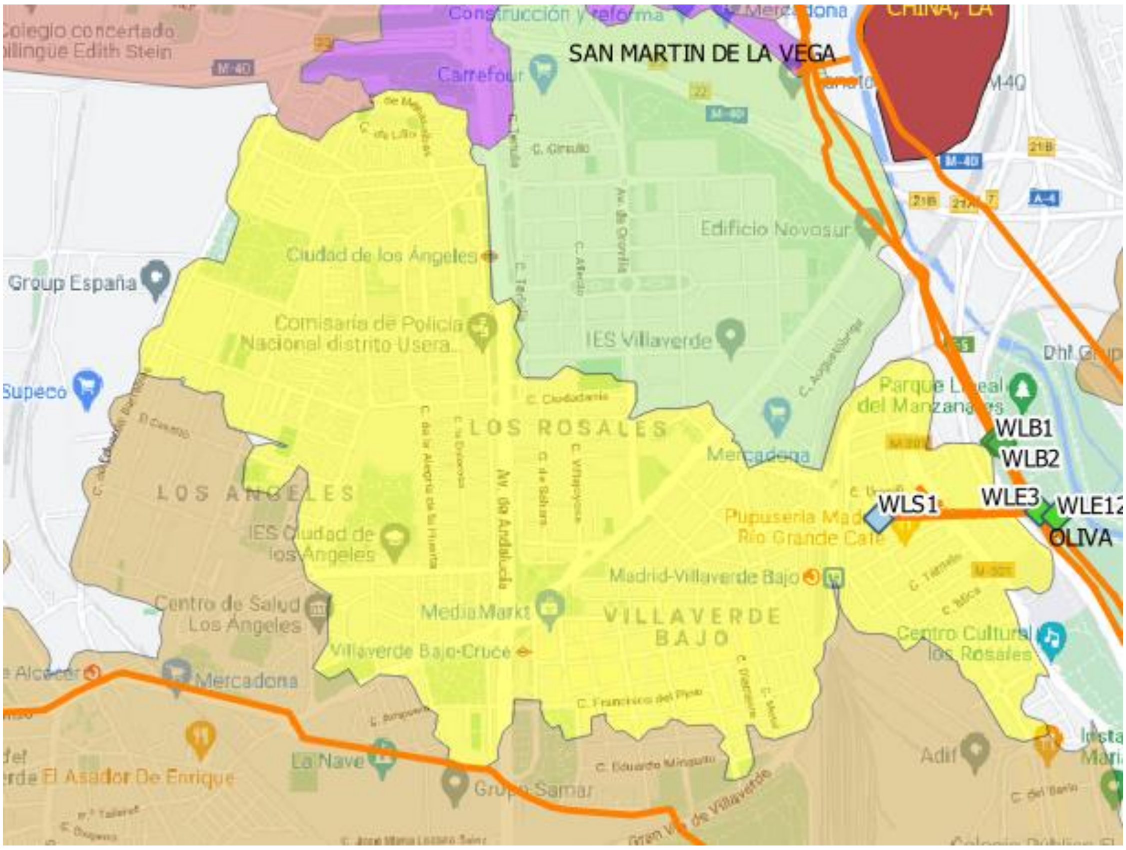

Figure 51.- Catchment (in yellow) and location of the sensor WLS1

- WLS2: It measures water from the main collector Butarque I
- WLS3: It measures water from the main collector Butarque II

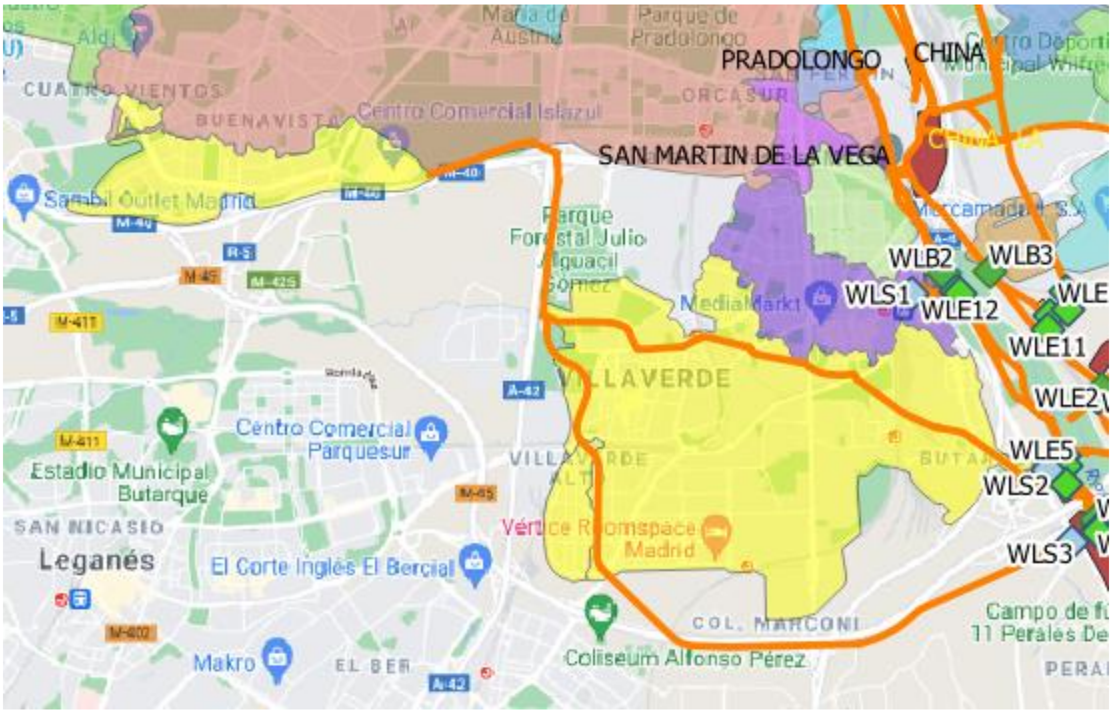

Figure 52.- Catchments being drained by collectors Butarque I and Butarque II measured by WLS2 and 3

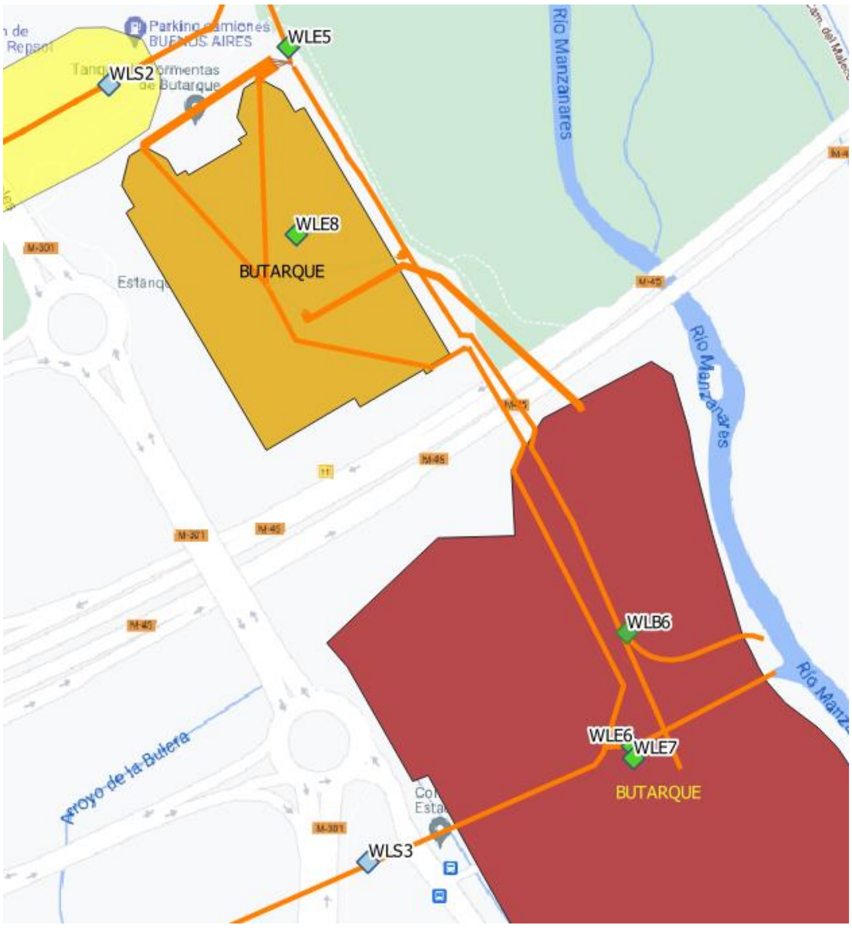

Figure 53.- Location of WLS2 and 3 located in the collectors Butarque I and Butarque II

3.1.3 Turbidity sensors

Turbidity measurements will be used to obtain correlation with other quality parameters that can not be measured in real time (TSS, COD and BOD, nutrients…).

5 turbidity sensors are planned to install in this project. These are:

- TS1: Turbidity sensor in the right margin interceptor before in the by-pass chamber upstream Butarque tank. It will measure the water quality of water flowing through this point which will be used to define also water quality of water entering Butarque tank, at the WWTP inlet, but also the one in the upstream Butarque tank CSO and WWTP upstream CSO point.
- TS2: Located in Abroñigales tank in the CSO channel will be used to define water quality getting into the tank, and also whenever a CSO is happening from the tank it will measure the quality of CSO.
- TS3: Located in the left margin interceptor it will measure quality of the water getting out of the pilot area towards SUR WWTP. Also whenever there is CSO from this collector in the Sur CSO discharge point this sensor will define the quality of the discharge.
- TS4: Located in La Gavia collector, in dry weather flow it will measure the quality of the effluent WWTP but also during rain events it will measure the quality of the mixture waters (effluent and by pass WWTP waters) discharging to the river from this point.
- TS5: It will measure WWTP primary treatment effluent discharge quality.

Figure 54.- Location of the turbidity sensors

3.2 Quality sensor calibration campaigns (mainly for quality sensors, if required)

Quality sensor campaigns will be necessary to correlate the turbidty real time measures provided by the sensors with other quality parameters at each point where these sensors are located.

These values will be used to calibrate the models but also as inputs for AQUD real time operation.

The parameters to be analyzed at each campaign are:

- TSS
- Turbidity

- Conductivity
- BOD5
- COD Total
- N-Total
- N-NH4+

Two types of quality campaigns are planned:

- Dry weather flow campaigns: In the locations where these campaigns are planned, 2 campaigns will be done one for weekday and another one for weekend taking and analyzing 6 samples per day (one sample for each 4 hours).
- Wet weather flow campaigns: In the locations where these campaigns are planned, 3 rain events campaigns will be done taking and analyzing an average of 6 samples per rain event with shorter sampling time at the starting of the event (15 minutes) and longer one at the end (30 minutes or even 1 hour)

According to the location of the turbidity sensors the following table summarizes the quality campaigns that are planned:

Table 2.- Quality campaigns planned

Location	Description	DWF	WWF
TS1	**Right margin interceptor**	**X**	**X**
TS2	**Abroñigales tank inlet and CSO**		**X**
TS3	**Left margin interceptor**	**X**	**X**
TS4	**La Gavia collector**	**X**	**X**
TS5	**WWTP primary treatment effluent**		**X**
Total		3	5

4 AQDV UD deployment requirements

4.1 LIFE RUBIES IT infrastructure

Following picture summarizes the AQDV UD solution and required general infrastructure.

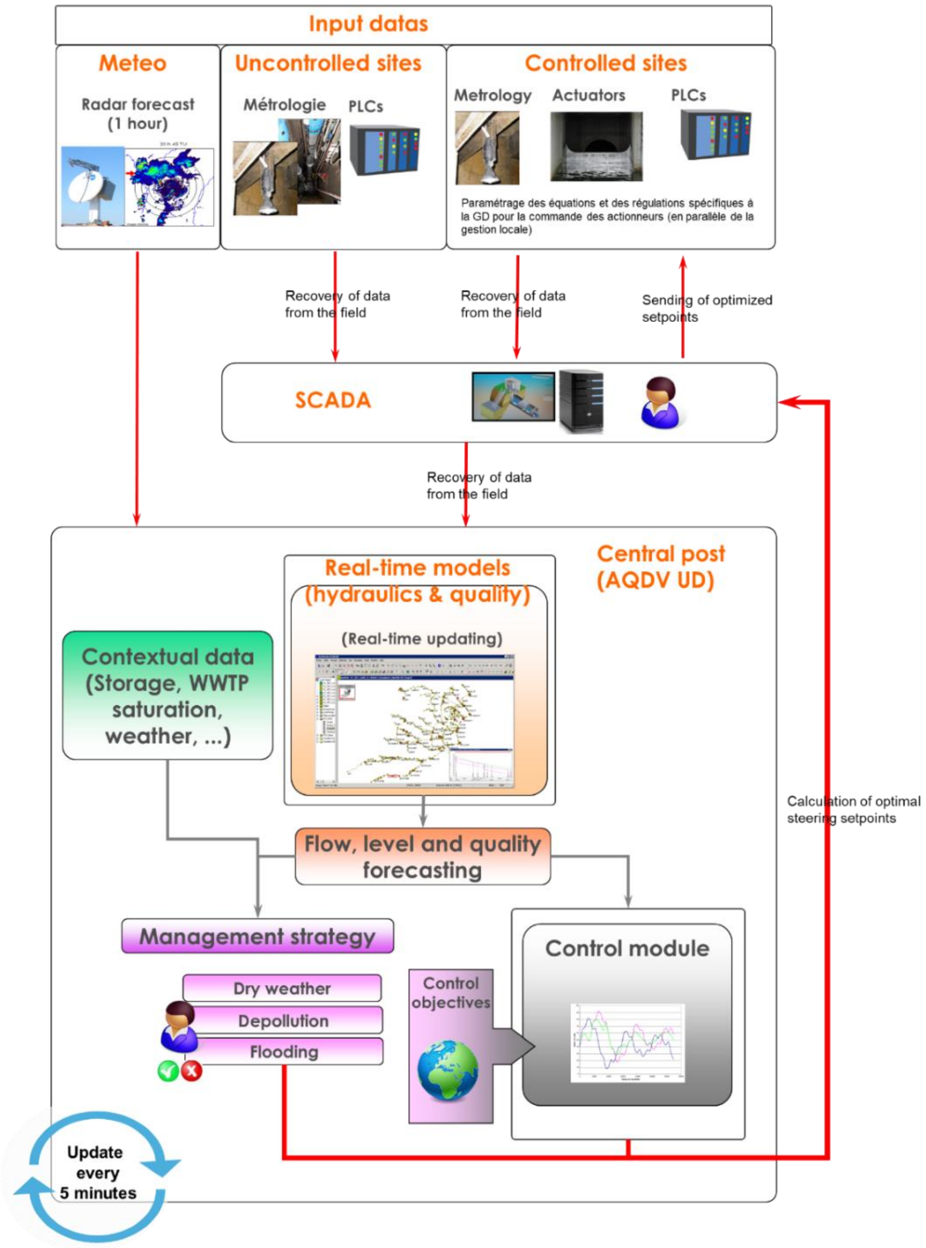

Figure 55.- AQDV UD connection with the Canal Isabel II IT system

Figure 55 shows the final configuration of AQDV UD with the SCADA system, which will be done via OPC connection to receive data from the field sensors and actuators positions, and also to provide the computed setpoints to the actuators.

But on a first stage, during the first phase of the implementation, there will not be setpoints to send back to the SCADA, so only one direction information will go from Canal IT system to AQDV UD, and this temporary connection is planned to be via FTP files.

4.2 AQDV UD configuration

Central platform of AQDV UD is built on 3 main components:

- 1 Database server to record all data and configuration
- 1 "Real-time application" server to run the app
- Different set of client application (HTML5) to configure the system and analyze all the data

The following table summarize the needed spec for these two servers. All specs still need to be approved in the incoming meeting:

Table 3.- Summary of the servers requirements

	Database server	Application server
CPU	**16 heart**	**16 heart**
RAM	**32 Gb**	**32 Go**
OS Hard-Drive	**150 Gb**	**150 Gb**
Data storage hard drive	**300 Gb**	**1 000 Gb**

In order to correctly transmit all the information from the sensors to AQDV UD, we must link each sensor and its data variable to an object in AQDV UD. To do so, an exchange tables system is used: next figure is an extract of one of these table is displayed.

Table 4.- Example of exchange tables to transmit and connect the required information from the sensors to AQDV UD

Variable	TYPE	Transmission	Variable ID	Units	Coments
Abroñigales tank WLE1	Level Sensor	SCADA	WLE1	cm	Measures water level at the collector bringing water at the entrance of the tank
Abroñigales tank WLE10	Level Sensor	SCADA	WLE10	cm	Measures water level at the collector by passing the tank.
Butarque RG1	Rain gauge	SCADA	RG1	mm	Rain gauge installed inside the installation of the WWTP of Butarque.
La Gavia RG2	Rain gauge	SCADA	RG1	mm	Rain gauge installed inside the installation of the WWTP of La Gavia.

4.3 Weather data acquisition

The active supervision module of AQDV will compute every 10 minutes a simulation based on the latest weather, hydraulic and quality data received. Weather data will be provided by:

- CYII from three rain gauges close to the pilot site

- Two temporary rain gauges spread across the study area (at WWTP of Butarque and WWTP of La Gavia)
- Radar data from an external service provided by HYDS. It service will provide 1 hour of observed Radar data from Spanish National Meteorological Agency (AEMET) and 1 hour of forecast data from a nowcasting service on 400km² around Manzanares river with a matrix of 1km² (1km x 1km), directly linked to AQDV UD.
- Radar data from CYII (to be confirmed)

These data will be directly displayed in AQDV UD Weather view

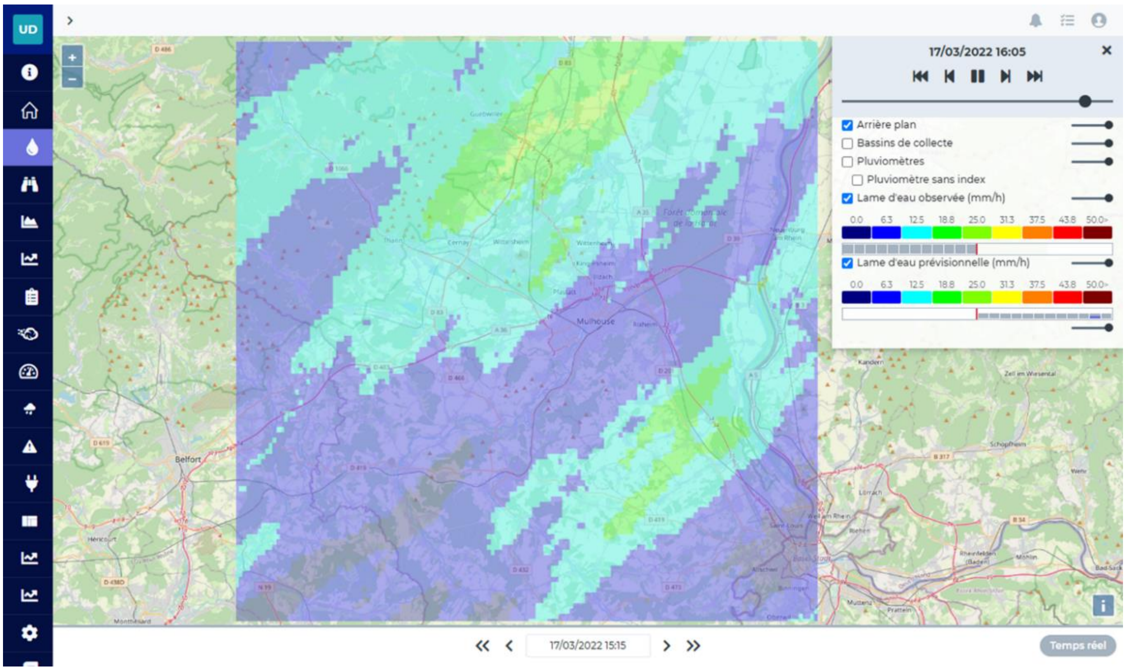

Figure 56.- AQDV UD weather view where the weather data will be displayed.

5 Update/development of models

5.1 Detailed hydraulics and quality model calibration

Chapter 2.4 presented the existing model in Manzanares system. As mentioned there, this is a simplified hydraulic model including the main sewers tanks and actuators of the system and it will be used as starting point for the RUBIES project.

The required tasks to update this detailed model so that it can be used in the Rubies project are:

- Update the existing hydraulic model with the updated GIS and inspection data available from the latest years, specially confirming or updating some of the assumptions done when it was first developed this model (these main assumptions are explained in chapter 2.4).
- Transfer the model from Infoworks ICM software to SWMM. The project could be developed in both softwares as they both are able to model the hydrologic, hydraulic and quality processes occurring to simulate the drainage systems. The main difference is that one is a commercial software that requires a license to run while the other is a free open source software. The decision of using SWMM has been taken based on project practical working questions: using SWMM will facilitate that several persons, teams and models are working in parallel at the same time, while having only one full Infoworks ICM license would not allow this making very difficult to coordinate all the people and teams that need to use the model to finish the project in the expected deadline.
- Initial hydraulic model calibration based on the available historic water level sensor data available from Canal. For that, the most relevant operational historic data and sensor data available in the case study will be selected for 3 to 5 rain events and these will be used for the initial hydraulic calibration.
- Hydraulic calibration using the sensors installed for the Rubies project and described in chapter 3.1.
- Quality model: The development of the quality model could be done based on two approaches. The first one would use the quality equations available in the modelling software so some input quality data is needed (such as DWF quality concentrations, concentrations in rainy flow depending on the time since last rain event, etc.) and then using the tubidity sensors data installed and the quality campaigns to calibrate the model. The second approach would use directly the turbidity sensor data and the correlations obtained from turbidity with the quality parameters to estimate the flow quality at the most relevant pilot site locations such as CSOs discharging points, WWTP influents, and main sewers. For the online real testing and operation the second approach is considered more convenient since there will be real time turbidity data available. For the virtual testing this turbidity data won't be available and for that case some assumptions and simplifications will need to be considered (modelling quality as

the first approach described or a more simple way considering quality average values for each relevant location depending on the sampling campaigns and turbidity sensors data available).

5.2 WWTP model

The WWTP model will be developed for the selected site Butarque WWTP. It will be done from scratch, since no previous model of the WWTP exists. Despite model building steps are usually common independently from the site or software, specific design must be selected in order to develop a realistic model of the selected WWTP. The steps regarding the model development are as follows:

- Model building.
    - Layout construction, based on the different units of the WWTP. The WWTPs was already described in chapter 2.1.4. The main units that will shape the model layout are a pretreatment stage, primary clarification, biological reactors (activated sludge process for carbon and nitrogen removal), and secondary clarification, for the water line, while sludge thickening, digestion and dewatering will be taken into account for sludge line configuration, especially regarding the overflow streams that are returned to the head of the plant.
    - Library and model selection for each process unit: DDBB and mathematic models used will be selected taking into account the process units and the critic parameters of interest within the model. Thus, the selection will take into account that flowrate and TSS concentration are the main outputs of interest to be obtained in the WWTP modelling; also, the library selection is important since it will fill the blanks where no real data are available.
    - Physical and operational parametrization: construction characteristics (equipment sizing, number of units, equipment type), as well as design, peak, minimum and normal operation values for different parameters required by the software will be provided from real WWTP characteristics.
    - Influent characterization: real data will be gathered, analyzed, treated and filtered in order to characterize the WWTP influent in a representative way. Historical data will be used in the study and complemented by analytical results from several campaigns. The most representative and reliable values will be used to define an influent characterization that will be the base dataset in order to calibrate the model once it is built. Also, the input variables required by the model will be considered. In this sense, not only flowrate and TSS values will be studied, but also a basic total characterization including, among others, COD, BOD, nitrogen, phosphorus, temperature, pH. This step is crucial to obtain accurate results from WWTP model.
    - Fractionation: the influent characteristics' dataset will be adjusted so the model can read them. Afterwards, data inputs' reading will be programmed in order to

translate data coming from the sewer model into a data matrix suitable for the model software to read it and run the calculations. The time slot for data reading will also be determined in order to ensure a realistic but feasible data reading and processing.

- Model calibration: this step consists of adjusting the control parameters of the model until obtaining a simulation result similar to the real values. In this case, the critical streams from which the modeling results and the actual values are compared correspond to the effluent of the WWTP, and the critical parameters, as mentioned, will be flowrate and TSS concentration.
    - Effluent characterization: it will be needed as a reference to compare the model results with. The process is very similar to influent characterization, combining analytical results with historical data.

The model calibration will be done under normal operation conditions in the WWTP. Different datasets can be used to test the calibration (i. e. single run, 1 hour running, 24 hours running) in order to ensure the results accuracy over time.

A functionality will be added as a part of the WWTP model that will allow to estimate the treatment capacity of the WWTP, based on the hydraulic (flowrate) and quality (TSS) outputs of the WWTP model. This functionality will be an input of the control system, allowing the decision making on how much wastewater should be sent to the WWTP and how much wastewater should by-pass the installation, minimizing the untreated wastewater discharge without compromising WWTP operation or WWTP effluent quality.

According to previous assessment from LIFE EFFIDRAIN on the selection of WWTP modelling software, GPS-X has been selected as the software to develop the WWTP model, as it will allow its integration in the sewer control system that will be developed over LIFE RUBIES project.

5.3 Hydraulics and quality model simplification

5.3.1 Context

Integrated urban wastewater systems (IUWS) which consider urban drainage networks (UDN), wastewater treatment plants (WWTP) and the receiving body are designed to collect and convey urban wastewater and storm water run-off through sewer network to WWTP for treatment before releasing them to the environment.

The environmental problem targeted by the LIFE RUBIES project is the pollution of surface waters due to overflows from UDNs and WWTPs during wet weather.

The use of real-time control (RTC) within UDNs has proven to be efficient for the management of UDNs, minimizing flooding and CSOs volumes, thus protecting the environment. However, nowadays, RTC strategies applied to UDN systems are only based on hydraulics (volumes and flows) without considering the pollution load of the effluents and without considering any communication with the WWTP.

To better protect the environment from UDN and WWTP impacts, LIFE RUBIES develops and demonstrates integrated RTC strategies for UDN and WWTP systems focused on minimizing not only the occurrence of CSO volumes, but also its polluting impact on the receiving water bodies during rain events through the use of real-time quantity and quality data.

LIFE RUBIES follows 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. Therefore, quality measurements are needed at the UDN and the WWTP for the implementation of Pollution-based controllers.

One of the main features for the monitoring, modelling and control techniques to be developed in the LIFE RUBIES is their transferability and replicability. To this end, and taking into account the assessment of the experts in the pilot sites, it has been decided that the only quality variable to be considered for real-time monitoring along the network will be turbidity, to be correlated with Total Suspended Solids. At the moment, and also according to Campisano et al., 2013, the pilot operators do not consider other measurements to be reliable enough to be used in real operation.

5.3.2 LIFE RUBIES RTC strategies

Following the discussion above, the choice RTC control strategies for the regulation of IUWS in presence of intense rain episodes are global, predictive, real-time control strategies (Schutze et al., 2004). Since the objective of the management is to minimize the effect of the disturbance (rain) on the system, optimization-based control appears to be a natural solution. However, several rule-based solutions have also been proposed, especially in the integrated modelling community (Meirlaen, 2002, Solvi, 2006, Vanrolleghem et al., 2005).

- Rule-based control of IUWS

  Rule-based control (RBC) or rule-based system (RBS) is a type of intelligent control techniques that can be used for real-time control of IUWS. Rule-based systems simulate 0 problem-solving behaviour of a group of experts who apply various problem solving methodologies and expertise in relation to a given formulated problem, this is why they are considered as a type of Expert Systems (ES). To do so, they use linguistic rules or conditional statements elicited from human experts to encode expertise which when chained in logical sequences can easily explore a situation and reach some conclusions.

  RBS have shown promising results due to its capabilities on representing heuristic reasoning and on working with large amounts of symbolic, uncertain and inexact data, and qualitative information which human operators comprehend best. They also permit implementation of human-like control strategies. Conventional or classical control methods cannot deal with these tasks.

- Model Predictive Control of IUWS

  Over the past few years, model predictive control (MPC) has proven to be one of the most effective and accepted control strategies for large-scale complex systems (Rawlings and Mayne, 2009; Ocampo-Martinez et al., 2012). The objective of using this technique for controlling IUWS is to compute, in a predictive way, the manipulated inputs to achieve the optimal performance of the network according to a given set of control objectives and predefined performance indices.

Nevertheless, the majority of MPC applied in IUWS have only focused on hydraulic model and control objectives without considering the polluting load inside the carried water, e.g. (Cembrano et al., 2004).

5.3.3 Hydraulics and quality model simplification

Considering the hydraulic and hydrology complexities of UDNs, simplified deterministic models, which can predict the approximate spatial and temporal evolution of the hydraulics and quality parameters, are necessary (Puig et al., 2009) to develop and apply RTC to UDNSs. TSS has been selected as a representative variable of water quality because it is correlated to turbidity measurements and it is also useful for estimating other quality variables.

The dynamics of solid concentration and loads are generally summarized into three behaviours (Rossman L. A., 2015):

- Accumulation of solid sediments over urban catchment;
- Wash-off of solid sediments by rainfall;
- Transfer, erosion, deposition of solids in sewer networks and retention tanks.

For the purpose of RTC of UDNs, a simple model structure should be used to represent the complex hydrology and to simulate the dynamics of TSS in sewer networks. The following principles (Puig et al., 2009) are followed:

- Representativeness of the main dynamics;
- Simplicity, flexibility, expendability and speed;
- Availability of on-line calibration and optimization.

Simplified models of the WWTP considered in the pilot site is also required in the framework of the LIFE RUBIES project to allow the implementation of MPC based on quality objective. As explained before, the only variables that can be used by the simplified models are the flow-rate and the TSS concentration.

The treatment processes of the WWTPs are complex and several variables are involved. Because of that, it has to be taken into account that the results obtained by simplified models using only TSS and flow-rate are approximations which could have a significant error. Derived from the approach proposed in the LIFE EFFIDRAIN project, the main purposed of the WWTP simplified model is to estimate the WWTP treatment capacity at every timed instant considering forecasts of the flow-rate and TSS of the WWTP inflow sent by the UDN. The WWTP treatment capacity estimation is used by the Pollution based – controller/optimizer (MPC or RB) in order to compute UDN control actions aiming to protect the environment but also avoiding the degradation of the WWTP processes. Specifically, WWTP treatment capacity is estimated in order to avoid the performance degradation of the secondary treatment unit.

Optimizers will be used in the LIFE RUBIES project with different RTC strategies based on RBS and MPC in order to optimize the sewer management and reduce the discharge of pollutants in the receiving bodies. In this context, simplified models (SMs) are required to simulate large amounts of scenarios and control strategies and to evaluate the corresponding performance to choose the best one.

In order to allow the optimizer system to work fast enough, it has to be taken into account during the development of the SMs of the sewer and of the WWTPs that it is more desirable to use simple equations in the SMs. Also, due to the way the optimizer works, the functions defining the simplified models have to be developed taking into account the type of expression they are. Some mathematical expressions are not desirable for the optimizer because it could happen that the optimizer would not be able to find a solution (optimum value) or it could find a wrong value. The following list contains the type of functions desirable for the optimizer (sorted by decreasing desirability).

- Linear functions
- Polynomial functions
- Logarithmic functions
- Exponential functions

The following situations are not desirable for the optimizer:

- Multiplying variables (var1·var2)
- Variables with negative exponents (varin, where n < 0)
- Non-linear expressions including if-statements (they may work but also can generate some problems).

In LIFE RUBIES, the deployment of the Pollution-based RTC methods (MPC / RB) will require the identification and calibration of the simplified models of the UDN and WWTP associated with the considered pilot perimeter described in Section 2.1. For the case of the WWTP, just Butarque WWTP is considered since given the considered pilot perimeter, there are no control actions affecting to La Gavia WWTP

5.4 RTC algorithm (MPC and/or RB) requirements

The demonstration of the Pollution-based RTC (MPC / RB) in the considered pilot perimeter requires both virtual testing and real testing. 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.

Virtual testing was the main focus of LIFE EFFIDRAIN project and the established protocols and framework will be used in LIFE RUBIES. For the real 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.

5.4.1 Virtual testing: RTC Closed-loop Simulation Algorithm (CLSA) Architecture and Functionalities

In order to properly describe the details of the algorithm implementing the simulation of UDN/WWTP processes according to RTC actions it is necessary to understand the concept of a closed-loop control system. According to the control theory terminology, measurements are called outputs of a system and orders performed their active elements, also known as actuators (such as gates, pumps or movable weirs), are called control actions. A control system is called a feedback control system or a closed-loop control system when the system outputs are used as the main information to iteratively compute updated control actions to achieve a given desired behaviour, called the system input.

To implement the simulation of a closed-loop control system means to reproduce, through computer simulations, the temporal sequence consisting of system evolution simulations to obtain outputs (measurements), and RTC algorithm evaluations to obtain control actions (Figure 57).

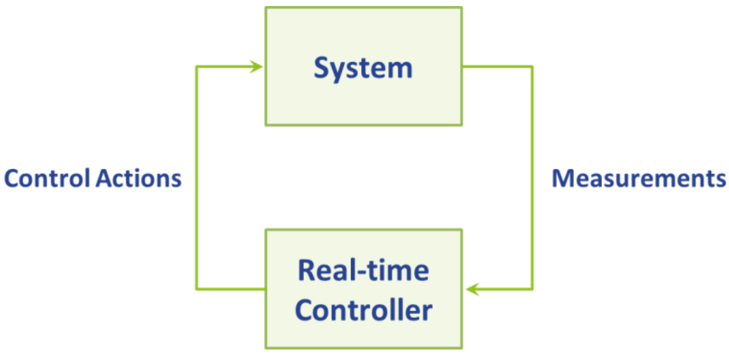

Figure 57.- Closed-loop/feedback control system.

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. These two models, however, do not share most of their variables: while UDN simulation models describe mostly hydraulic processes, WWTP simulation models, based on the Activated Sludge Model (ASM; Henze et al., 2000), focus on chemical processes. The problem of connecting the two systems has been an important topic of research in the development of integrated urban drainage models (Rauch et al., 2002). The current solution is based first, on the inclusion of models within UDN simulators to reproduce the dynamics of some elements contained in sewage water such as TSS and chemical oxygen demand (COD); and secondly, on the hypotheses behind the so-called fractionation models, which allow to establish empirical correlations between the network variables of flow, TSS and COD, and the over-fifteen types of suspended and diluted chemical components used by the WWTP ASM-based simulators.

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. At this point no assumption needs to be made about the type of controller implemented in the RTC module: it is simply an element that receives system measurements (and possibly disturbance forecasts) and computes control actions for the system actuators. Once control actions are computed, they can be used into the configuration of the UDN simulator to start again the whole procedure. Figure 58, shows a detailed diagram of the variables involved in the whole process.

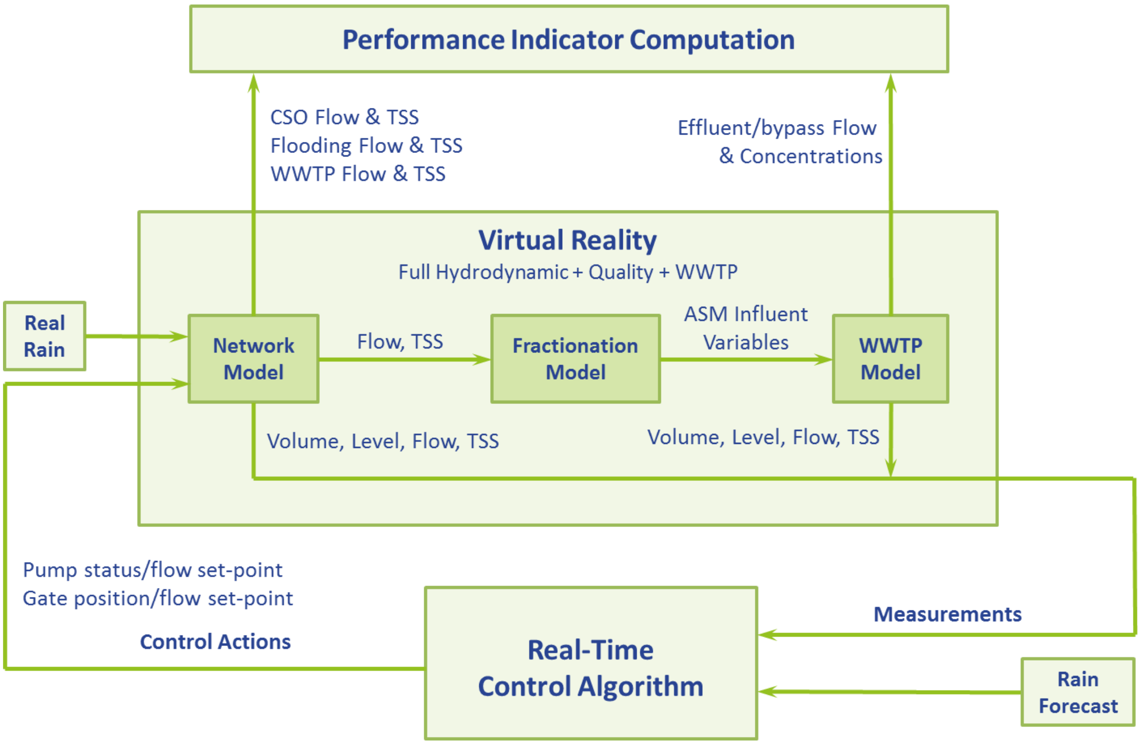

Figure 58.- Elements and variables taking part in a closed-loop simulation of RTC algorithm applied to integrated control of UDN and WWTP.

To implement a Closed-Loop Simulation Algorithm (CLSA), the conceptual information workflow described above and shown in Figure 58 must be translated to a set of software executions orders and file management routines. Notice that a CLSA run may be composed of many iterations (e.g. 288 iterations of 5 minutes for a 24 hour simulation) of the simulator-controller loop. Therefore, all the software executions must be run without the need for manual interaction with the Graphical User Interface (GUI) of the different involved software elements, taking advantage of APIs or command line executions.

Four main steps to be automatically executed in a loop have been identified. Slight variations depending on the particular simulation software are detailed in the next sections. The four main steps are:

- Editing the simulation configuration parameters of the models used as a Virtual Reality, including:
    - Simulation start and end time and date

    - Rain event time series file and name
    - Hotstart files
        - Input hotstart file containing the current simulation initial conditions
        - Output hotstart file containing the current simulation final conditions to be used as initial conditions in the next iteration
    - RTC configuration
- Running the simulation (through command line or Applications Programming Interface (API)) of the models used as a Virtual Reality
- Extract the simulation results to:
    - Store them in suitable format for KPI analysis
    - Modify the initial conditions file in the RTC module with the new results obtained
- Running RTC algorithms (and other simulation software, if necessary)

Figure 59 shows a schematic of these four main steps (blue boxes), together with the main files needed as inputs and generated as outputs in each one (green boxes):

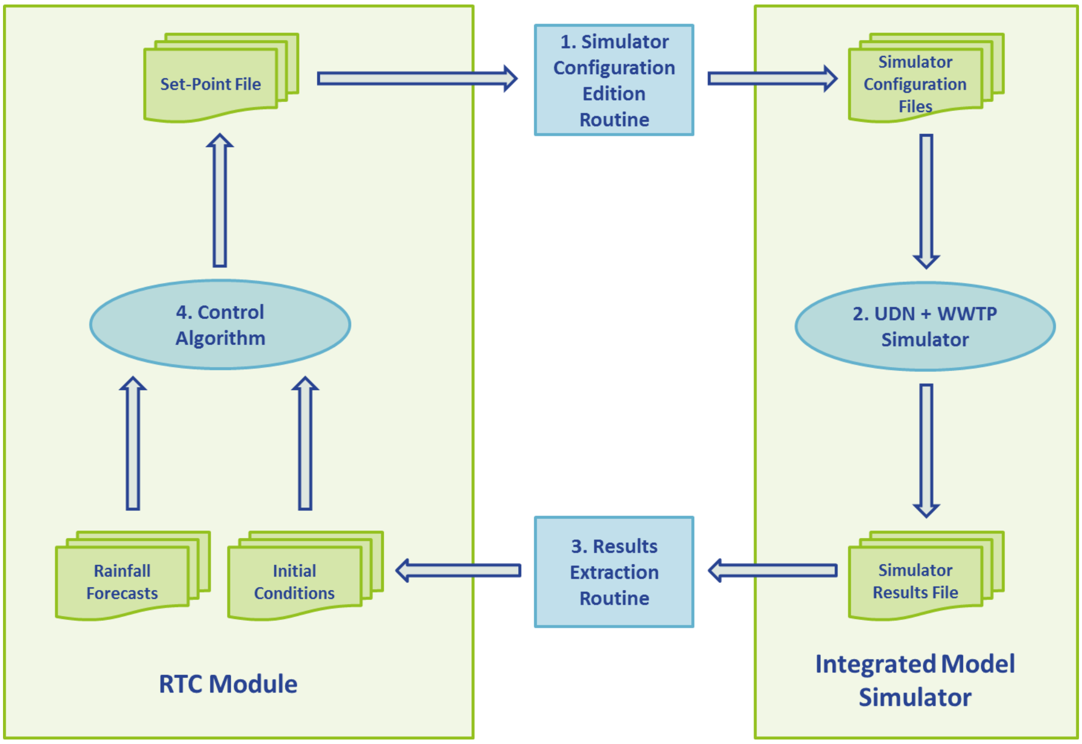

Figure 59: ***CLSA implementation steps and information flow between a virtual reality simulator and a real-time controller.***

5.4.2 Real testing: integration of the CLSA with the reality

In order to enable real testing, CLSA implementing PBRTC method will be connected to the reality through AQDV platform as depicted in Figure 60. 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 send 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.

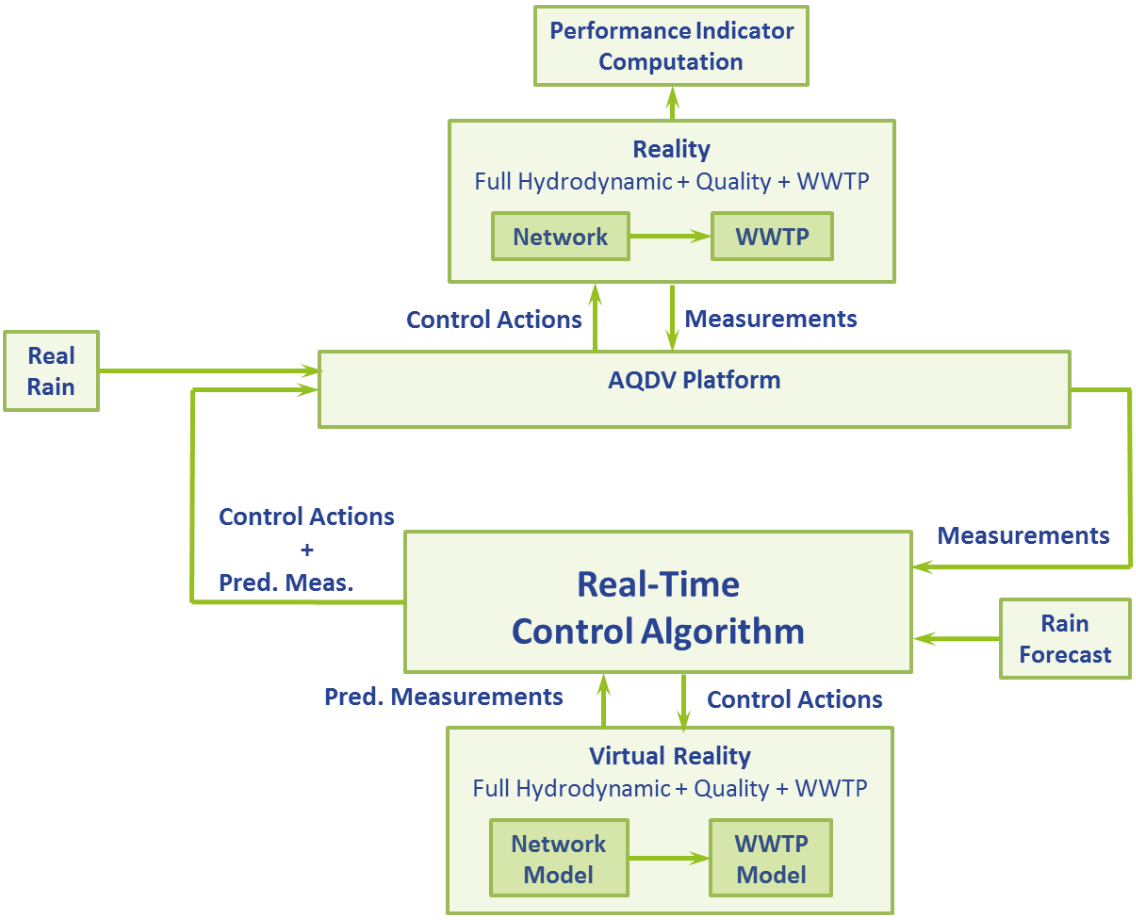

Figure 60: Connection of the RTC CLSA with the AQDV platform in order to enable real testing to the PBRTC method.

5.5 Developments for data monitoring assimilation for model hotstart

As described in Section 5.4, CLSA is connected with the virtual reality both for virtual (Figure 58) and real testing (Figure 60) following the workflow depicted in Figure 59. In this sense, at every time instant (or closed-loop iteration), CLSA initializes the virtual reality with network and wwtp conditions computed at the previous iteration (hotstart file) and run a new simulation applying the control actions computed by the PBRTC method obtaining the hotstart file and the virtual measurements for the next iteration.

For the case of the real testing, both virtual and real measurements will be available and once the measurements are validated, they can be compared with the virtual measurements in order to check if there is any major discrepancy. According to the workflow depicted in Figure 59, deviations between real and virtual measurements could force a meaningful drift between the dynamics evolution of the virtual reality and the reality. Then, in case the virtual measurements are used by the PBRTC algorithm in order to complement the real measurements, control actions computed at every time instant may not be very optimal in terms of protecting the environment.

To tackle the effect of deviations between measurements and virtual measurements, in action B1, data assimilation mechanisms to adapt the virtual reality according to the observations (real measurements) will be considered. On one hand, these mechanisms can update the hotstart file used as initial condition for the new virtual reality simulation according to the real observations and on the other hand, certain virtual reality parameters could be re-calibrated in order to reduce deviations between the reality and the estimations provided by the virtual reality.

The detailed requirements to perform this data assimilation is done in another action of the project and then it is coded in AQDV UD, so in fact here we only configure and implement it in the pilot case of Madrid.

6 Planification of environmental impact assessment

6.1 General Manzanares river description

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.

6.2 Manzanares river in the Tagus river basin hydrological planning

The Manzanares river belongs to the "Jarama-Guadarrama" Exploitation System, within the Tagus river basin. The International River Basin District of the Tagus is shared between Spain and Portugal.

The main relevant considerations of the Manzanares basin collected from the Hydrological Planning of the Spanish river basin management (Tagus river, planning cycle 2021-2027), are presented below. Specifically, the water body in which the reach studied is located is called "RÍO MANZANARES A SU PASO POR MADRID" (code ES030MSPF0427021).

6.2.1 Manzanares river basin in the Tagus River District

The International River Basin District of the Tagus is a demarcation shared between Spain and Portugal. The Spanish part of this river basin district extends over five autonomous communities of which eleven provinces are part. The autonomous community that occupies the most territory in the demarcation is Castilla - La Mancha, which is also the second in population. Madrid, despite occupying only 14% of the territory, contributes more than 80% of the total population of the basin. In the following figure the Manzanares river basin in the context of Tagus river basin is shown.

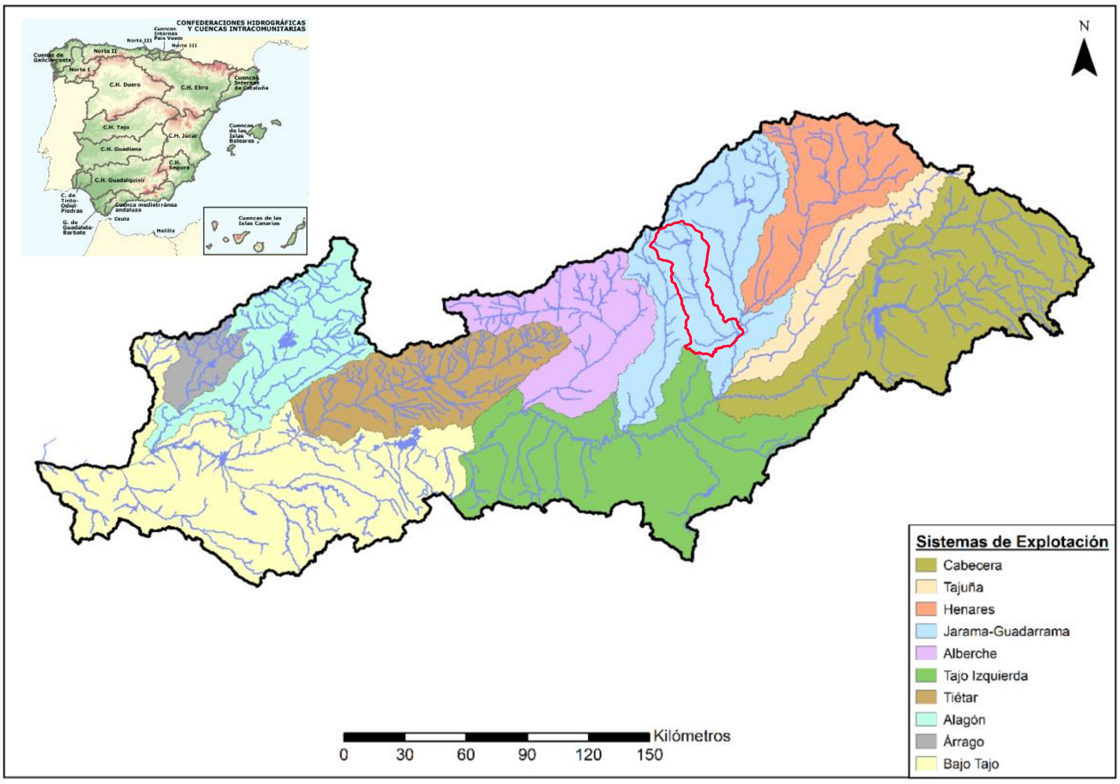

Figure 61.- International Tagus River Basin District (Spanish part). Manzanares river basin, within the Jarama-Guadarrama exploitation system, is highlighted in red.

6.2.2 Characteristics of surface water bodies linked to the Manzanares River

The Hydrological Planning establishes a methodology for the identification and characterization of water bodies. The "typology" of the river-type water bodies is shown in the following figure.

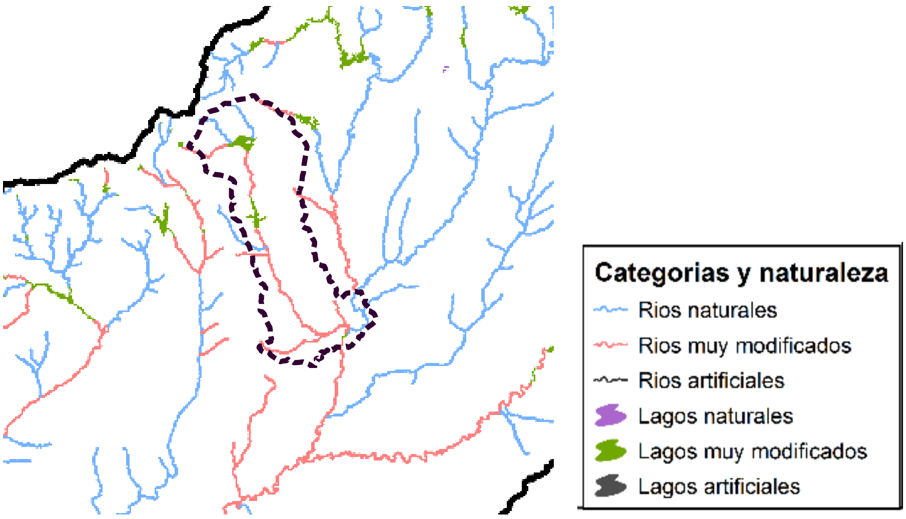

Figure 62.- Categories and nature of the surface water bodies of the Manzanares river basin.

The water body of interest for this project is the "Manzanares river on its way through Madrid" as mentioned above. The different water bodies of this river reach are shown in the following Table.

Table 5.- Water bodies of the tipology river linked to the Manzanares river. Manzanares river details.

WATER BODY CODE	NAME	CODE	HYDROMORPHOLOGICAL ALTERATION	RATING
ES030MSPF0427021	**Manzanares river on its way through Madrid**	**R-T15**	**2.1.2 CHANNEL**	**HEAVILY MODIFIED**
ES030MSPF0428021	Manzanares river from El Prado reservoir to Trofa stream	R-T15	2.1.1.2 DOWNSTREAM EFFECT 2.1.1.3 BARRIER EFFECT	HEAVILY MODIFIED
ES030MSPF0430021	Manzanares river from the Mazanares basin to el Prado reservoir	R-T11	2.1.1.2 DOWNSTREAM EFFECT 2.1.1.3 BARRIER EFFECT	HEAVILY MODIFIED
ES030MSPF0432010	Manzanares river to Manzanares el Real basin	R-T11		
ES030MSPF0433021	Los Prados rivercreek	R-T01	2.1.2 CHANNEL	HEAVILY MODIFIED
ES030MSPF0434021	Culebro stream	R-T12	2.1.2 CHANNEL	HEAVILY MODIFIED
ES030MSPF0435021	Zarzuela stream	R-T01		
ES030MSPF0436010	Trofa stream	R-T01		

The water bodies that are of greatest interest for this project are the Manzanares River as it flows through Madrid, the Culebro Stream, and Los Prados stream. The three bodies of water are considered HEAVILY MODIFIED in the Hydrological Planning. The river code of the Manzanares, R-T15, is an important figure as it will determine its physico-chemical water quality objectives.

6.2.3 Reference flow discharges

The ecological flow rate (discharge) is defined in Article 3 of the Hydrological Planning Regulation (RPH; RD 907/2007) as the "flow that contributes to achieving good ecological status or good potential in rivers or transitional waters and maintains, as a minimum, the fish life that would or could naturally inhabit the river, as well as its riparian vegetation". The proposed ecological minimum flows in the Manzanares River are presented in the following table.

Table 6.- Proposal of minimum ecological flow rates. Quarterly minimum flow rates (in m³/s) according to Tagus River Basing Hydrological Planning

Code	Name	Temporality	Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sep
ES030MSPF0427021	Manzanares river on its way through Madrid	Permanent	0,840	1,090	1,120	0,500
ES030MSPF0428021	Manzanares river from El Prado reservoir to Trofa stream	Permanent	0,820	0,940	0,980	0,490
ES030MSPF0429020	Manzanares river from the Mazanares basin to el Prado reservoir	Permanent	0,820	0,930	0,970	0,490
ES030MSPF0433021	Manzanares river to Manzanares el Real basin	Intermitent	0,003	0,004	-	-
ES030MSPF0434021	Los Prados rivercreek	Seasonal	0,001	0,027	0,026	-
ES030MSPF0435021	Culebro stream	Intermitent	-	0,003	0,002	-
ES030MSPF0436010	Zarzuela stream	Seasonal	0,006	0,027	0,019	-

Climate change has evident and progressive effects on the hydrometeorological variables that determine the water balance and, therefore, water resources: runoff and aquifer recharge. The study "Evaluation of the impact of climate change on water resources and droughts in Spain" (CEDEX, 2017), provides an estimation of the possible variation of resources in three impact periods: short-term (2010/11-2039/40), medium-term (2040/41-2069/70) and long-term (2070/71-2099/2100), which are compared with the control period extending from the hydrological year 1961/62 to 1999/2000. In accordance with Spanish Instruction of Hydrologial Planning, Tagus river basing plan has estimated the effects of climate change for a scenario set in the year 2039. The estimated percentages of variation in the RCP 8.5 emissions scenario are shown in the following table.

Table 7.- Percentage change in quarterly runoff in the exploitation systems of the Tagus basin (RCP 4.5 and RCP 8.5 emissions scenarios).

	RCP4.5				RCP8.5			
Tipo	OND	EFM	AMJ	JAS	OND	EFM	AMJ	JAS
Cabecera	-14	-6	-8	-10	-20	-9	-15	-16
Tajuña	-13	-6	-6	-8	-19	-10	-13	-15
Henares	-14	-2	-8	-13	-21	-6	-16	-18
Jarama-Guadarrama	-10	2	-9	-21	-15	-3	-18	-25
Alberche	-11	3	-11	-21	-19	-2	-21	-26
Tajo Izquierda	-12	2	-7	-10	-20	-3	-19	-18
Tiétar	-11	0	-13	-31	-17	-1	-20	-37
Alagón	-11	1	-14	-27	-16	0	-20	-32
Árrago	-13	0	-13	-18	-20	-2	-21	-23
Bajo Tajo	-16	-1	-12	-24	**-24**	-3	-23	**-29**

The estimated average reduction of resources in the basin as a whole is about 16%. The monthly distribution of this reduction is heterogeneous with maximum reduction percentages in the months of October and March (-35%) and a positive increase in January (7%). The Manzanares river basin, integrated into the Jarama-Guadarrama exploitation system, could have a reduction of up to 25% in the months of July-August-September.

6.2.4 Characteristics of the water body "Manzanares River on is way through Madrid"

The following is a more detailed description of the water body "ES030MSPF0427021 - Manzanares River, as it flows through Madrid". This water body, include Manzaneras river reach downstream the confluence with the Trofa stream and up to the tail end of El Rey reservoir, running through the municipality and city of Madrid, and the municipality of Getafe, belonging to the community of Madrid. It has a length of 20,6 km. The mass runs through protected areas of the Regional Park, the Natura 2000 Network of the "Vegas, and southeastern Madrid", and the basins of the Jarama and Henares rivers (see next figure).

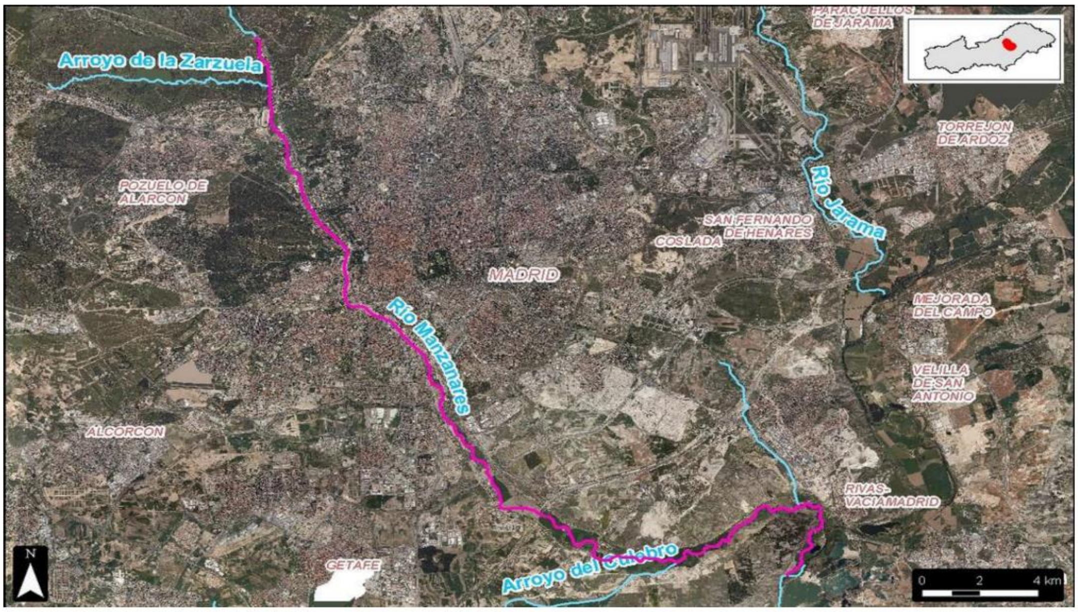

Figure 63.- Detail of the water body "Manzanares river, as it flows through Madrid".

This water body was considered as HEAVILY MODIFIED from the beginning because it is channeled or with bank protection. Riverbanks have been lined with rigid materials, the riverbed has been lined with any other material, or the river has been cut or diverted within the channeled section.

Data are available for biological quality indicators, for the "phytobenthos" element (IPS indicator), being MODERATE in 2015 and 2017, and DEFICIENT in 2016; for the invertebrate benthic fauna (IBMWP indicator) being DEFICIENT in 2015 and 2016, and MODERATE in 2017 and, about macrophyte (IBMR indicator), data are available for the year 2017 which was MODERATE. Therefore, the BIOLOGICAL QUALITY has been DEFICIENT status in 2015 and 2016, and MODERATE status in 2017.

With respect to the PHYSICOCHEMICAL QUALITY indices, the available data indicates that water quality has been WORSE THAN GOOD in all three years of data.

In relation to the HYDROMORPHOLOGICAL QUALITY, data is available for the riparian vegetation index (QBR indicator) being this WORSE THAN GOOD in 2015, 2016, and 2017, and with respect to the river habitat index (IHF indicator), data is only available in 2015, so the HYDROMORPHOLOGICAL QUALITY of the mass in the 3 years is WORSE THAN GOOD.

The value of the global index of hydromorphological alteration (from 0 to 9) is 6.40 in this water body, and under natural conditions, would correspond to Type 15. A summary of the classification state of the water body, classifications stablished in the river basin planning and the status of the water body is presented below.

Table 8.- Summary of the classification of state of the water body "Manzanares river, as it flows through Madrid"

Quality	2015	2016	2017
Biological	Deficient	Deficient	Moderate
Physicochemical	Worse than good	Worse than good	Worse than good
Hydromorphological	Worse than good	Worse than good	Worse than good
Ecological	Deficient	Deficient	Moderate

Table 9.- Status of the water bodies surface (Tagus River Basin plan 2021-2027).

Code	Water body	Ecological status/ Ec.Potential	Chemical status	Final status
ES030MSPF0427021	Manzanares river on its way through Madrid	MODERATE	GOOD	WORSE THAN GOOD
ES030MSPF0428021	Manzanares river from El Prado reservoir to Trofa stream	DEFICIENT	GOOD	WORSE THAN GOOD
ES030MSPF0429020	El Pardo reservoir	MODERATE	GOOD	WORSE THAN GOOD
ES030MSPF0430021	Manzanares river from the Mazanares basin to el Prado reservoir	MODERATE	GOOD	WORSE THAN GOOD
ES030MSPF0431020	Manzanares el Real reservoir	MODERATE	GOOD	WORSE THAN GOOD
ES030MSPF0432010	Manzanares river to Manzanares el Real basin	GOOD	GOOD	GOOD OR BETTER THAN GOOD
ES030MSPF0432110	Mediano stream	VERY GOOD	GOOD	GOOD OR BETTER THAN GOOD
ES030MSPF0433021	Los Prados rivercreek	MODERATE	GOOD	WORSE THAN GOOD
ES030MSPF0434021	Culebro stream	DEFICIENT	No good condition	WORSE THAN GOOD
ES030MSPF0435021	Zarzuela stream	MODERATE	GOOD	WORSE THAN GOOD
ES030MSPF0436010	Trofa Stream	DEFICIENT	GOOD	WORSE THAN GOOD

The objectives and deadlines adopted in the Hydrological Planning 2021-2027 for the Manzanares river reach are the ones for river type T-15:

- Good ecological potential, and good chemical status by 2027 at the latest.
- Indicators to verify compliance of the good ecological potential:
  - Biological: IBMWP: max. 172 - CERlim 0.42; IMMi-T: max. 1 - CERlim 0.628; IBMR: max. 9.3 - CERlim 0.68; IPS: max. 17.7 - CERlim 0.73.
  - Physicochemical: 6 ≤ pH ≤ 9; Dissolved DO ≥ 5 mg/L; 60 ≤ %OD ≤ 120; Ammonium ≤ 0.6 mg/L; Phosphates ≤ 0.5 mg/L; Nitrates ≤ 25mg/L

- Hydromorphological: QBR: max. 100, CERlím 0.800.

➢ At clear risk of not meeting their good status objectives, despite having them lowered: LESS RIGOROUS OBJECTIVES.

The methodology for the preparation of water plans establishes the need to estimate the risk of not meeting the defined objectives.

The total risk value considers the effect that physicochemical and hydromorphological impacts have on the biological quality of the water body, as well as the results provided by the indirect habitat indicators (IIdeH) in relation to the status of the water body. Once each of the risks identified in the water body has been weighted, the total risk is calculated and qualitatively assessed, considering the categorization ranges shown in the following table.

Table 10.- Total risk categorization ranges.

Total risk	Qualitative risk
< 2	No significant risk
2-4	Medium
4-5	High
>5	Very High

According to the previous risk levels, the following Table shows the risks for the water bodies of explotation area.

Table 11.- Results of the risk assessment in the exploitation area. Water bodies related with the present study are highlighted in bold.

Category	EMMSPFCod	Name	Risk	Risk quantif.
River	ES030MSPF0427021	Manzanares river on its way through Madrid	**Very High**	**6,83**
River	ES030MSPF0428021	Manzanares river from El Prado reservoir to Trofa stream	**High**	**4,38**
Lake	ES030MSPF0429020	El Pardo reservoir	**Medium**	**4,00**
River	ES030MSPF0430021	Manzanares river from the Mazanares basin to el Prado reservoir	**High**	**4,38**
Lake	ES030MSPF0431020	Manzanares el Real reservoir	**Medium**	**4,00**

River	ES030MSPF0432010	Manzanares river to Manzanares el Real basin	**No significant risk**	**0,30**
River	ES030MSPF0432110	Mediano stream	**No significant risk**	**0,30**
River	ES030MSPF0433021	Los Prados rivercreek	**Medium**	**2,53**
River	ES030MSPF0434021	Culebro stream	**Very High**	**8,83**
River	ES030MSPF0435021	Zarzuela stream	**Medium**	**2,53**
River	ES030MSPF0436010	Trofa stream	**Very High**	**6,43**

6.2.5 Conclusions on the environmental situation of the Manzanares River in the river reach of interest.

The reach of river of interest for the project is the water body known "Manzanares River as it passes through Madrid", as already mentioned with 40.5 km long (the total river length is 92 km). 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 ≥ 5 mg/L; $60 \leq \%OD \leq 120$; Ammonium ≤ 0.6 mg/L; Phosphates $\leq 0,5$ mg/L; Nitrates ≤ 25mg/L.

As it will be presented later, when briefly describing the pressures and presenting values of the currently measured physico-chemical quality, it will be shown that reaching these values 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.

6.3 Manzanares river significant pressures

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 64). 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.

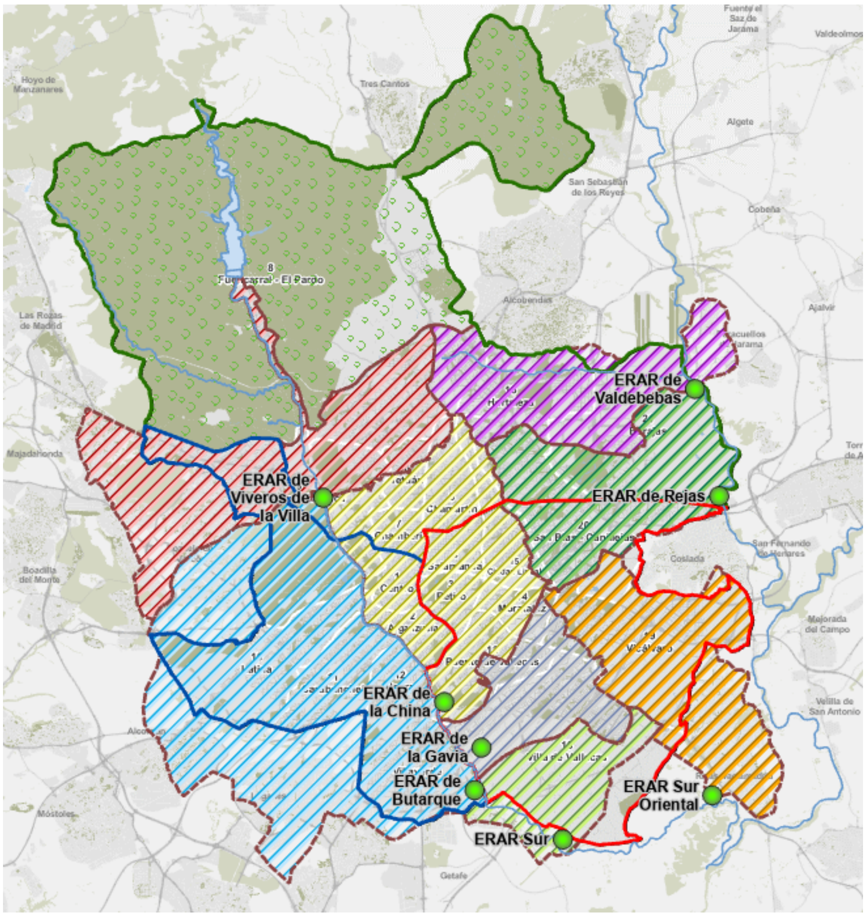

Figure 64.- Sewerage sub-basins of Madrid, linked to its main WWTP.

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 following table shows the types of treatment available in the different WWTPs in Madrid.

Table 12.- Data on the WWTP and type of treatment processes (https://www.canaldeisabelsegunda.es/documents)

WWTP	Authorised flow (m3/day)	Authorised flow (m3/s)	Design eq. inhabitants (h-e)	Biological nutrient removal	Chemical phosphorus removal	Water regeneration

Viveros	190.080	2,200	700.000	YES	YES	YES
La China	321.855	3,725	1.335.000	NO	YES	YES
La Gavia	172.800	2,000	1.353.600	YES	YES	YES
Butarque	306.541	3,548	1.612.800	NO	YES	NO
Sur	561.086	6,494	2.937.600	NO	YES	NO
Sur Oriental	69.120	0,800	288.000	YES	YES	YES
Arroyo Culebro Cuenca Baja	172.800	2,000	1.353.600	YES	NO	NO
Arroyo Culebro Cuenca Media Alta	129.600	1,500	1.224.720	YES	NO	YES
TOTAL	1.923.882	22,27	10.805.320			

The total flow that can be discharged by the treatment plants into the river Manzanares has an maximun value 22 m3/s. The flow discharged by treatment plants upstream of the La Gavia WWTP is 6 m3/s; upstream of the Sur WWTP it is 11 m3/s.

Throughout this document, the complexity of the Madrid sanitation and drainage system has already been described, as well as the existence of numerous CSO discharge points. Each CSO spill presents different characteristics in terms of pollution. In the same spillway, the hydrographs and polutogrphs vary due to the rainfall variability, the preceding dry weather days, etc., as well as the type of control and treatment infrastructure (e.g. their specific storage volume).

The following table shows CSO pollution values measured in a study carried out by Canal de Isabel II as a reference to the type and pollution concentrations of discharges that reach the Manzanares River during wet weather events

Table 13.- Pollutant concentrations in CSO in several pilot basins in the sanitation system of Madrid.

Pollution parameters	MAX – C (maximum concentration)				EMC (event mean concentration)			
	MEAN	**MEDIAN**	**TP.DESV.**	**VC**	**MEAN**	**MEDIAN**	**TP.DESV.**	**VC**
TOTAL-N (mg/L)	20,4	17,1	12	59%	10,7	9,3	7,8	73%
N-NH4+ (mg/L)	14,2	11,9	9,7	68%	7,7	6,2	7,6	98%
COD (mg/L)	829	672	520	63%	387	253	260	67%
TOTAL –P (mg/L)	4,8	4,9	2,8	58%	2,3	2,1	1,3	57%
BOD5 (mg/L)	375	306	216	58%	171	140	112	65%
TSS (mg/L)	639	337	445	70%	293	267	168	57%
pH	7,2	6,9	0,5	7%	6,9	6,8	0,4	5%
EC (µs/cm)	498	498	168	34%	357	346	138	39%
TURBIDITY (NFU)	221	139	134	61%	120	99	57	47%

As can be seen in the table above, the values of the CSO discharges in terms of Event Mean Concentration (EMC) for BOD5 are about 140 mg/L, and ammonium of the order 6,2 mg/L. Maximum concentrations are even worse.

The following figure shows the location of the 34 storm tanks in Madrid's sewerage system.

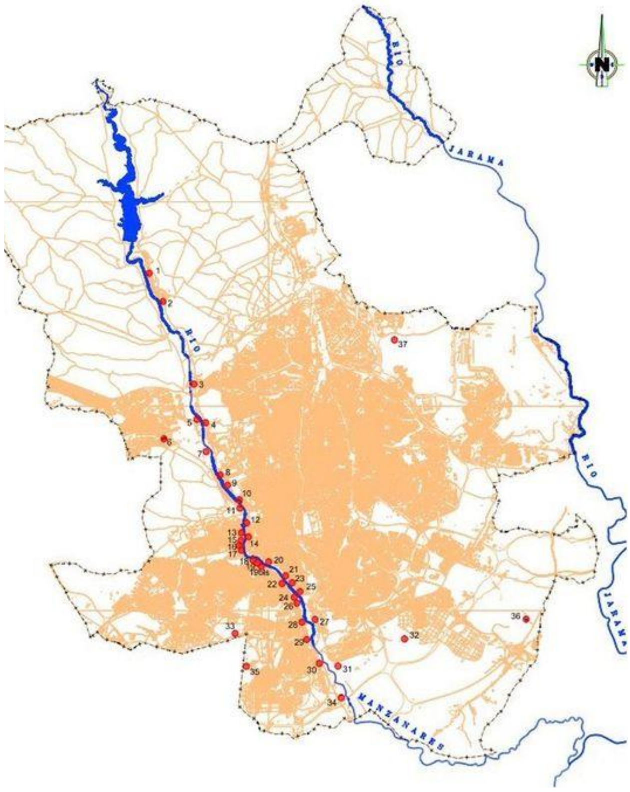

Figure 65.- CSO discharge points on the Manzanares River.

6.4 River water quality monitoring stations in the project area

6.4.1 Networks for water body monitoring

The main objective of surface water monitoring programs is to generate the necessary information for effective management of the status of water bodies. They constitute a basic tool for river basin managers as monitoring data can be used to determine the effectiveness of the measures adopted and the degree of compliance with the objectives fixed by the hydrological planning.

In the following figures the main monitoring stations available in Manzanares river area of interest for physico-cheminal and biological characterization and river discharge gauging are shown. Monitoring stations upstream and downstream of the study area are marked with a red circle.

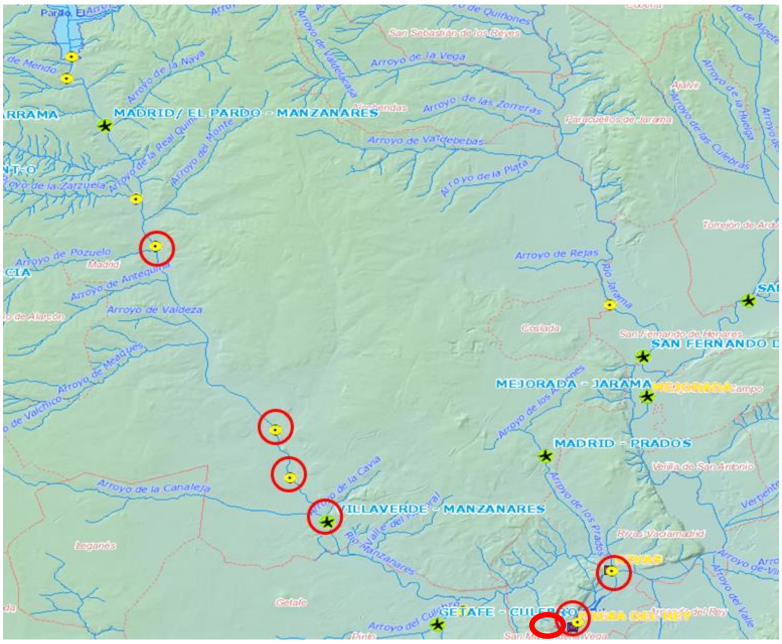

Figure 66.- Control monitoring stations of physicochemical and biological quality of the water bodies of the interest section in the Manzanares River.

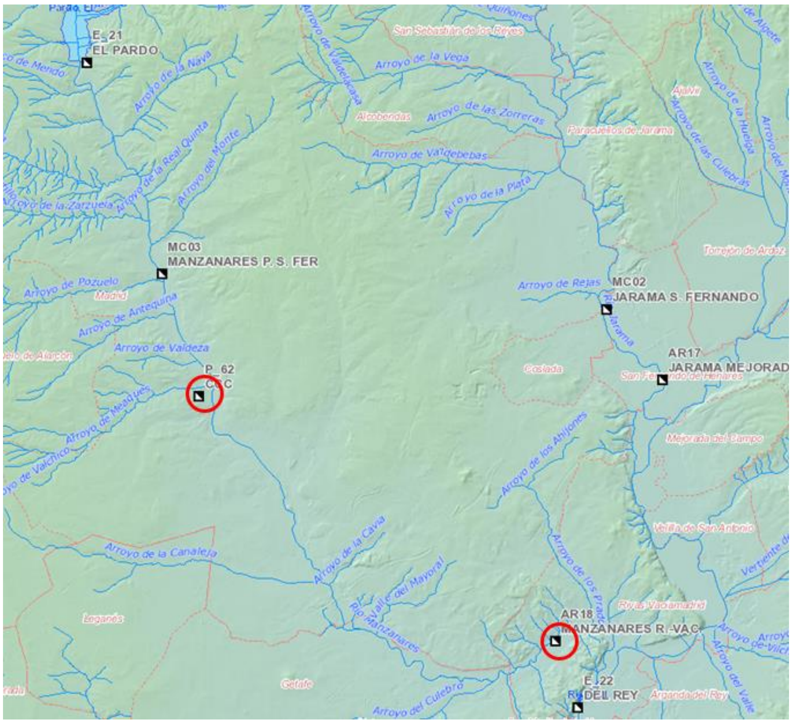

Figure 67.- Flow measurement stations of the water bodies of the interest section in the Manzanares River.

The following figure shows a sketch of the different monitoring stations in the study area. EA and SAIH stations are for flow gauging records, ICA stations are periodic water quality sampling points, and SAICA stations records water quality parameters, as it will be describe in the following section.

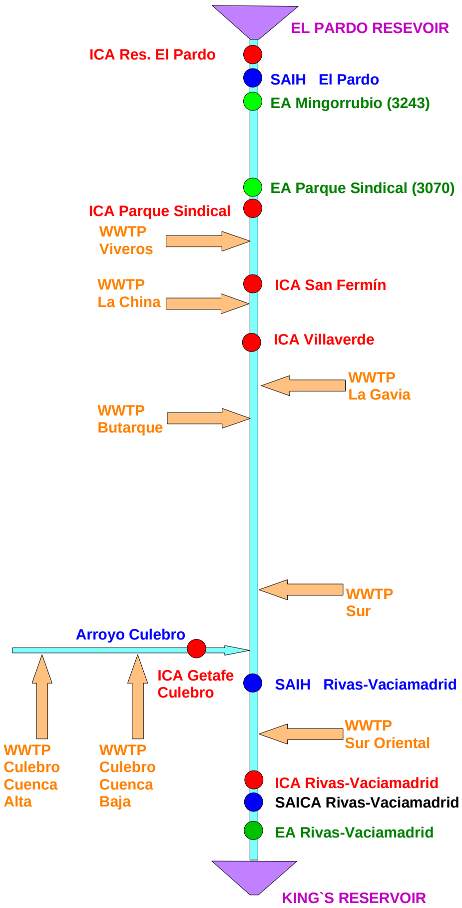

Figure 68.- Sketch showing the location of the WWTPs and the water quality and flow control stations.

6.4.2 SAICA Stations

The Automatic Water Quality Information System (SAICA) is Spanish nationwide monitoring network running since 1993. SAICA monitoring stations provide water quality information in real time with a sampling period of 15 minutes. For the study area, the information of SAICA network is available through http://saicaweb.chtajo.es/saica/. As it can be seen in Figure 69, Rivas is the monitoring station that can provide information relevant to the project. Some examples of data retrieved from this monitoring station are shown below.

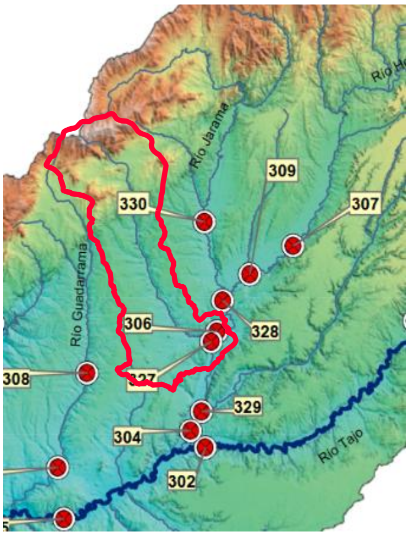

Figure 69.- Location of the SAICA stations on the Manzanares River. The RIVAS station (306) is monitors the river downstream Madrid city.

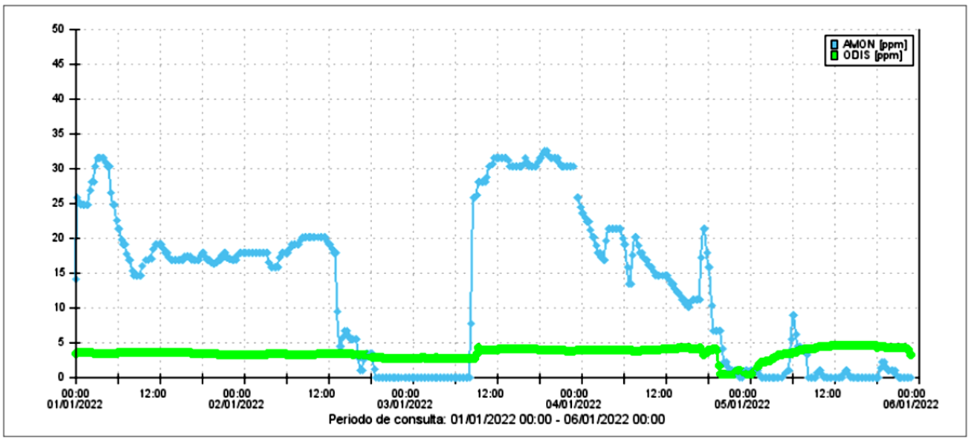

Figure 70.- Example of dissolved oxygen (green) and ammonium (blue) timeseries at Rivas Station (January-June 2022)

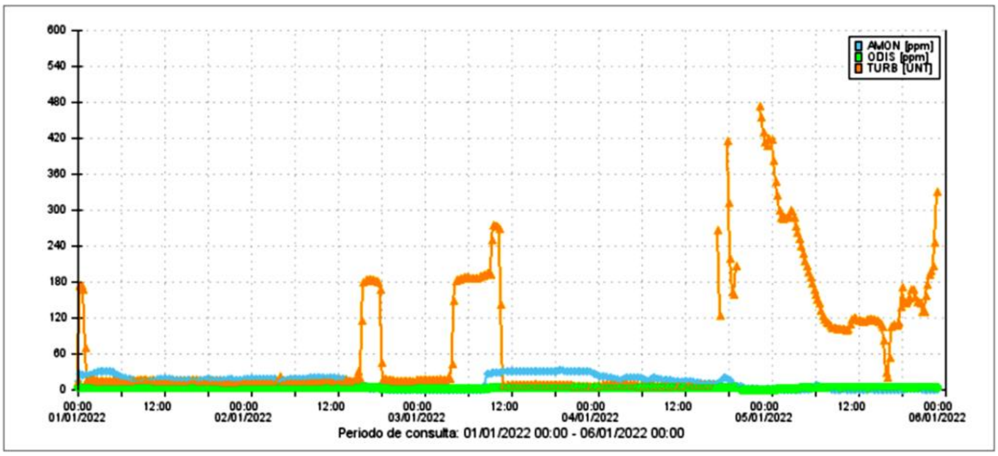

Figure 71.- Example of dissolved oxygen (green), ammonium (blue) and turbidity (orange) timeseries at Rivas Station (January-June 2022)

Ammonium concentrations exceed even the less rigorous objectives (relaxation of the limit allowed by legislation when disproportionate costs are involved) set at 10 mg/L in Hydrological Planning (RD 1/2016). Furthermore, recorded values exceeds dramatically the reference threshold concentrations fixed at 0,6 mg/L for Manzanares river water body (RD817/2015). It can be stated that treated wastewater spills in dry weather conditions, and partially treated and CSO spills in wet weather conditions affects dozens of kilometers downstream Madrid city, affecting the Jarama river and the main axis of the Tagus River.

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 70.
- Ammonium concentrations upstream el Pardo reservoir are below 0,1 mg/L and in Rivas monitoring station range from 5 to 25 mg/L.
- Ammonium concentrations in CSO spill from different CSO tanks in Madrid city are on average about 6 mg/L, with maximum values of 12 mg/L (median value).

6.5 Scope of the Manzanares river reach and river quality control sections

As described in chapter 2.1 the pilot site is located in the downstream part of the Manzanares sewer system (Figure 1 and Figure 2) and the set of infrastructures on which the optimisation strategy will focus comprises La Gavia WWTP, Butarque WWTP, and Oliva, Abroñigales and Butarque stormwater tanks covering a river reach of about 3.5 km (Figure 72).

From the point of view of assessing the improvements that would be observed in the river reach as a result of the operation and management of effluents from WWTPs and CSO tanks, it is necessary to establish an upstream reference control point and a number of downstream reference control points.

Figure 72.- Sketch of the main section of interest where the infrastructures to be intervened in this project are concentrated.

Upstream reference point will be set upstream of Oliva CSO tank and downstream of La China WWTP. In this area there is a periodic sampling water quality station called "ICA Villaverde - Station 66". It will be of great interest to collect and analyze all the historical information of this monitoring section. However, for the interests and objectives of the project it is considered necessary to install a probe for the continuous measurement of different water quality parameters during the monitoring period.

About 5.5 km downstream of the set of infrastructures covered by the project is Sur WWTP, which also forms part of Madrid's sewerage infrastructures and is interconnected with the previous ones, as it receives the excess flow not treated by the previous WWTPs. So the river reach downstream between Butarque and Sur WWTP is mainly affected by Butarque WWTP (placed downstream of the drainage system pilot area).

Thus, it is of great interest to measure the water quality downstream of Butarque WWTP spill. Two possibilities can be considered. The first would be to set up a control section in the vicinity of this discharge (at a suitable distance to ensure complete mixing), and the second would be to set up a control section downstream, in the vicinity of the Sur WWTP, before the discharge of its effluent.

This second option would allow a certain evolution of the water quality of the river to be known, and also a certain "damping" of the intermittent point-discharges from CSO tanks and WWTP by-pass discharges. At these two points it is also considered of interest to install and operate a multi-parameter water quality probe. The continuous monitoring station in the vicinity or inside the WWTP could benefit from operational support.

The next control section with continuous measurement of water quality parameters is the existing monitoring station at Rivas, located 13 km downstream of the Sur WWTP (18,5 km from Butarque), but in this case it has already received the waters of the Arroyo Culebro (with the influence of two large WWTP), 9 km downstream of the South WWTP, and the discharge from the Sur East WWTP. Between the two end control sections there are about 9 km.

As a summary:

- 3 river monitoring control sections (RMCS) 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
    - I n Sur WWTP upstream of its effluent.
- In each one of those sections a probe for the continuous quality measurement
    - 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. These are RMCS1 and RMCS2
    - The one in RMCS3 will be rented and installed to assess the river quality during the monitoring period of the Rubies project.
- There is also a secondary interest reach (longer downstream of the previous one)

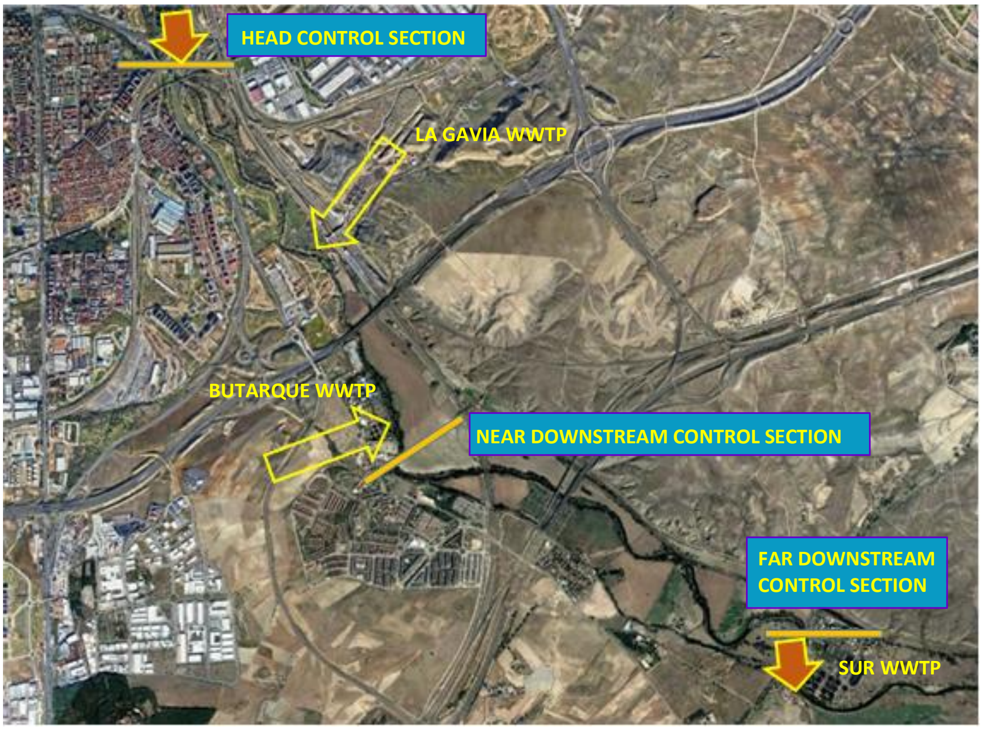

Figure 73.- Planned river quality control sections.

Figure below shows an sketch with the reference available control stations and the proposed monitoring stations for the project.

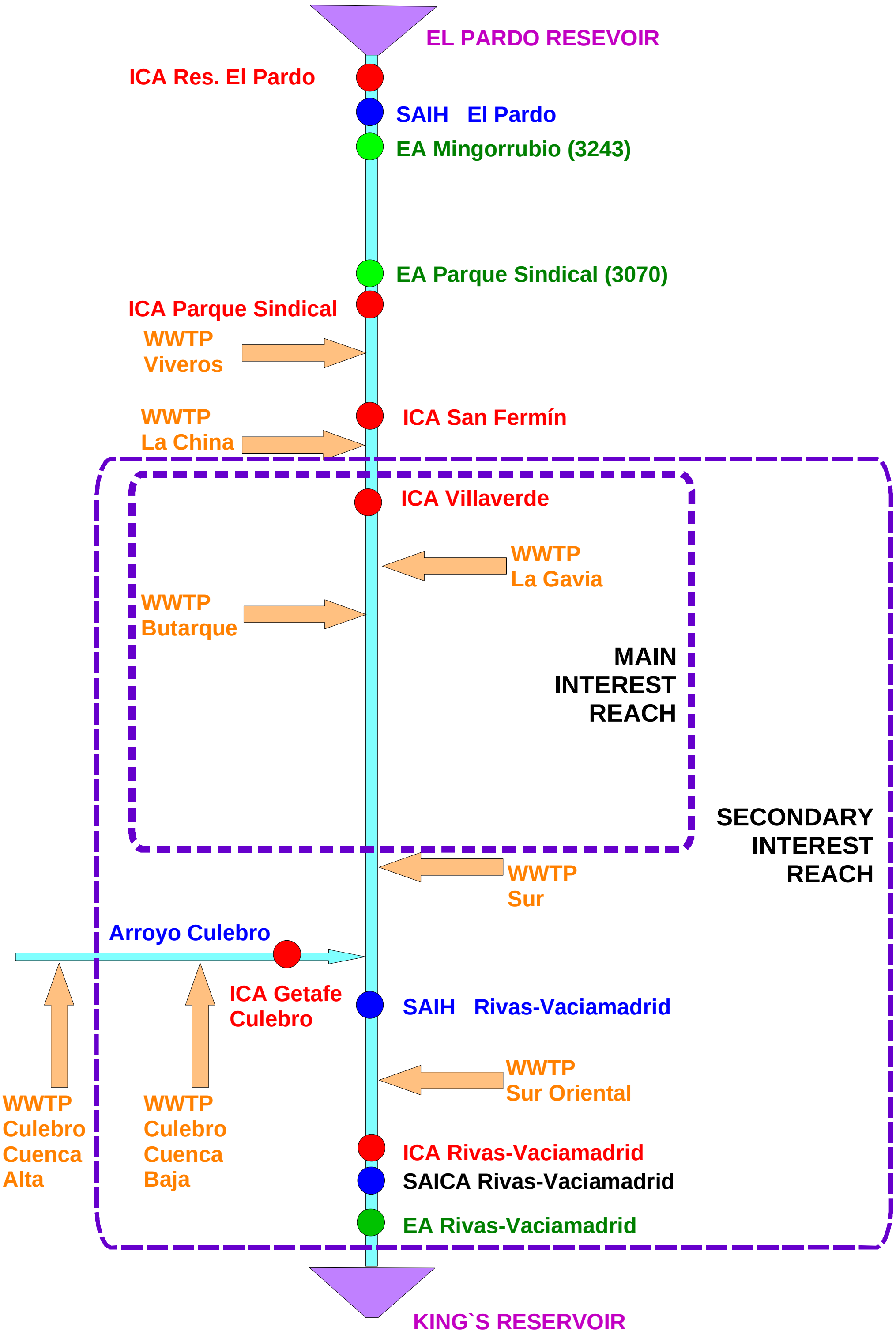

Figure 74.- Sketch with the main river control sections, existing stations and WTTPs in the framework of the analyzed area.

6.6 Activities for the river environmental impact assessment

The following subchapters will describe the planned activities for the evaluation of the environmental river improvements.

The previous chapters have highlighted the poor quality of the aquatic ecosystem of the body of water of interest, which is under great pressure from the discharges from the WWTPs and the CSOs. The environmental problems are both acute and chronic (or cumulative).

The pollutants discharged (BOD, COD, ammonium and nutrients), cause an unacceptable oxygen depletion (BOD, COD), toxic values for aquatic life (ammonium) and accumulated nutrient loads promote eutrophication problems in water bodies downstream of Madrid city.

Environmental assessment can be carried out either by the reduction of physico-chemical pollutants concentrations (both in dry and wet weather flow periods), or by the total reduction of pollutant loads (mass) of some specific pollutants. These values can be obtained from direct river sensor measurements (comparing the values at the beginning of the project with the ones recorded at the end once the AQDV UD with RTC control is implemented) or by numerical modelling.

The two options will be used although more consistent conclusions are expected by numerical modelling. In this case, as the scenario involves continuous dry-weather WWTP spills and variable -intermitent- CSO and WWTP spills in wet-weather, the model should be able to analyze variable flows. For this approach, both Iber (http://www.iberaula.es/) and HEC-RAS (https://www.hec.usace.army.mil/software/hec-ras/) software can be considered.

Iber and HEC-RAS are able to simulate non-steady flows in rivers using 2D shallow water modelling. Hydrodynamic modules are linked in both codes with water quality routines to simulate dissolved oxygen concentrations in the river reach as a function of water temperature, salinity, surficial aeration and oxygen depletion. Oxygen depletion depends on organic matter consumption and nitrogren processes mainly.

6.6.1 Compilation of information and preliminary diagnosis

Environmental river assessment requires prior work to gather information to perform an in-depth preliminary diagnosis and also to define the following steps in the analysis. After this initial analysis a better definition of the river control monitoring stations can be defined, both in terms of their representativeness (data accuracy) and their ease of operation over a long period of time.

The required steps for the definition of the preliminary analysis will consist on collecting the following data:

- River data: Definition of the riverbed and river floodplains (river topography, bathimetry, roughness coefficients), time-series of flow discharges and selected pollutants.
- Pressures: WWTP effluent characterization (flow discharges, pollutographs in wet- and dry-weather flow conditions), CSO characterization (flow discharges, pollutographs)

- Other climatic data: air temperature, water temperature, rainfall

6.6.2 River quality monitoring

As suggested in the previous section, the methodology involves the installation of 2 or 3 control sections with continuous measurement of water quality parameters. Multiparametric probes will be installed, either submerged in the river or off-line, fed by a pump.

In the control sections it is considered of interest to measure ammonium, dissolved oxygen, turbidity/SS, EC (conductivity), temperature and pH. From the analysis of historical values recorded at the monitoring stations placed in the river, a correlation analysis will be performed to determine regression analysis of BOD5 and COD concentrations with on-line measurements.

Field campaigns will involve the following main activities:

- Preparation of campaigns and control sections:
  - Selection of monitoring sections and preparation of measuring stations.
  - Installation of auxiliary services (electricity, water, security, health and safety issues,...).
  - Installation of sensors.
  - Calibration of sensors.
- Exploitation: operation and maintenance
  - Definition of an operating plan for the section (frequency of data recording, cleaning, recalibration, data retrieval, etc.).
  - Data pre-processing and data validation
  - Data analysis: event parametrization, creation of a database of events.
  - Data assessment and milestones supervision.

6.6.3 Water quality model development

Numerical model will be developed using the proposed software Iber or HEC-RAS. Both models have high computational quality in terms of the hydraulic model and the quality model, and integrate numerous kinetics and relationships for physico-chemical parameters of water quality. However, is mandatory to calibrate and validate the models with field data to ensure truly credible and useful model outputs. Otherwise their predictive capacity to make good decisions based on evidence is almost zero (or at least uncertain). In the following paragraphs we propose in a schematic form, a methodology for the development of the Manzares river reach water quality model.

As stated before, numerical models consist, in a simplistic way, of two fundamental sub-models: the hydraulic model and the water quality model. The calibration and validation of the sub-models involves the availability of hydraulic quality data (flow rates and dispersion phenomena) and water quality/pollution data, both for the river being modelled and for tributaries and discharges.

Once a calibrated and validated model has been developed, it is possible to proceed to test different scenarios that simulate critical water quality conditions and different strategies to improve it. The numerical model domain will be set between the reach upstream control section -downstream of the La China WWTP-, and downstream section -placed upstream of Sur WWTP spill-. As previously mentioned, after the preliminary data assessment model domain will be fixed in detail.

The methodology for the "construction" of a water quality model adapted to a river is presented in the following table:

Table 14.- Methodology for the elaboration of theriver water quality model.

METHODOLOGICAL PROPOSAL FOR THE ELABORATION OF A P-Q WATER QUALITY MODEL FOR THE RIVER SECTION OF INTEREST.
Phase 1.- SETTING OBJECTIVES
Phase 2.- COLLECTING BASELINE INFORMATION OF THE AQUATIC SYSTEM AND ITS CONTEXT
➢ Collection and analysis of historical data (old quality campaigns, data from gauging or quality control stations, in operation or abandoned, ...). ➢ Recognition of significant pressures (mainly point discharges, either of treated or untreated water, both in dry and wet weather...; there could also be significant diffuse background pollution due to agricultural, livestock or industrial activities). ➢ Assessment of the watetr quality problems and analysis of the incidence of the different pressures. Identification of discharges to be taken into account in the model. ➢ Definition of the simulation strategy (spatial and temporalSelection of parameters to be modeled. It must be decided which physical-chemical parameters are of interest to correctly analyze the functioning of the river and the influence of the different discharges.
Phase 3.- SELECTION OF THE MODELING TOOL
➢ Selection of the numerical water quality simulation model.
Phase 4.- CONCEPTUALIZATION OF THE RIVER REACH DOMAIN
➢ Definition of the river reach to be modeled. ➢ Establishment of the geometry and roughness coefficients. ➢ Definition of boundary conditions and initial conditions: o Definition of hydraulic conditions (wet and dry weather) o Selection of most important pressures. o Definition of pollution mass inflows and outflows.

➢ Adaptation of the previous information to the requirements and data structure of the numerical model.
Phase 5.- PREMODEL ELABORATION
➢ Selection of model variables (kinetic constants) from similar rivers and from the literature. ➢ Qualitative sensitivity analysis.
Phase 6.- ELABORATION OF A CALIBRATED MODEL
➢ Based on field campaigns and historical information: configuration of the "calibration scenario". o Hydrological-hydraulic campaigns. o Water quality/pollution campaigns. o Interpretation and assessment of field campaigns results. o Calibration of kinetic parameters of the water quality sub-models. ➢ Evaluation of the calibrated model.
Phase 7.- ELABORATION OF A VALIDATED MODEL
➢ Based on field campaign: configuration of the "validation scenario". o Hydrological-hydraulic campaigns. o Water quality/pollution campaigns. o Interpretation and assessment of field campaigns results. o Calibration of kinetic parameters of the water quality sub-models. ➢ Validation of the calibrated model.
Phase 8.- APPLICATION OF THE RIVER MODEL
➢ Definition of scenarios of interest. ➢ Definition of assessment scenarios. ➢ Performance of simulations. ➢ Assessment of the fulfillment of objectives.

This methodology, especially the calibration and validation phases, is highly conditioned by field campaigns.

6.6.4 Assessment of the improvements and the impacts reduction

This assessment will follow the two previously mentioned approaches:

➢ Evaluation based on field campaign data

The records from probes installed at the control points downstream of the set of infrastructures of the area of interest will be used to assess whether improvements in water quality are noticeable in rainy periods. Specific events involving data from both the WWTPs and the CSOs spills will be analysed during the project lifetime

- Evaluation based on water quality modelling

  The objective of carrying out the water quality model is to take advantage of its potential to generate specific scenarios of interest. In the case of the River Manzanares it is proposed to analyse the following scenarios:

  - Scenario 1.- Dry weather to estimate influence of WWTP in river quality
    - E1.1. - River reach with different flow rates (low and average) and WWTP effluents in the current situation.
    - E1.2.- River reach with different flow rates (low and average) and WWTP effluents assuming a reduction of nutrient loads.
    - E1.3.- River reach with different flow rates (low and average) and WWTP effluents fixed to meet the physico-chemical water quality objectives of the water body.
  - Scenario 2.- Wet weather to estimate the influence of WWTP in river quality
    - E2.1.- River reach with different flow rates, WWTP effluents in the current situation and CSO discharges. At least two scenarios will be defined with different rainfall records.
    - E2.2.- River reach with different flow rates, WWTP effluents assuming a reduction of nutrient loads and CSO discharges. At least two scenarios will be defined with different rainfall records.
    - E2.3.- River reach with different flow rates, WWTP effluents fixed to meet the physico-chemical water quality objectives of the water body and CSO discharges. At least two scenarios will be defined with different rainfall records.
  - Scenario 3.- Wet weather to estimate the impact of AQDV UD optimization in the river quality
    - E3.1.- River reach with different flow rates, WWTP in the current situation and CSO discharges and WWTP computed assuming AQDV UD operation. At least two scenarios will be defined with different rainfall records.
    - E3.2.- River reach with different flow rates, WWTP effluents assuming a reduction of nutrient loads and CSO discharges and WWTP computed assuming AQDV UD operation. At least two scenarios will be defined with different rainfall records.
    - E3.3.- River reach with different flow rates, WWTP effluents fixed to meet the physico-chemical water quality objectives of the water body

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and CSO discharges and WWTP computed assuming AQDV UD operation. At least two scenarios will be defined with different rainfall records.

7 LIFE RUBIES deployment and demonstration schedule

7.1 General schedule for task B03. Spanish Pilot site deployment operation

The tasks that have been described in the previous chapters of this deliverable are scheduled in Figure 75 and in the next figures a detailed schedule for each task is included.

Also, in the next subchapter a short description of each subtask is provided.

7.2 Detailed task description

7.2.1 B03.1 Deployment of instrumentation

This first tasks include the installation of the required sensors for sewer operation described in chapter 3.1 (rain gauges, water level sensors, and turbidimeters) as well as the monitoring campaigns defined in chapter 3.2

The planned subtasks are:

- B03.1.1 Detailed analysis of existing instrumentation and data available (sewer + WWTP)
- B03.1.2 Detailed study to define key locations to install sensors
- B03.1.3 2 Rain gauges, 5 Water level and 5 turbidimeter installation (including communications for real time connection)
- B03.1.4 Water sampler installation and monitoring campaigns
    - B03.1.4.1 3 water sampler campaigns for turbidity correlation
    - B03.1.4.2 2 (+1) water sampler campaigns for turbidity correlation

We will have 3 water samplers so the monitoring campaign is planned in two time slots of 6 months duration each one, so in the first one 3 locations will be monitored and in the second one the other 2, and in case a water sampler from the first time stamp does not work properly or the monitoring campaign takes longer than expected we can always overlap one monitoring location with the second time slot. Of course, we have planned 6 months duration for each one, but it could be longer specially for the wet weather flow campaigns where we depend on the rainy days.

7.2.2 Deployment of AQDV UD environment

This is where we implement different versions of the AQDV UD. 3 versions are planned to be installed although the first one (monitoring) is not critical and maybe it could be avoided and directly install v2 version that will come from a previous task of the project (task B02)

The subtasks are listed below:

- Detailed analysis of CYII IT infrastructure, sensors, communication (sewer + WWTP)

- AQDV UD _ v1 (monitoring)
    - Installation and communications with existing sensors, actuators, radar data and rain forecasts
    - Configuration of AQDV UD monitoring
    - Communications and configuration with new sensors installed (the ones from subtask B03.1.3)
- AQDV UD _v2 (hydraulic operation) installation and communication with SCADA setpoints
    - Installation and communication with SCADA setpoints
    - Local PLC programming to receive setpoints from AQDV UD
- AQDV UD _v3 (quality operation - Installation update). This will also require updating the communication channels with the SCADA to receive and give data related with water quality.

7.2.3 Virtual testing

This is where the different models are created and calibrated (chapter 5) and the RTC algorithms are tested before being implemented in the real environment of Canal Isabe II installations (chapter 5.4.1).

The subtasks are listed below:

- B03.3.01 Virtual testing preparation
    - B03.3.01.01 Defining IT environment, model connections and scenarios
    - B03.3.01.01 Programming IT environment
- B03.3.02 Hydraulic virtual testing
    - B03.3.02.01 Detailed hydraulic sewer model update and calibration
    - B03.3.02.02 Simplified hydraulic sewer model
    - B03.3.02.03 MPC and RBC configuration
    - B03.3.02.04 Modelling scenarios and result comparison with current operation
- B03.3.03 Quality virtual testing
    - B03.3.03.01 Detailed quality sewer model update and calibration
    - B03.3.03.02 Simplified quality sewer model
    - B03.3.03.03 WWTP model
    - B03.3.03.04 MPC and RBC configuration

- B03.3.03.05 Modelling scenarios and result comparison with current and hydraulic operation

Initial tasks related with the Virtual testing preparation (B03.3.01) are included here for consistency but in fact they are developed in action B02.

7.2.4 Real testing and operation

Once the RTC solution is tested and validated in a virtual environment first based only in hydraulic parameters and later including quality, the solution is tested in the real world (description provided in chapter 5.4.2). Again, this step is done first implementing the hydraulic solution and later on the quality part. Each one is done in a 2 steps approach, first the setpoints provided by AQDV UD will require human operator validation, and once we are all confident with the decisions taken by the system, then it will be configured to operate without human validation.

The subtasks are listed below:

- B03.4.01 Hydraulic operation real testing
  - B03.4.01.01 Configuration and testing (setpoint validation by operators)
  - B03.4.01.02 Configuration and testing (autonomous operation)
- B03.4.02 Quality operation real testing
  - B03.4.02.01 Configuration and testing (setpoint validation by operators)
  - B03.4.02.02 Configuration and testing (autonomous operation)

The real operation of the solution configured will continue beyond the LIFE Rubies project duration but at month 39 results of this operation will be analyzed in order to compute the different KPI required to validate the solution.

7.2.5 River environmental impact assessment

Finally, we schedule this task although in the project proposal corresponds to action B05. This is where the work for the Manzanares river environmental assessment is planned (chapter 6.6).

The subtasks are listed below:

- B03.5.01 Compilation of information and preliminary diagnosis
- B03.5.02 Field campaigns to monitor the water quality of the river reach.
  - B03.5.02.01 Preparation of campaigns and control sections
  - B03.5.02.02 Exploitation: operation and maintenance
- B03.5.03 Water quality model development
  - B03.5.03.01 Setting objectives
  - B03.5.03.02 Collecting baseline information of the aquatic system and its context

- B03.5.03.03 Selection of the modelling tool
- B03.5.03.04 Conceptualization of the river domain
- B03.5.03.05 Premodel elaboration
- B03.5.03.06 Elaboration of a calibrated model
- B03.5.03.07 Elaboration of a validated model
- B03.5.03.08 Application of the river model

- B03.5.04 Assessment of the improvements and the reduction of impacts
    - B03.5.04.01 Evaluation based on field campaigns
    - B03.5.04.02 Evaluation based on water quality modelling (scenarios and results)

Figure 75.- Action B03 Spanish Pilot Site deployment operation general schedule

ACTION B03	Spanish Pilot Site deployment operation	Start M	End M	Year 1												Year 2												Year 3												Year 4											
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
				01/10/2021	01/11/2021	01/12/2021	01/01/2022	01/02/2022	01/03/2022	01/04/2022	01/05/2022	01/06/2022	01/07/2022	01/08/2022	01/09/2022	01/10/2022	01/11/2022	01/12/2022	01/01/2023	01/02/2023	01/03/2023	01/04/2023	01/05/2023	01/06/2023	01/07/2023	01/08/2023	01/09/2023	01/10/2023	01/11/2023	01/12/2023	01/01/2024	01/02/2024	01/03/2024	01/04/2024	01/05/2024	01/06/2024	01/07/2024	01/08/2024	01/09/2024	01/10/2024	01/11/2024	01/12/2024	01/01/2025	01/02/2025	01/03/2025	01/04/2025	01/05/2025	01/06/2025	01/07/2025	01/08/2025	01/09/2025
B03.1	Deployment of instrumentation	7	24																																																
B03.2	Deployment of AQDV UD environment	7	35																																																
B03.3	Virtual testing	8	31																																																
B03.4	Real testing and operation	20	42																																																
B03.5	River environmental impact assessment	8	40																																																

Figure 76.- Detailed task description for task B03.1 Deployment of instrumentation

B03.1	Deployment of instrumentation	Start M	End M	Year 1												Year 2												Year 3												Year 4											
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
				01/10/2021	01/11/2021	01/12/2021	01/01/2022	01/02/2022	01/03/2022	01/04/2022	01/05/2022	01/06/2022	01/07/2022	01/08/2022	01/09/2022	01/10/2022	01/11/2022	01/12/2022	01/01/2023	01/02/2023	01/03/2023	01/04/2023	01/05/2023	01/06/2023	01/07/2023	01/08/2023	01/09/2023	01/10/2023	01/11/2023	01/12/2023	01/01/2024	01/02/2024	01/03/2024	01/04/2024	01/05/2024	01/06/2024	01/07/2024	01/08/2024	01/09/2024	01/10/2024	01/11/2024	01/12/2024	01/01/2025	01/02/2025	01/03/2025	01/04/2025	01/05/2025	01/06/2025	01/07/2025	01/08/2025	01/09/2025
B03.1.01	Detailed analysis of existing instrumentation and data available (sewer + W	7	8																																																
B03.1.02	Detailed study to define key locations to install sensors	9	10																																																
B03.1.03	2 Rain gauges, 5 Water level and 5 turbidimeter installation (including com	10	14																																																
B03.1.04	Water sampler installation and monitoring campaigns	13	24																																																
B03.1.04.01	3 water samplers campaigns for turbidity correlation	13	18																																																
B03.1.04.02	2 (+1) water samplers campaigns for turbidity correlation	19	24																																																
B03.1	**Deployment of instrumentation**	7	24																																																

Figure 77.- Detailed task description for task B03.2 Deployment of AQDV UD environment

B03.2	Deployment of AQDV UD environment	Start M	End M	Year 1 1 01/10/2021	2 01/11/2021	3 01/12/2021	4 01/01/2022	5 01/02/2022	6 01/03/2022	7 01/04/2022	8 01/05/2022	9 01/06/2022	10 01/07/2022	11 01/08/2022	12 01/09/2022	Year 2 13 01/10/2022	14 01/11/2022	15 01/12/2022	16 01/01/2023	17 01/02/2023	18 01/03/2023	19 01/04/2023	20 01/05/2023	21 01/06/2023	22 01/07/2023	23 01/08/2023	24 01/09/2023	Year 3 25 01/10/2023	26 01/11/2023	27 01/12/2023	28 01/01/2024	29 01/02/2024	30 01/03/2024	31 01/04/2024	32 01/05/2024	33 01/06/2024	34 01/07/2024	35 01/08/2024	36 01/09/2024	Year 4 37 01/10/2024	38 01/11/2024	39 01/12/2024	40 01/01/2025	41 01/02/2025	42 01/03/2025	43 01/04/2025	44 01/05/2025	45 01/06/2025	46 01/07/2025	47 01/08/2025	48 01/09/2025
B03.2.01	Detailed analysis of CYII IT infrastructure, sensors, communication (sewer +	**7**	**9**																																																
B03.2.02	AQDV UD _v1 (monitoring)	**8**	**15**																																																
B03.2.01.01	Installation and communications with existing sensors, actuators, radar da	8	12																																																
B03.2.01.02	Configuration of AQDV UD monitoring	11	14																																																
B03.2.01.03	Communications and configuration with new sensors	15	15																																																
B03.2.03	AQDV UD _v2 (hydraulic operation) installation and communication with SC	**10**	**24**																																																
B03.2.03.01	Installation and communication with SCADA setpoints	10	21																																																
B03.2.03.02	Local PLC programming to receive setpoints from AQDV UD	16	24																																																
B03.2.04	AQDV UD _v3 (quality operation - Installation update??)	**27**	**35**																																																
B03.2	**Deployment of AQDV UD environment**	7	35																																																

Figure 78.- Detailed task description for task B03.3 Virtual testing

B03.3	Virtual testing	Start M	End M	Year 1 1 01/10/2021	2 01/11/2021	3 01/12/2021	4 01/01/2022	5 01/02/2022	6 01/03/2022	7 01/04/2022	8 01/05/2022	9 01/06/2022	10 01/07/2022	11 01/08/2022	12 01/09/2022	Year 2 13 01/10/2022	14 01/11/2022	15 01/12/2022	16 01/01/2023	17 01/02/2023	18 01/03/2023	19 01/04/2023	20 01/05/2023	21 01/06/2023	22 01/07/2023	23 01/08/2023	24 01/09/2023	Year 3 25 01/10/2023	26 01/11/2023	27 01/12/2023	28 01/01/2024	29 01/02/2024	30 01/03/2024	31 01/04/2024	32 01/05/2024	33 01/06/2024	34 01/07/2024	35 01/08/2024	36 01/09/2024	Year 4 37 01/10/2024	38 01/11/2024	39 01/12/2024	40 01/01/2025	41 01/02/2025	42 01/03/2025	43 01/04/2025	44 01/05/2025	45 01/06/2025	46 01/07/2025	47 01/08/2025	48 01/09/2025
B03.3.01	Virtual testing preparation	**10**	**18**																																																
B03.3.01.01	Defining IT environment, model connections and scenarios	10	13																																																
B03.3.01.01	Programming IT environment	12	18																																																
B03.3.02	Hydraulic virtual testing	**8**	**23**																																																
B03.3.02.01	Detailed hydraulic sewer model update and calibration	8	14																																																
B03.3.02.02	Simplified hydraulic sewer model	13	16																																																
B03.3.02.03	MPC and RBC configuration	17	19																																																
B03.3.02.04	Modelling scenarios and result comparison with current operation	19	23																																																
B03.3.03	Quality virtual testing	**12**	**31**																																																
B03.3.03.01	Detailed quality sewer model update and calibration	15	18																																																
B03.3.03.02	Simplified quality sewer model	17	20																																																
B03.3.03.03	WWTP model	12	25																																																
B03.3.03.04	MPC and RBC configuration	26	29																																																
B03.3.03.05	Modelling scenarios and result comparison with current and hydraulic oper	27	31																																																
B03.3	**Virtual testing**	8	31																																																

Figure 79.- Detailed task description for task B03.4 Real testing and operation

B03.4	Real testing and operation	Start M	End M
B03.4.01	Hydraulic operation real testing	**20**	**31**
B03.4.01.01	Configuration and testing (setpoint validation by operators)	20	26
B03.4.01.02	Configuration and testing (autonomous operation)	26	31
B03.4.02	Quality operation real testing	**32**	**42**
B03.4.02.01	Configuration and testing (setpoint validation by operators)	32	37
B03.4.02.02	Configuration and testing (autonomous operation)	38	42
B03.4	**Real testing and operation**	**20**	**42**

Year	Month	Date
Year 1	1	01/10/2021
	2	01/11/2021
	3	01/12/2021
	4	01/01/2022
	5	01/02/2022
	6	01/03/2022
	7	01/04/2022
	8	01/05/2022
	9	01/06/2022
	10	01/07/2022
	11	01/08/2022
	12	01/09/2022
Year 2	13	01/10/2022
	14	01/11/2022
	15	01/12/2022
	16	01/01/2023
	17	01/02/2023
	18	01/03/2023
	19	01/04/2023
	20	01/05/2023
	21	01/06/2023
	22	01/07/2023
	23	01/08/2023
	24	01/09/2023
Year 3	25	01/10/2023
	26	01/11/2023
	27	01/12/2023
	28	01/01/2024
	29	01/02/2024
	30	01/03/2024
	31	01/04/2024
	32	01/05/2024
	33	01/06/2024
	34	01/07/2024
	35	01/08/2024
	36	01/09/2024
Year 4	37	01/10/2024
	38	01/11/2024
	39	01/12/2024
	40	01/01/2025
	41	01/02/2025
	42	01/03/2025
	43	01/04/2025
	44	01/05/2025
	45	01/06/2025
	46	01/07/2025
	47	01/08/2025
	48	01/09/2025

Figure 80.- Detailed task description for task B03.5 River environmental impact assessment

B03.5	River environmental impact assessment	Start M	End M
B03.5.01	Compilation of information and preliminary diagnosis	**8**	**9**
B03.5.02	Field campaigns to monitor the water quality of the river reach.	**10**	**40**
B03.5.02.01	Preparation of campaigns and control sections	10	13
B03.5.02.02	Exploitation: operation and maintenance	14	40
B03.5.03	Water quality model development	**14**	**37**
B03.5.03.01	Setting objectives	14	16
B03.5.03.02	Collecting baseline information of the aquatic system and its context	16	19
B03.5.03.03	Selection of the modelling tool	20	20
B03.5.03.04	Conceptualization of the river domain	20	22
B03.5.03.05	Premodel elaboration	23	26
B03.5.03.06	Elaboration of a calibrated model	27	30
B03.5.03.07	Elaboration of a validated model	31	33
B03.5.03.08	Application of the river model	34	37
B03.5.04	Assessment of the improvements and the reduction of impacts	**37**	**40**
B03.5.04.01	Evaluation based on field campaigns	37	39
B03.5.04.02	Evaluation based on water quality modelling (scenarios and results)	38	40
B03.5	**River environmental impact assessment**	**8**	**40**

Year	Month	Date
Year 1	1	01/10/2021
	2	01/11/2021
	3	01/12/2021
	4	01/01/2022
	5	01/02/2022
	6	01/03/2022
	7	01/04/2022
	8	01/05/2022
	9	01/06/2022
	10	01/07/2022
	11	01/08/2022
	12	01/09/2022
Year 2	13	01/10/2022
	14	01/11/2022
	15	01/12/2022
	16	01/01/2023
	17	01/02/2023
	18	01/03/2023
	19	01/04/2023
	20	01/05/2023
	21	01/06/2023
	22	01/07/2023
	23	01/08/2023
	24	01/09/2023
Year 3	25	01/10/2023
	26	01/11/2023
	27	01/12/2023
	28	01/01/2024
	29	01/02/2024
	30	01/03/2024
	31	01/04/2024
	32	01/05/2024
	33	01/06/2024
	34	01/07/2024
	35	01/08/2024
	36	01/09/2024
Year 4	37	01/10/2024
	38	01/11/2024
	39	01/12/2024
	40	01/01/2025
	41	01/02/2025
	42	01/03/2025
	43	01/04/2025
	44	01/05/2025
	45	01/06/2025
	46	01/07/2025
	47	01/08/2025
	48	01/09/2025

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