H2OforAll

WP3 - Environmental Impacts Risk Assessment

of DBPs and Prevention Measures Analysis

Task 3.5 - Hydraulic and Quality modelling of the water distribution network

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Innovative Integrated Tools and Technologies to Protect and Treat Drinking Water from Disinfection Byproducts (DBPs)

Funded by the European Union

Under the Grant Agreement: GA101081953

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Innovative Integrated Tools and Technologies to Protect and
Treat Drinking Water from Disinfection Byproducts (DBPs)

Task 3.5 - Hydraulic and Quality modelling of the water distribution network

Task Activities

Task 3.5 – Hydraulic and quality modelling of the water distribution network

1. Selection of District Metered Areas (DMAs) to be used as a case study;
2. Collection of available water distribution network information;
3. Development of Hydraulic and Water Quality model;

    3.1. Calibration and validation of results supported by field measurements;

    3.2. Hydraulic and Water Quality modelling through several simulation scenarios.

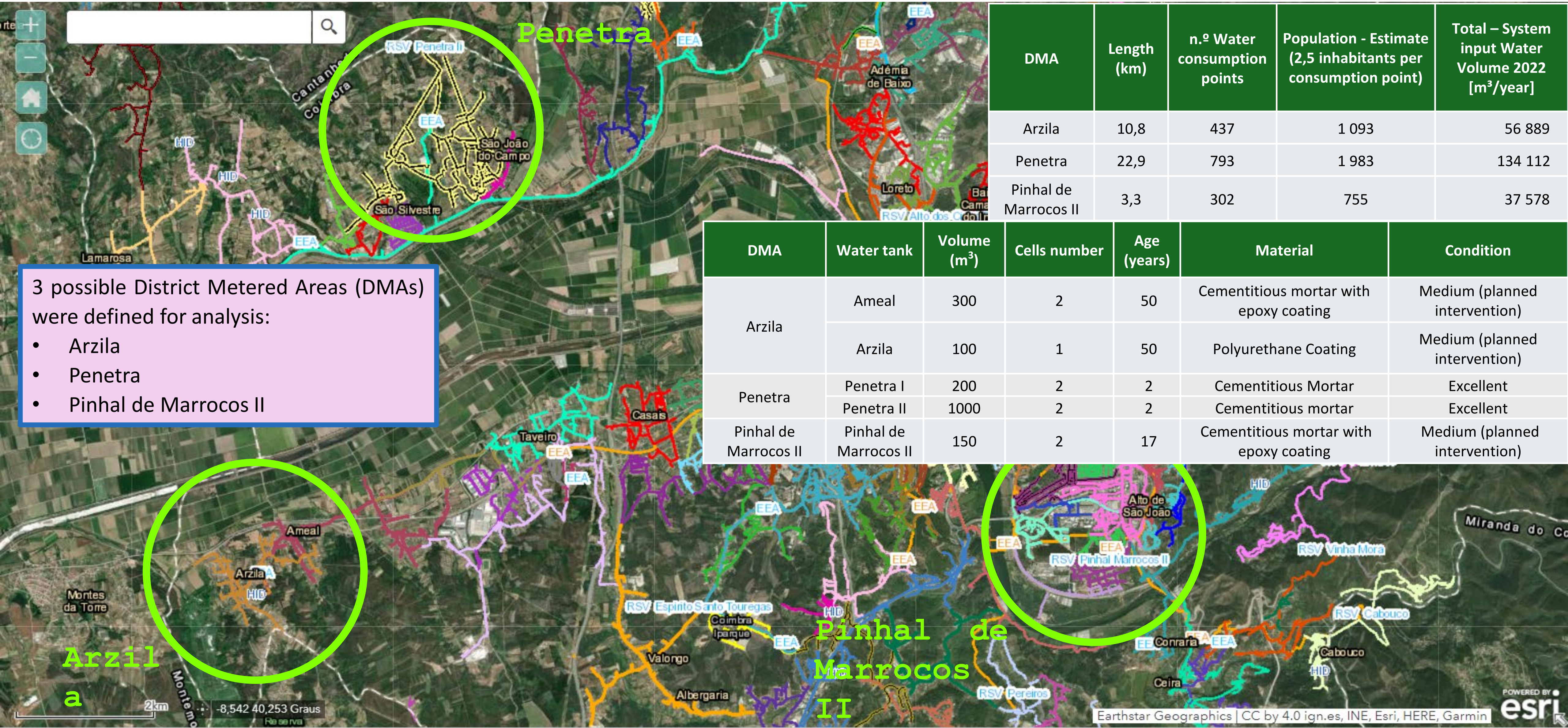
Selection of DMAs

DMA	Length (km)	n.º Water consumption points	Population - Estimate (2,5 inhabitants per consumption point)	Total – System input Water Volume 2022 [m³/year]
Arzila	10,8	437	1 093	56 889
Penetra	22,9	793	1 983	134 112
Pinhal de Marrocos II	3,3	302	755	37 578

DMA	Water tank	Volume (m^3)	Cells number	Age (years)	Material	Condition
Arzila	Ameal	300	2	50	Cementitious mortar with epoxy coating	Medium (planned intervention)
	Arzila	100	1	50	Polyurethane Coating	Medium (planned intervention)
Penetra	Penetra I	200	2	2	Cementitious Mortar	Excellent
	Penetra II	1000	2	2	Cementitious mortar	Excellent
Pinhal de Marrocos II	Pinhal de Marrocos II	150	2	17	Cementitious mortar with epoxy coating	Medium (planned intervention)

3 possible District Metered Areas (DMAs) were defined for analysis:

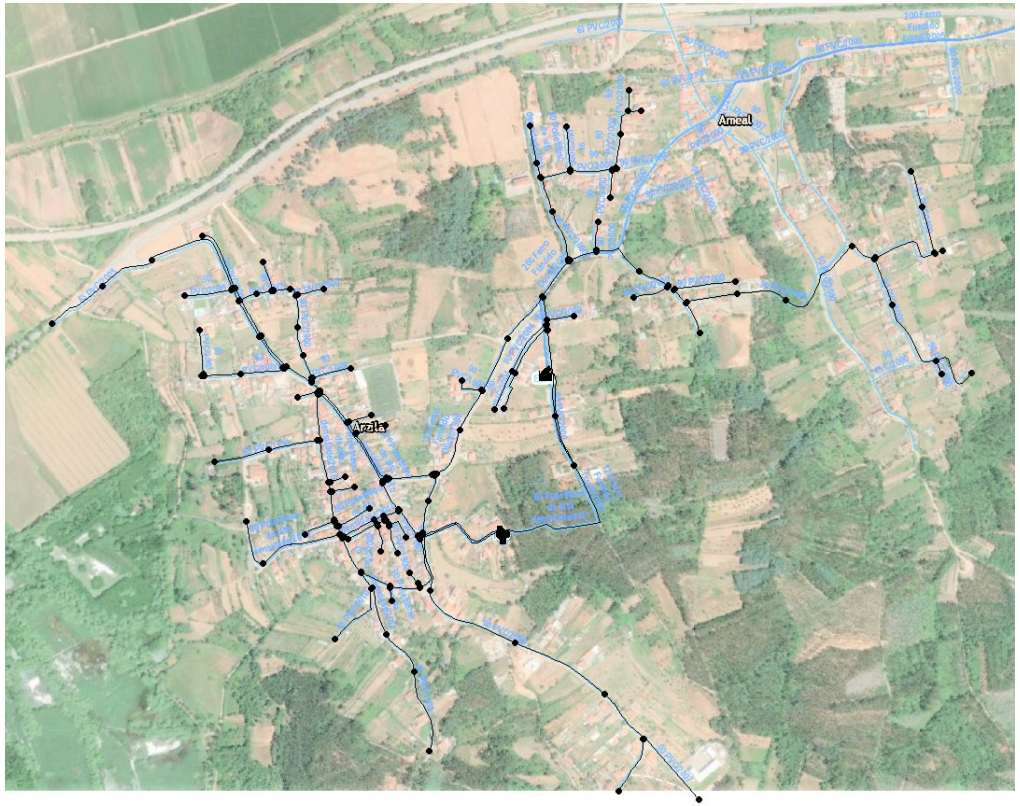
- Arzila
- Penetra
- Pinhal de Marrocos II



Collection of available information

Collection of available water distribution network information:

- Topology
- Topography
- Water consumptions
- Type of materials
- Age of pipes
- Possible degradation



Collection of available information

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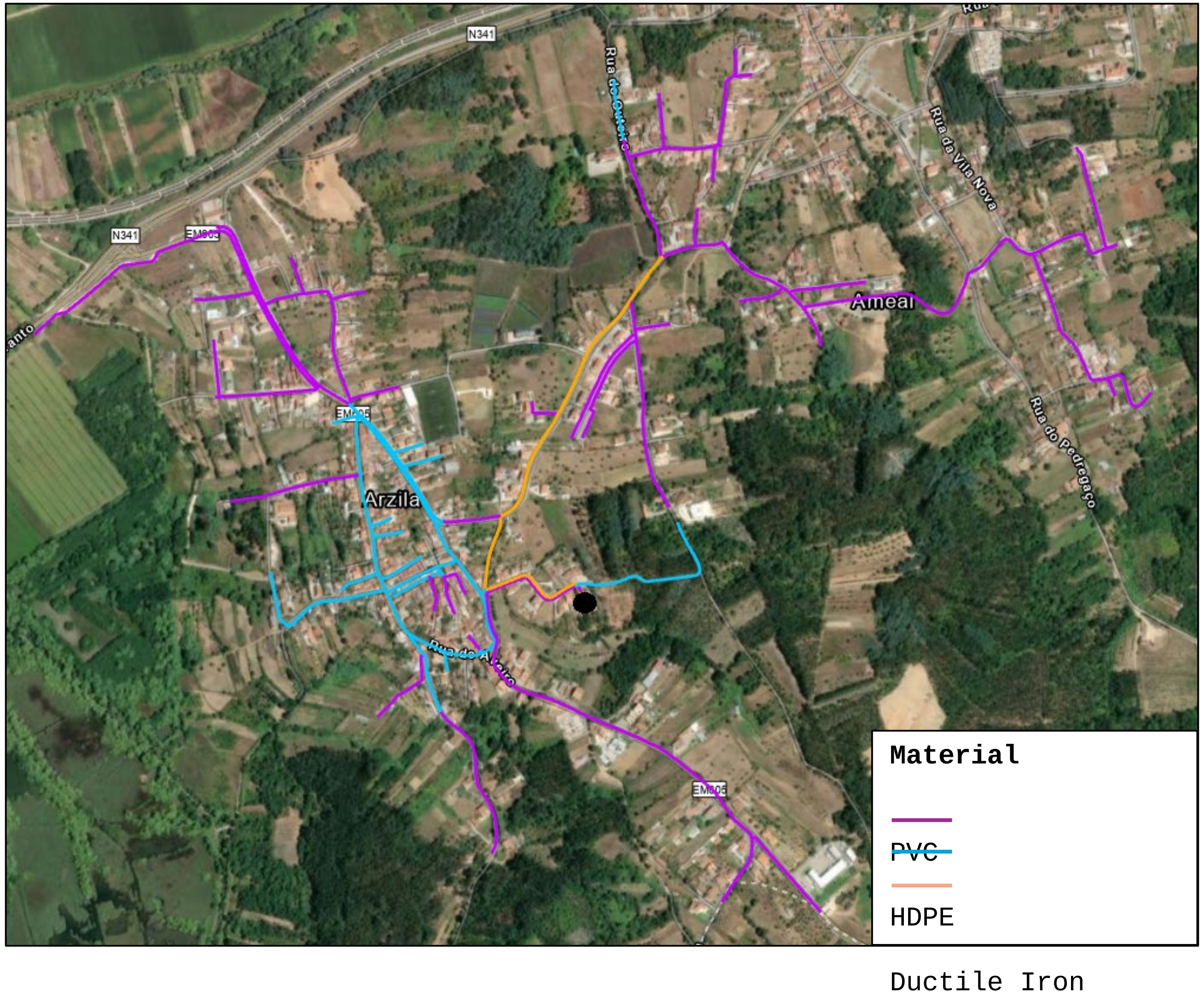
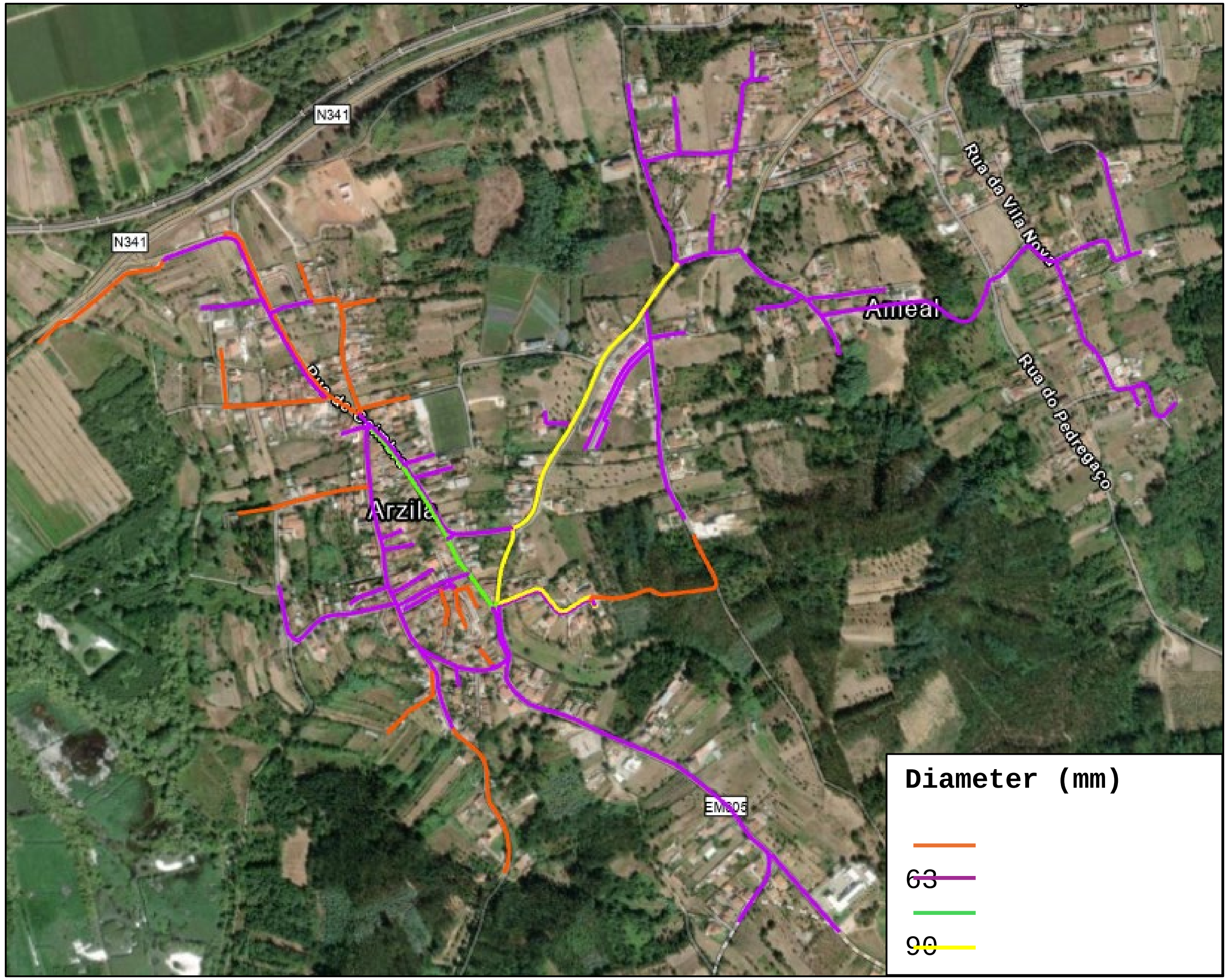
Pipe Materials – **Arzila DMA**



Collection of available information

Pipes Diameter – **Arzila DMA**



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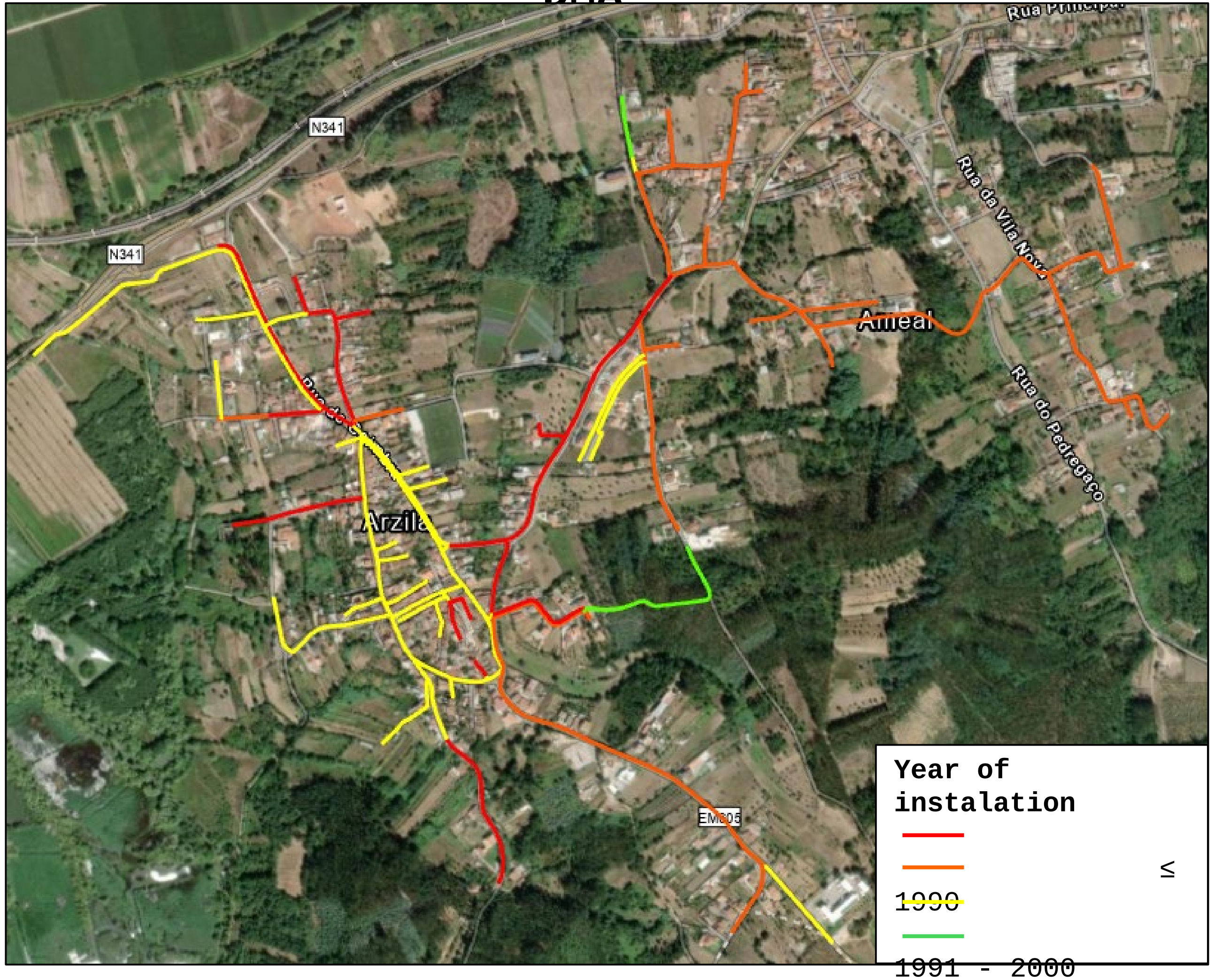
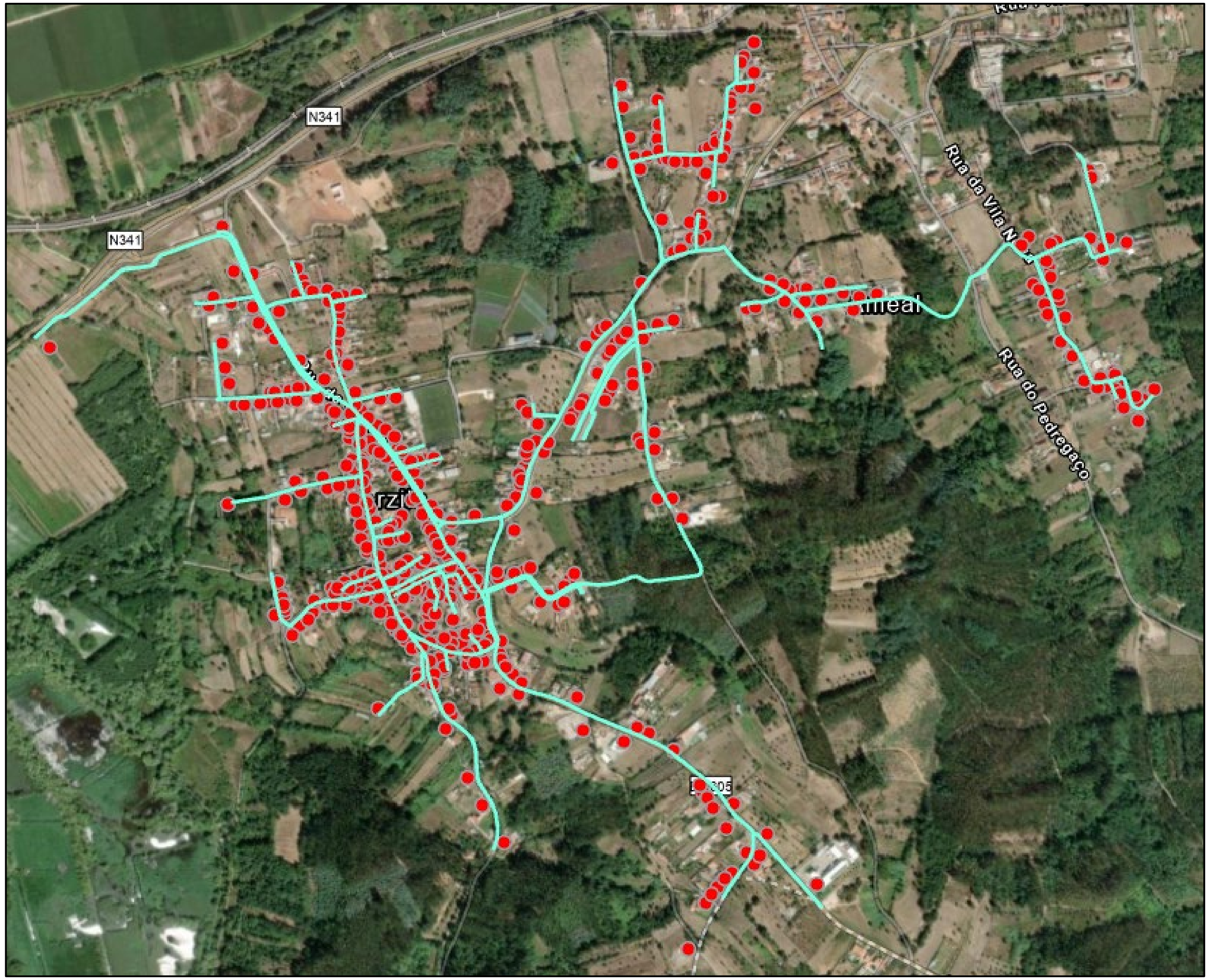
Collection of available information

Year of pipe installation (Age) – **Arzila DMA**



Collection of available information

Water Consumption Points – **Arzila DMA**



Development of Hydraulic and Water Quality models

- All the information collected
  <u>and</u>
- Using EPANET

HYDRAULIC MODELS WERE DEVELOPED!

Development of Hydraulic and Water Quality models

The governing equations for EPANET's **water quality solver** are based on the principles of conservation of mass coupled with reaction kinetics.

1. Advective Transport in Pipes
2. Mixing at Pipe Junctions
3. Mixing in Storage Tanks
4. Bulk Flow Reactions
5. Pipe Wall Reactions

Development of Hydraulic and Water Quality models

- **Bulk flow reactions**

EPANET defines the rate of reaction as a power function of concentration:

$$r = K_b\, C^n$$

where K_b is a bulk reaction constant and n is the reaction order. Simple first-order decay reaction equations ($R = K_b\, C$) are normally used for simulating the decay of many substances such as chlorine.

- **Pipe wall reactions**

For first-order kinetics, the rate of a pipe wall reaction can be expressed as:

$$r = \frac{2k_w k_f C}{R(k_w + k_f)}$$

where k_w is the wall reaction rate constant (length/time), k_f is the mass transfer coefficient (length/time), and R is the pipe radius.

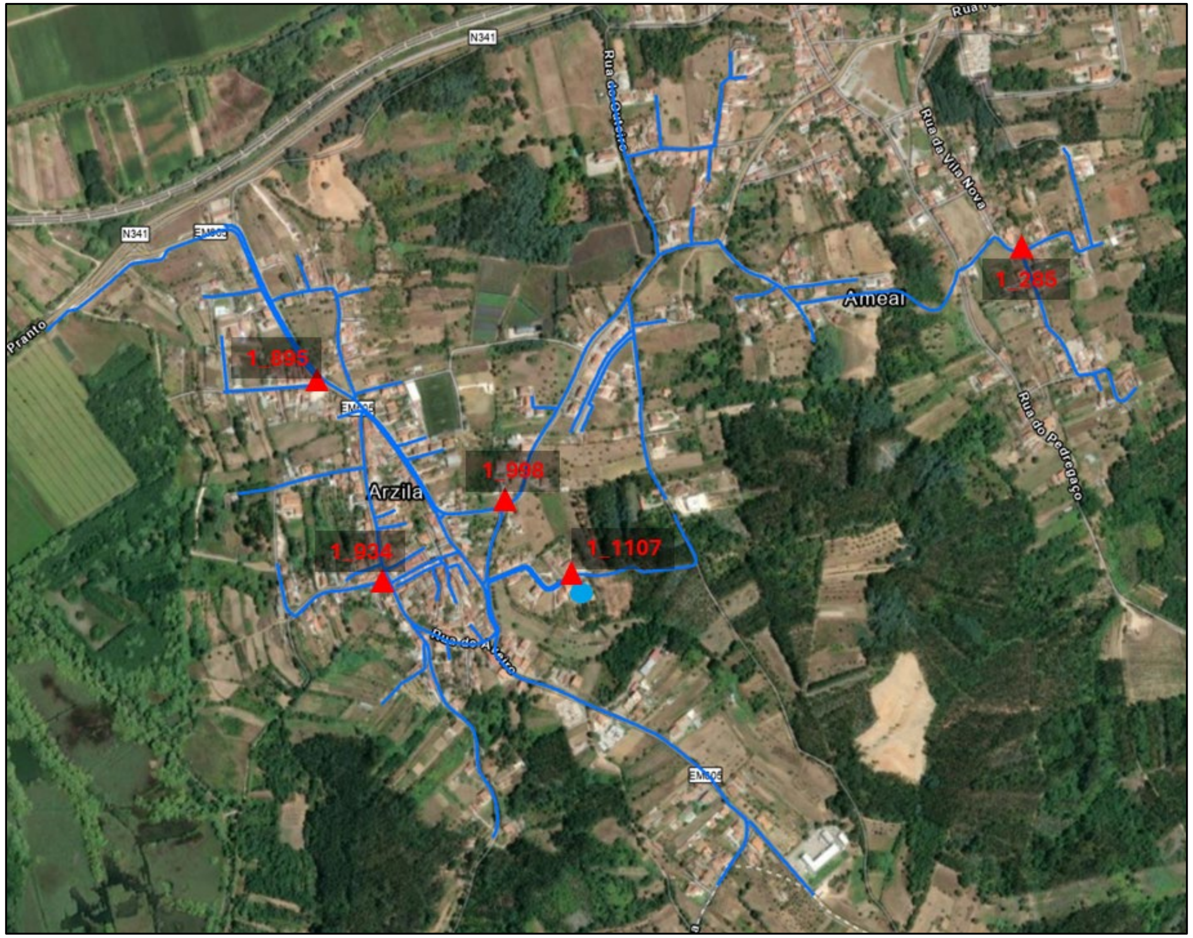
Development of Hydraulic and Water Quality models

- Water samples were collected at several points of the network in each DMA (50 to 100 collections per day, over 9 days) and **chlorine concentrations** were obtained;

- With the support of UC (Chemical Engineering Department), **chlorine decay measurements** were performed in the laboratory, to obtain suitable chlorine decay prediction equations.

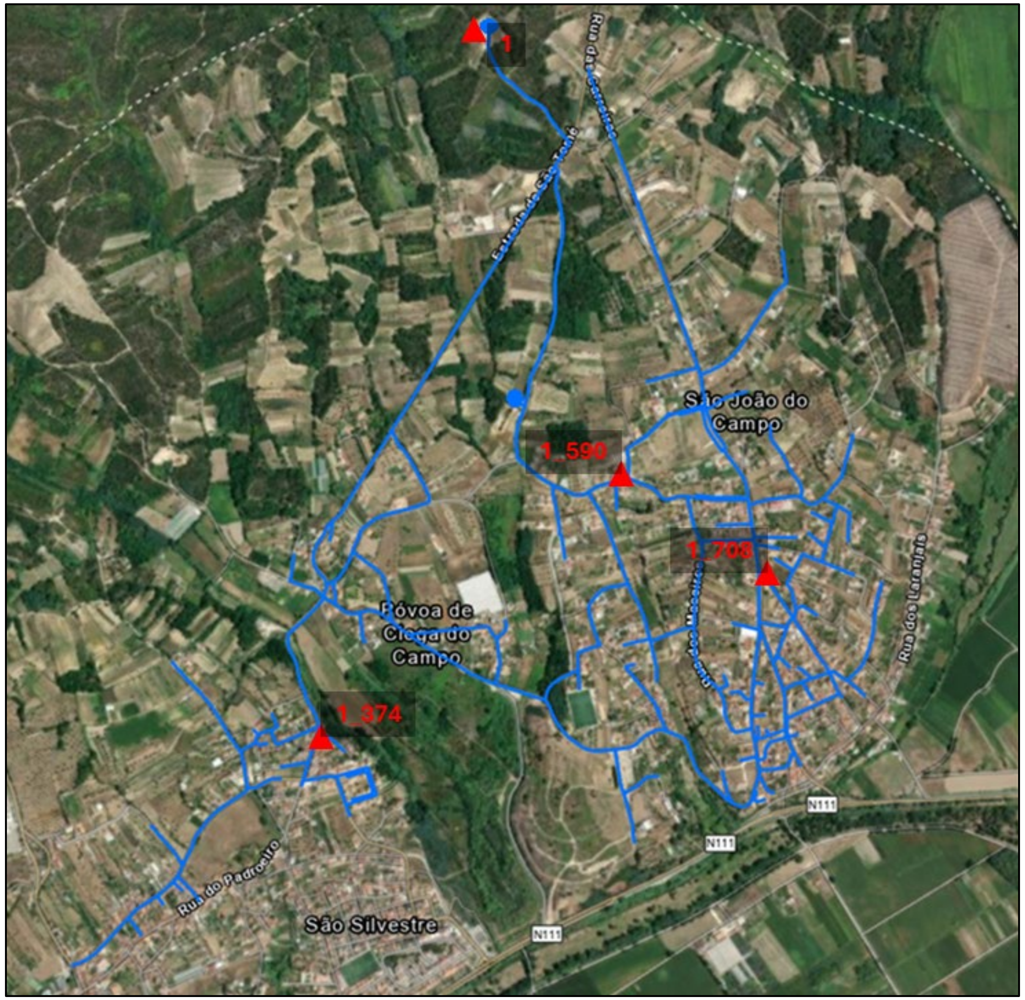
Development of Hydraulic and Water Quality models

- Water sampling – **Arzila DMA** collection points location



Development of Hydraulic and Water Quality models

- Water sampling – **Penetra DMA** collection points location



Development of Hydraulic and Water Quality models

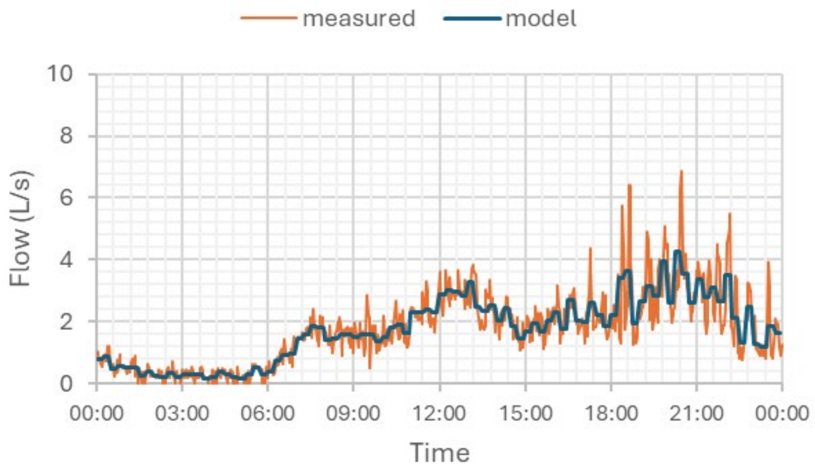
- Water sampling – **Pinhal de Marrocos II DMA** collection points location

Calibration and validation

2 scenarios for calibration in each DMA:	1 scenario for validation in each DMA:
➢ Arzila: ❖ 06/06/2024 ❖ 26/06/2024 ➢ Penetra: ❖ 11/07/2024 ❖ 12/07/2024 ➢ Pinhal de Marrocos II: ❖ 10/07/2024 ❖ 06/09/2024	➢ Arzila: ❖ 03/07/2024 ➢ Penetra: ❖ 02/09/2024 ➢ Pinhal de Marrocos II: ❖ 09/09/2024

Results

CALIBRATION: ARZILA – 06/06/2024



Comparison of flow rate measured and modelled at the exit of Arzila water tank

Calibration Report - Chlorine

Statistics | Correlation Plot | Mean Comparisons

Calibration Statistics for Chlorine

Location	Num Obs	Observed Mean	Computed Mean	Mean Error	RMS Error
1_998	16	0.15	0.15	0.028	0.036
1_285	6	0.14	0.11	0.039	0.053
1_934	11	0.15	0.15	0.024	0.032
1_895	10	0.15	0.14	0.019	0.024
1_1007	19	0.17	0.17	0.000	0.000
Network	62	0.16	0.15	0.018	0.030

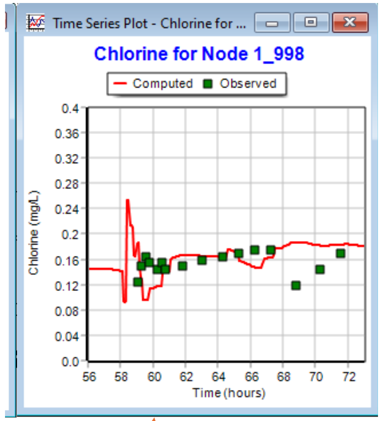
Calibration statistics: EPANET data

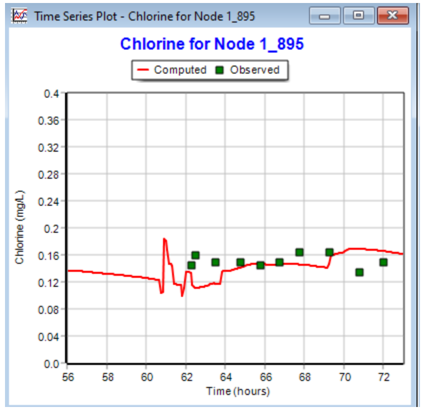
Mean error: 0,018

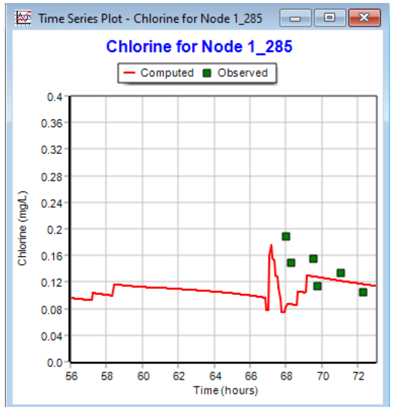
Results

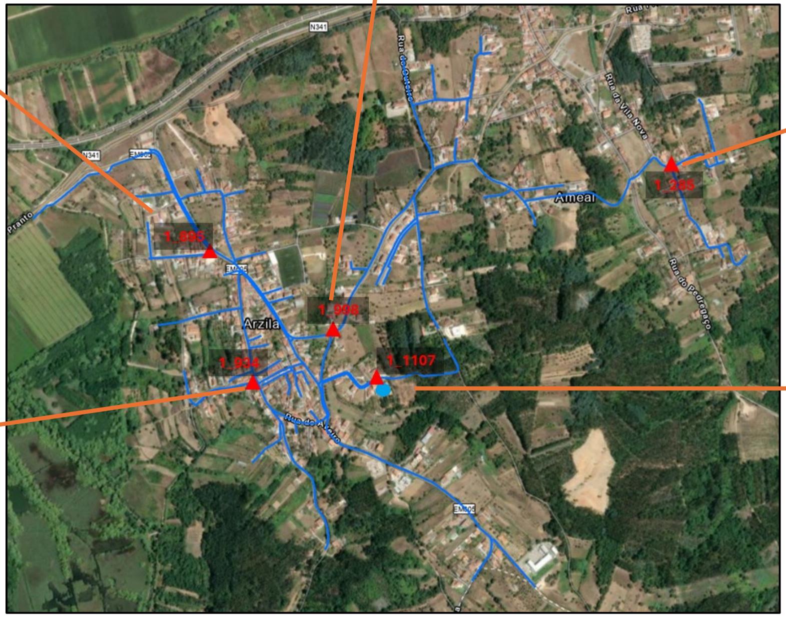
CALIBRATION: ARZILA – 06/06/2024

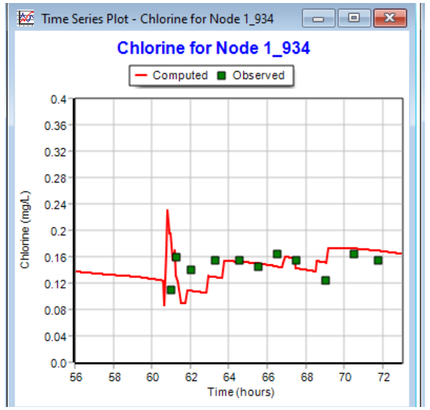
Comparison between modelled and measured Chlorine concentration values

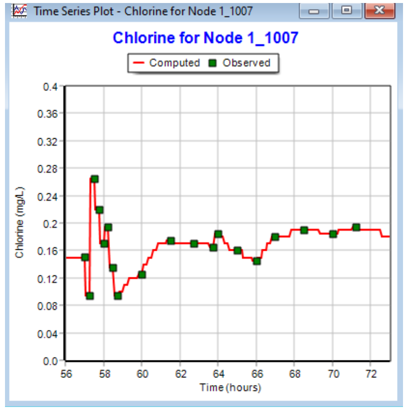






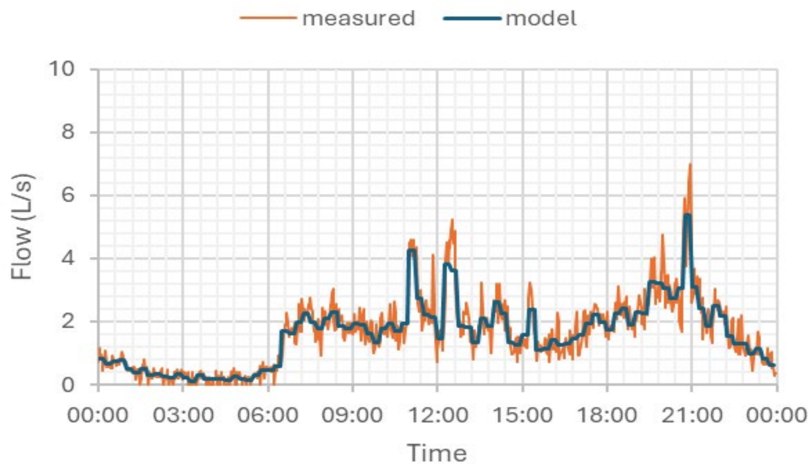






Results

VALIDATION: ARZILA – 03/07/2024



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1_998	16	0.21	0.22	0.021	0.025
1_934	11	0.20	0.20	0.034	0.038
1_895	10	0.19	0.20	0.021	0.025
1_285	6	0.17	0.15	0.018	0.024
Network	64	0.20	0.21	0.016	0.024

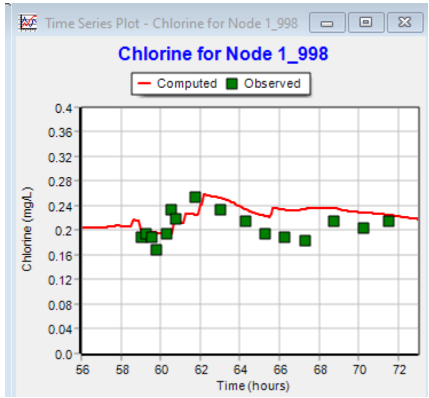
Calibration statistics: EPANET data

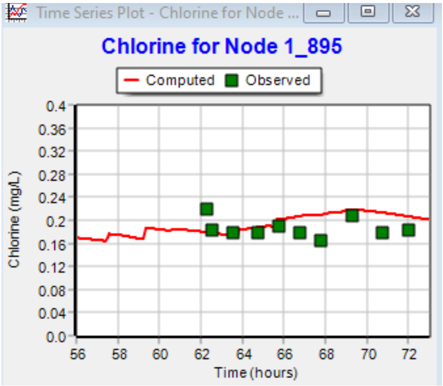
Mean error: 0,016

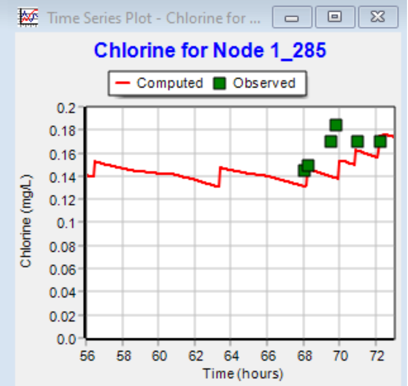
Results

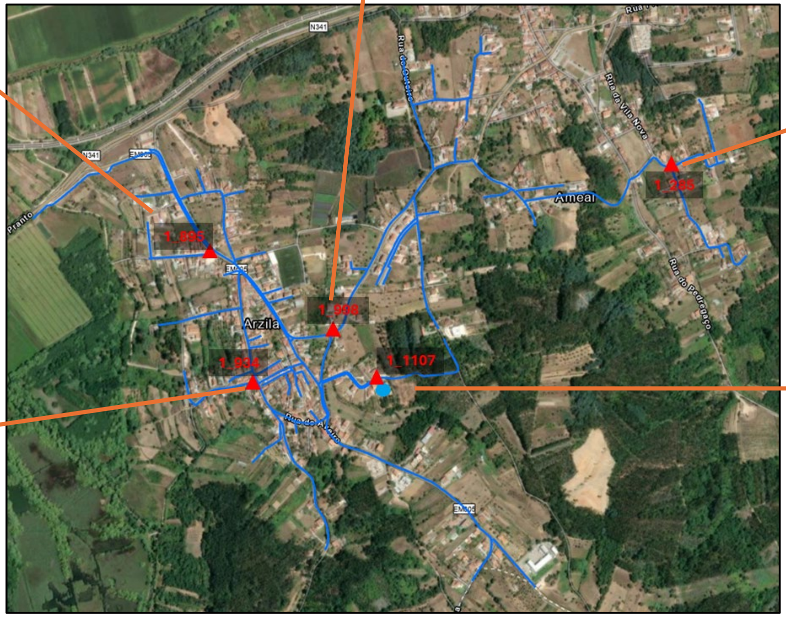
VALIDATION: ARZILA – 03/07/2024

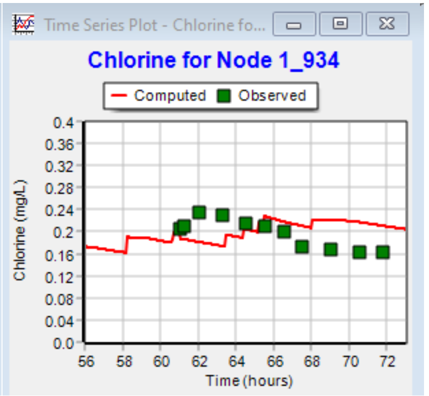
Comparison between modelled and measured Chlorine concentration values

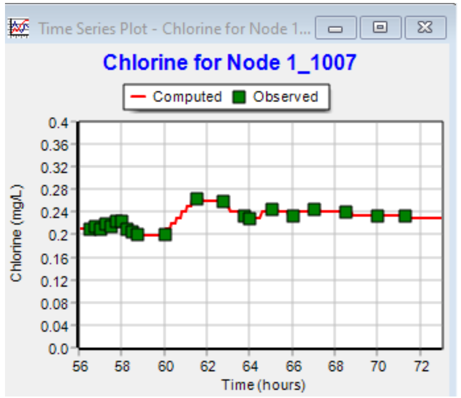












Work Developed

- Selection of DMAs and collection points location determined;
- Collection of available water distribution network information;
- Hydraulic models developed using EPANET;
- Water Samples collected (50 to 100 per day over 9 days);
- Determination of coefficients (*Bulk flow kinetic constant* and *pipe wall mass transfer constant*) for water quality calibration;
- Water Quality models developed using EPANET;
- Multiple scenarios tested.

Conclusions

- Bulk flow kinetic constant, K_b = -0.5 day^{-1}, and pipe wall mass transfer constant, K_w = -0.01 day^{-1} defined.
- Water quality models depend on having a good hydraulic model and are affected by their uncertainties.
- These calibrated models enable us to understand the behaviour of the chlorine concentration within the networks.
- Knowing the chlorine concentration along the networks makes it possible to predict the probability of DBPs formation since there is a relationship between chlorine concentrations and the formation of DBPs.
- With the water quality models developed, Águas de Coimbra will be able to predict the behaviour of the networks regarding the spread of chlorine concentration along them. This enables the making of re-chlorination injection plans with the minimal chlorine necessary and, consequently, less formation of DBPs.

THANK YOU!

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Águas de Coimbra

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