



SMARTGREENS 2021

10th International Conference on Smart Cities and
Green ICT Systems

Final Program and Book of Abstracts

28 - 30 April, 2021

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PAPERS AVAILABLE AT



Complete Paper #24: Model-based Systems Design for Green IoT Systems, <i>by Kristin Majetta, Jan Bräunig, Christoph Sohrmann, Roland Jancke and Dirk Mayer</i>	21
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Thursday Sessions: April 29

Session 3 (10:45 - 12:15)

Room 4: <i>Smart Cities and Green ICT Systems</i>	25
Complete Paper #1: An Artificial Neural Network-based Real Time DSS to Manage the Discharges of a Wastewater Treatment Plant and Reduce the Flooding Risk, <i>by Loris Termite, Emanuele Bonamente, Alberto Garinei, Daniele Bolpagni, Lorenzo Menculini, Marcello Marconi, Lorenzo Biondi, Andrea Chini and Massimo Crespi</i>	25
Complete Paper #16: Role of Citizens in the Development of Smart Cities: Benefit of Citizen's Feedback for Improving Quality of Service, <i>by Priyanka Singh, Fiona Lynch and Markus Helfert</i>	25
Complete Paper #26: A Comparative Analysis of Smart Cities Frameworks based on Data Lifecycle Requirements, <i>by Claudia Roessing and Markus Helfert</i>	25
Complete Paper #27: Hazard Analysis for Decentralized Charging Management of Electric Vehicles, <i>by Stylianos Karatzas, Panagiotis Farmakis, Athanasios Chassiakos and Zoi Christoforou</i>	25

Keynote Lecture (12:30 - 13:30)

Room Plenary 1	26
Optimization, Modeling and Assessment of Smart City Transportation Systems, <i>by Hesham Rakha</i>	26

Session 4 (14:45 - 16:00)

Room 4: <i>Case Studies and Innovative Applications for Smart(Er) Cities</i>	26
Complete Paper #21: Building Indoor Point Cloud Datasets with Object Annotation for Public Safety, <i>by Mazharul Hossain, Tianxing Ma, Thomas Watson, Brandon Simmers, Junaid Khan, Eddie Jacobs and Lan Wang</i>	26
Complete Paper #29: An Automated Clustering Process for Helping Practitioners to Identify Similar EV Charging Patterns across Multiple Temporal Granularities, <i>by René Richard, Hung Cao and Monica Wachowicz</i>	26

Friday Sessions: April 30

Session 5 (10:30 - 12:00)

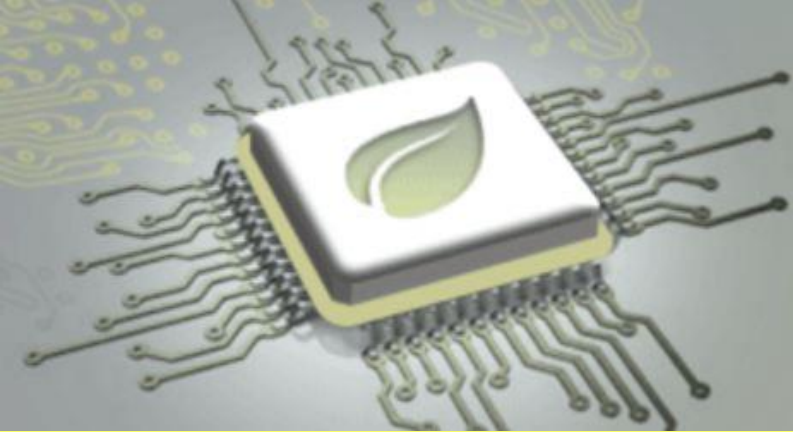
Room Plenary 1: <i>Energy-Aware Systems and Technologies</i>	29
Complete Paper #9: Toward Sustainable Energy Communities, <i>by Giuseppe Anastasi and Marco Raugi</i>	29
Complete Paper #19: Detection and Prevention of Denial-of-Service in Cloud-based Smart Grid, <i>by Abdul Razaq, Muhammad Hussain, Waqas Javed, Tasmiyah Javed and Zulfiqar Memon</i>	29
Complete Paper #22: Energy Efficiency of Low Voltage Direct Current Supplies Including PV Sources, <i>by Anis Ammous, Ammar Assaidi, Abdulrahman Alahdal and Kaiçar Ammous</i>	29
Complete Paper #23: Design of a Very Low Frequency Test Device for Faults Diagnosis in Underground Cable, <i>by Anis Ammous, Mohamed Zdiri, Ammar Assaidi, Abdulrahman Alahdal and Kaiçar Ammous</i>	29

Keynote Lecture (12:15 - 13:15)

Room Plenary 2	30
Nationwide Digital Twin: Innovation for Resilience and Sustainability, <i>by Markus Eisenhauer</i>	30

Closing Session (13:15 - 13:30)

Room Plenary 2	30
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10th International Conference on Smart Cities and Green ICT Systems

Online Streaming | 28 - 30 April, 2021

An Artificial Neural Network-based Real Time DSS to Manage the Discharges of a Wastewater Treatment Plant and Reduce the Flooding Risk

Loris Francesco Termite¹, Emanuele Bonamente², Alberto Garinei^{3,4}, Daniele Bolpagni⁵,
Lorenzo Menculini⁴, Marcello Marconi^{3,4}, Lorenzo Biondi^{3,4}, Andrea Chini⁶ and Massimo Crespi⁶

1 K-Digitale Srl, Italy

2 University of Perugia, Italy

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4 Idea-Re Srl, Italy

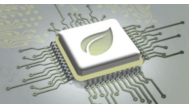
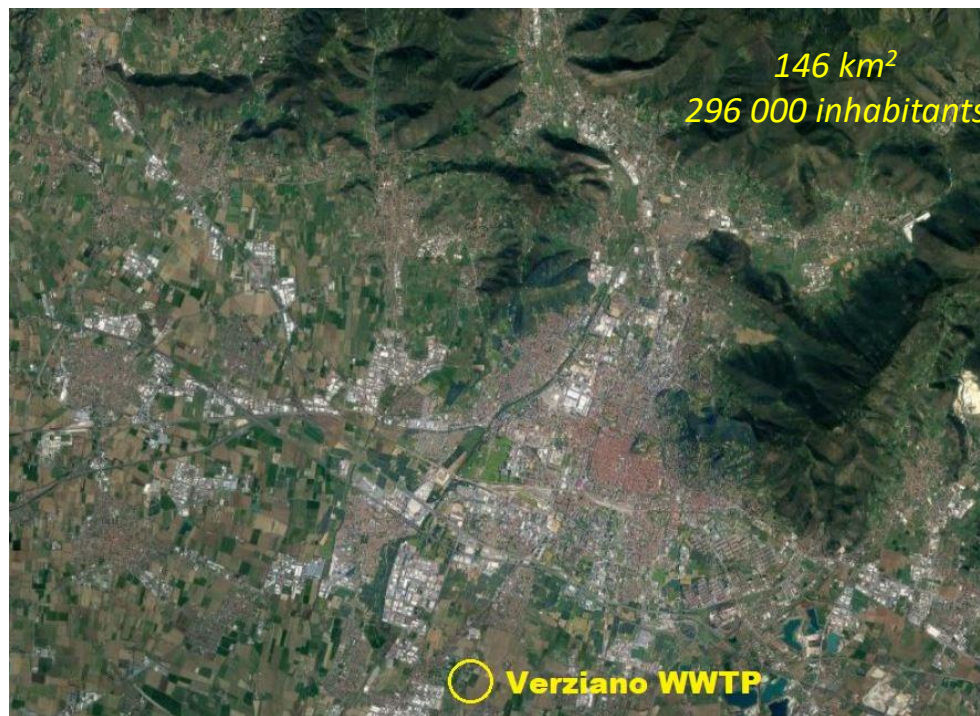
5 A2A Ciclo Idrico SpA, Italy

6 Radarmeteo Srl, Italy

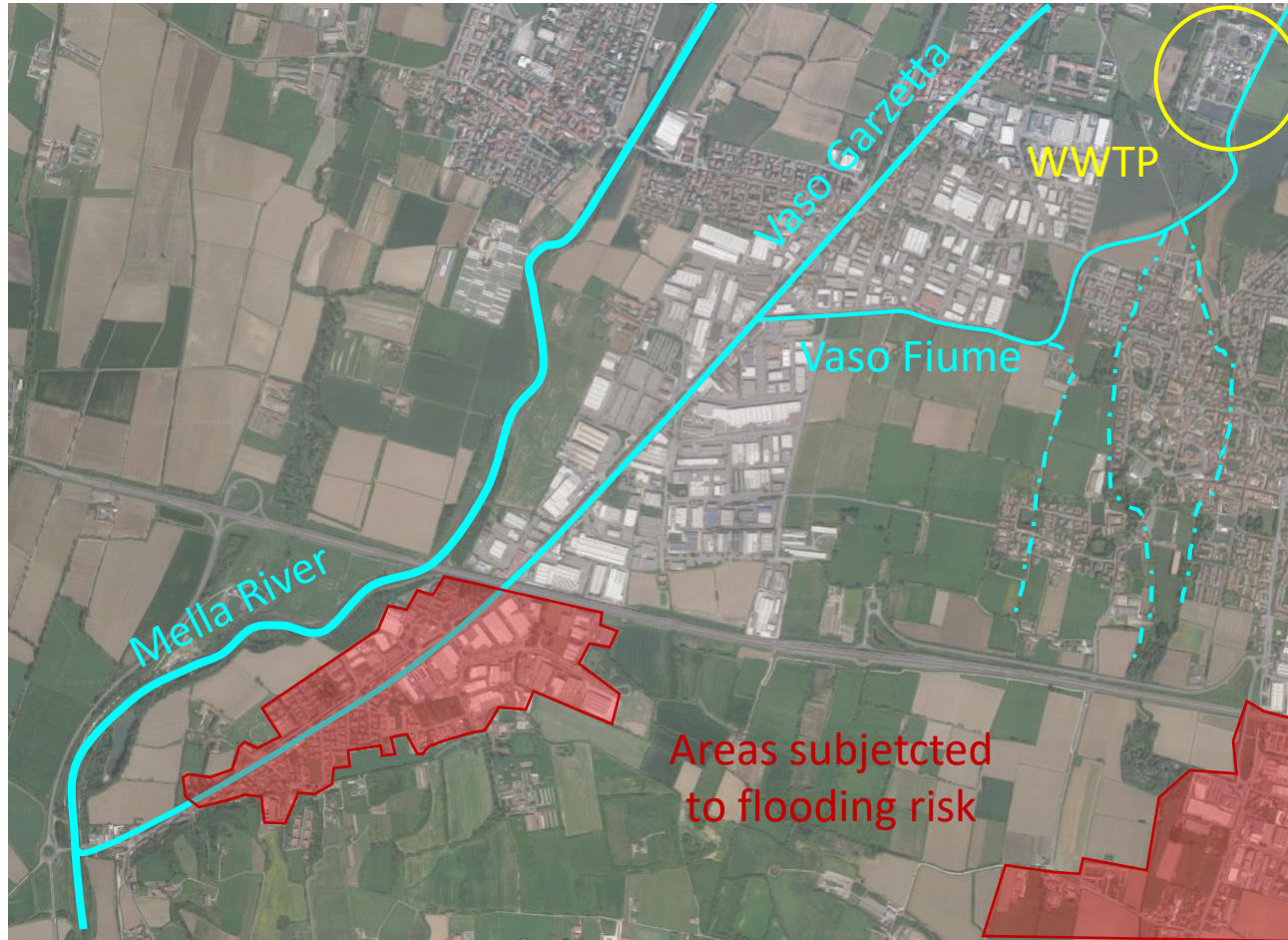
Introduction

A2A Ciclo Idrico manages the **sewage network** in the city of Brescia, Italy, and its surrounding area.

It also manages the **wastewater treatment plant** located in the Verziano district, south of the city.



The whole system is subjected to several issues in case of high-intensity rainfall events.



Upstream

Combined sewer flows must be spilled before entering the WWTP, respecting environmental law limitations.

Downstream

- Critical management of Vaso Fiume due to raise in Vaso Garzetta level;
- Limit lateral spillways from Vaso Fiume within law limitations;
- Several floods over the years.

Previously

Acquired data were stored in diverse databases and visualized in separate interfaces.



*Rainfall data
(measurements from 6 pluviometers)*



Gate openings and VF levels



Sewer flows



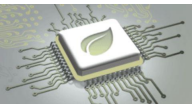
Lack of comprehensive view!

No information about forthcoming rainfall, levels and flows

Mitigation strategies based on operator experience

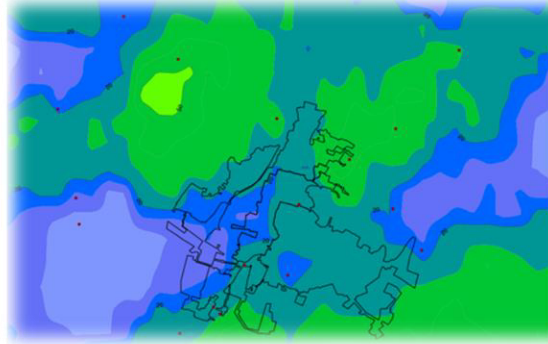


VG levels



Now: data collection

All acquired and computed data are collected in a dedicated DB.



*Rainfall data
(pluviometers and radar measurements + nowcasting)*

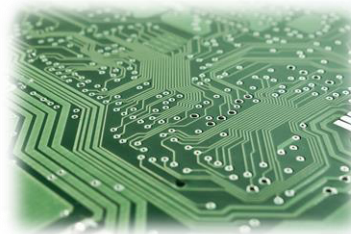
Gate openings and VF levels



Sewer flows



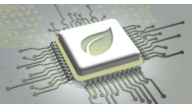
PostgreSQL



Computed data (including future levels and flows)



VG levels



The DSS structure



Rainfall

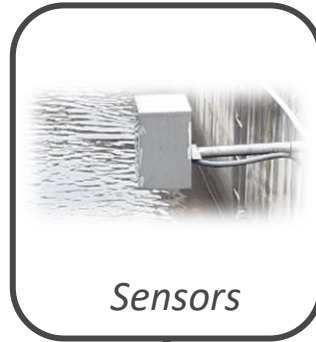
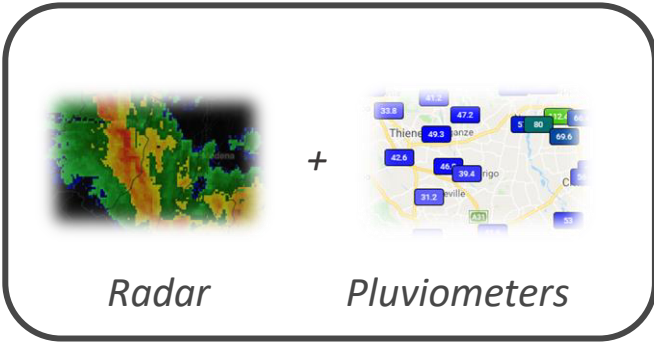


Levels/Flows

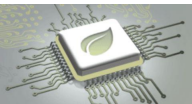
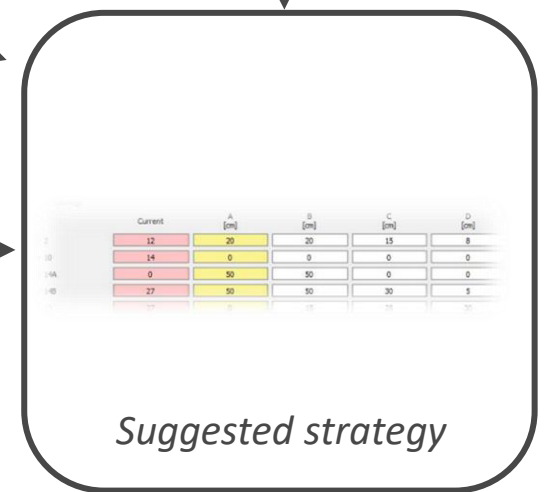
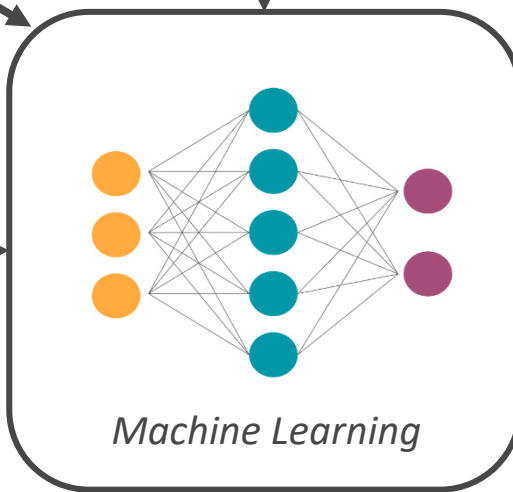
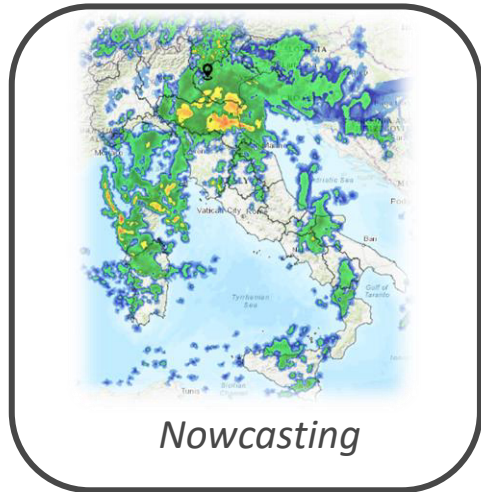


Gate opening rate

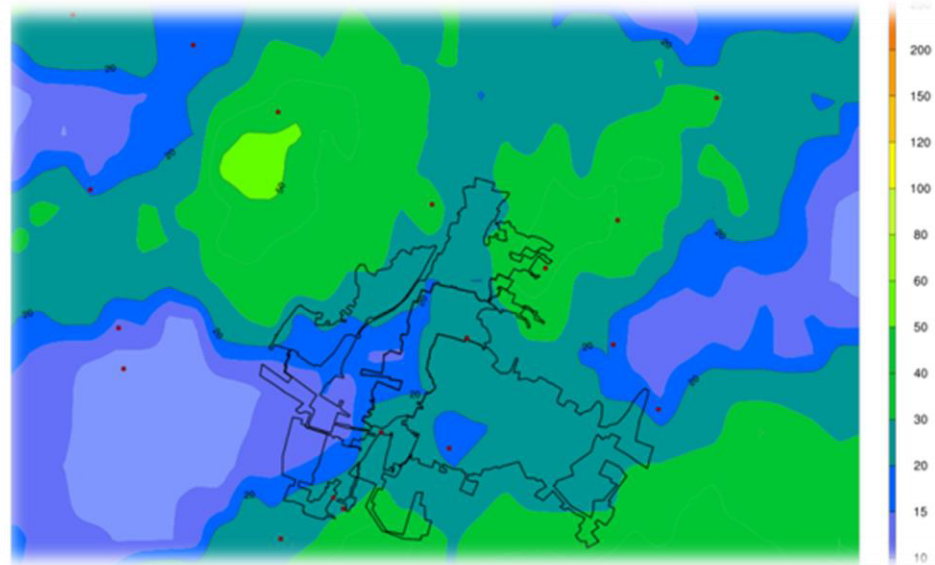
Measurements



Forecasts/Strategies



Rainfall data



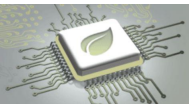
Measurements

- Merging of pluviometers and radar data
 - distributed measurements are calibrated through punctual records
 - 1×1 km spatial resolution
 - 10-min time resolution
 - reliability: value accuracy and spatial variability

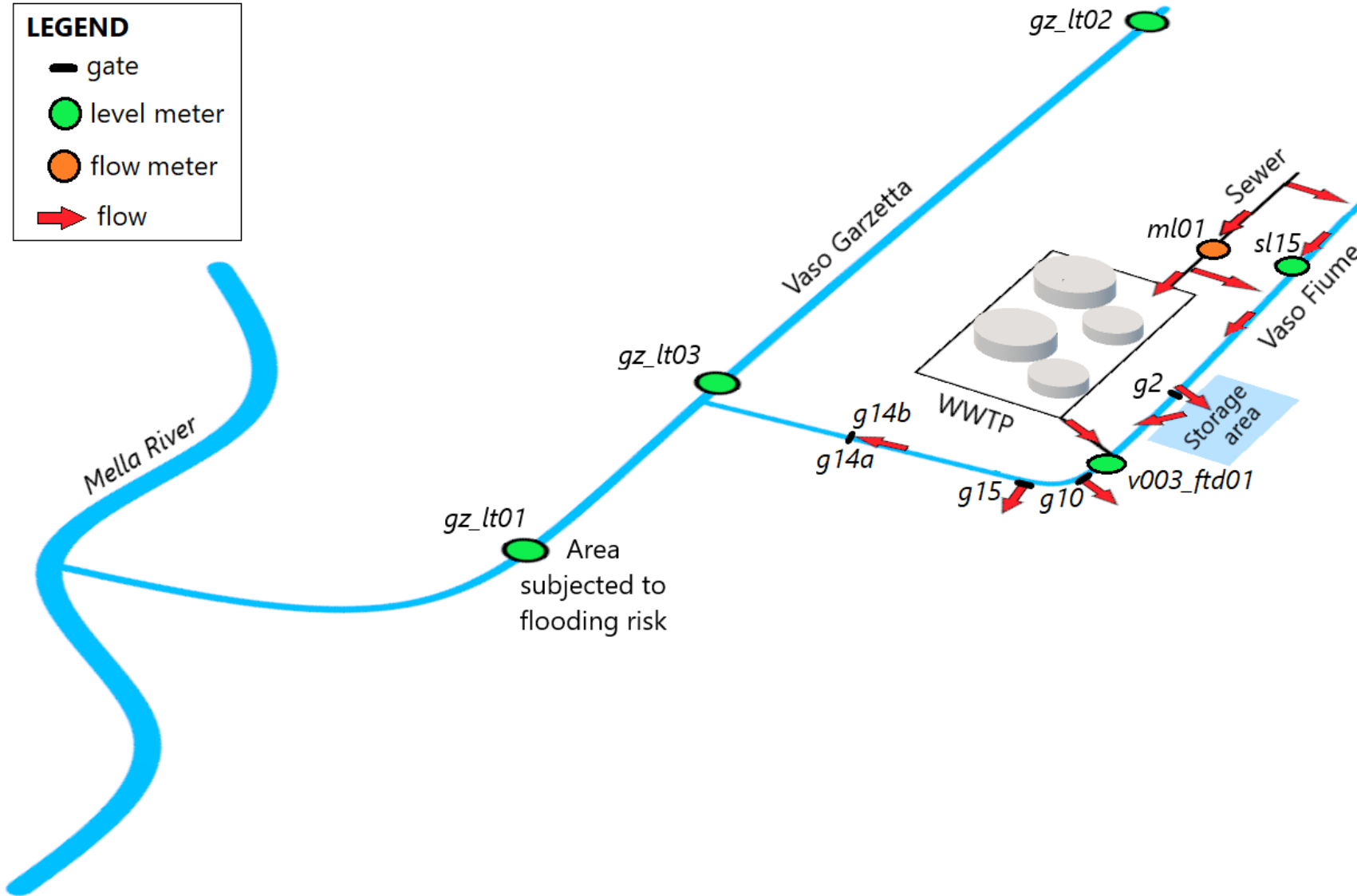
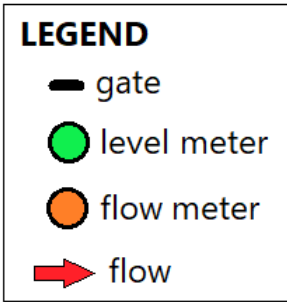
Forecasts

- Very-short-term Quantitative Precipitation Estimates (“Nowcasting”)
 - algorithms working on radar measurements
 - up to +180 minutes (up to +80 minutes are used)
 - 5 to 20-min update frequency

All rainfall measurements and forecasts are averaged over the whole catchment to obtain single values to be used for next computations.



Level and flow measurements



- New meters were added to those which were already installed
- VG level is monitored at 3 strategic locations
- All flows are measured or computed by means of algebraic sum of known values
- Sewer flow at *ml01* is an important piece of information to manage internal WWTP operations

Artificial Neural Networks for level and flow forecasts

Predicted variables

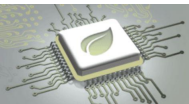
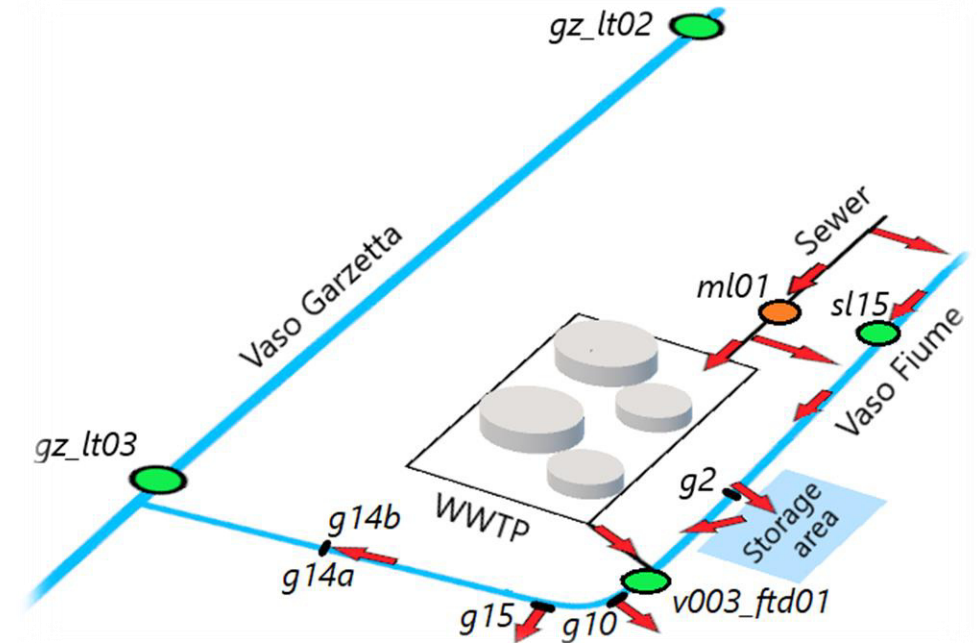
- VG level at *gz_lt02* meter: to promptly act on VF gates
- Sewer flow at *ml01* meter: to manage internal WWTP operations

Two time horizons

- “Short-term”: up to + 60 min
 - based on measured rainfalls only
- “Long-term”: up to + 140 min
 - based on measured rainfalls and nowcasting up to +80 min

ANNs details

- 20-nodes single hidden layer MLP
- Data subsetting: approx. 80% for training, 20% for validation
- 2000 runs for each ANN training, Levenberg-Marquadt BP algorithm
- Multi-objective optimization to select the best performing ANNs



Artificial Neural Networks for level and flow forecasts

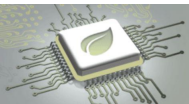
3 thresholds were defined for *gz_lt02* level (70, 100, 140 cm) and for *m/01* flow (2.5, 3.5, 4.5 m³/s).

Accuracy and timing of threshold crossing prediction play a key role in optimization criteria.

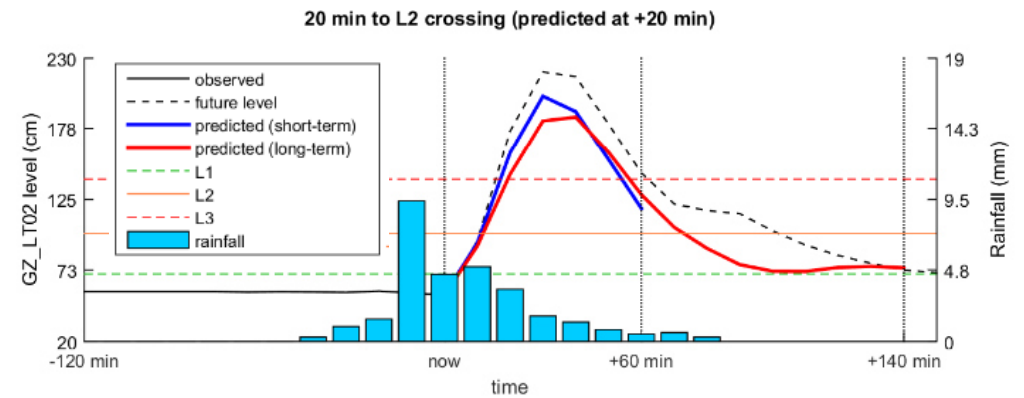
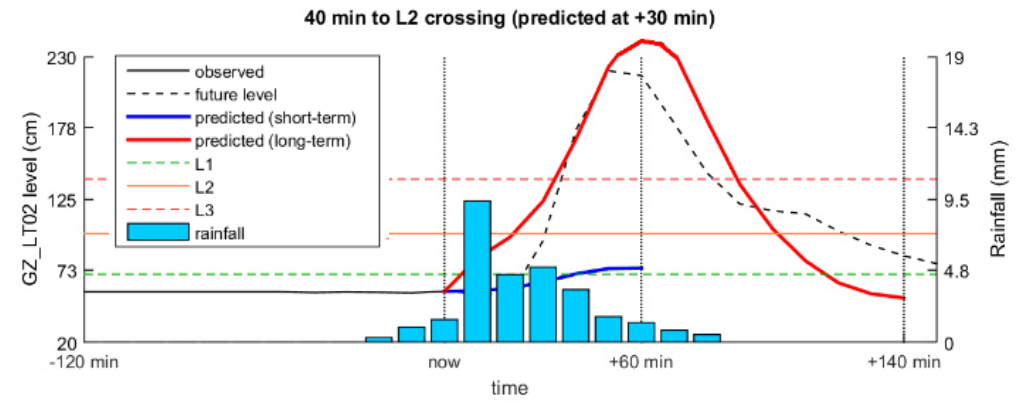
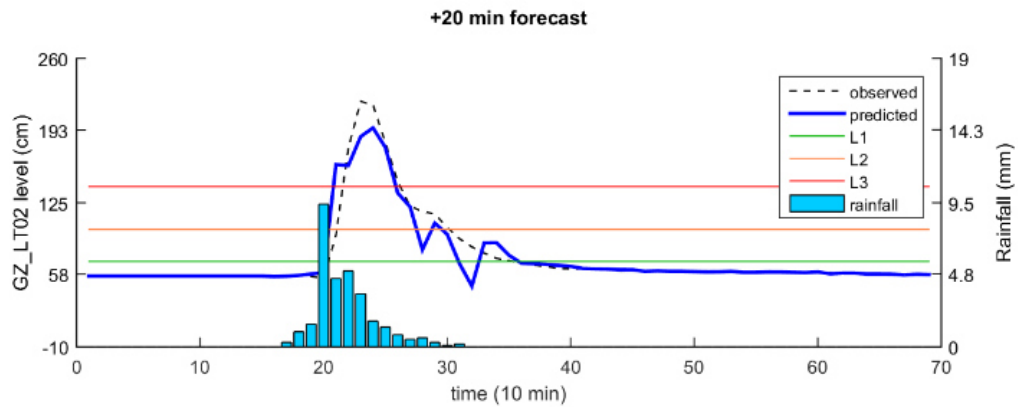
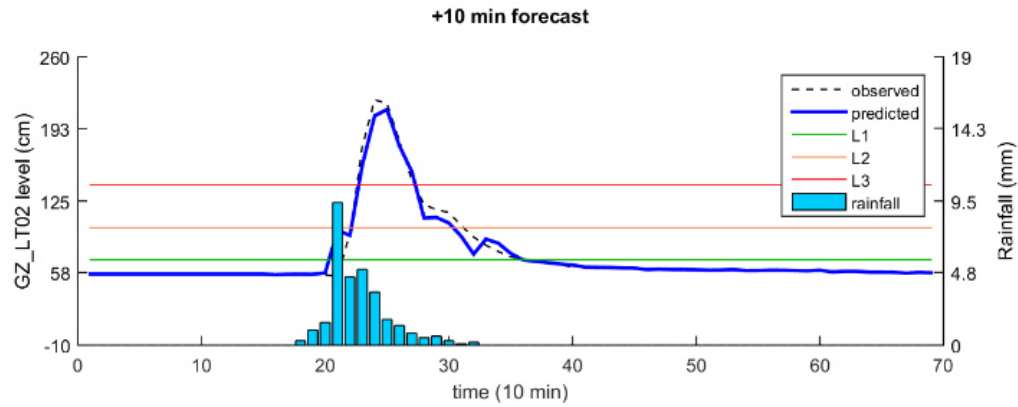
		Threshold 1	Threshold 2	Threshold 3
ANN _{LS} Level Short-term	n. observed.	22 (17 / 5)	9 (6 / 3)	4 (2 / 2)
	n. predicted.	22 (17 / 5)	6 (4 / 2)	3 (2 / 1)
	predicted %	100.0 (100.0 / 100.0)	66.7 (66.67 / 66.67)	75.0 (100.0 / 50.0)
	a.w.t. (min)	36.8 (35.2 / 42.0)	25.0 (27.5 / 20.0)	33.3 (35.0 / 30.0)
	a.p.d. (min)	3.2 (3.6 / 2.0)	1.7 (0.0 / 5.0)	-3.3 (0.0 / -10.0)
	false alerts	10 (7 / 3)	1 (1 / 0)	0 (0 / 0)
ANN _{LL} Level Long-term	n. observed.	22 (17 / 5)	9 (6 / 3)	4 (2 / 2)
	n. predicted.	22 (17 / 5)	5 (3 / 2)	3 (2 / 1)
	predicted %	100.0 (100.0 / 100.0)	55.6 (50.0 / 66.67)	75.0 (100.0 / 50.0)
	a.w.t. (min)	97.7 (91.8 / 118.0)	116.0 (110.0 / 125.0)	113.3 (115.0 / 110.0)
	a.p.d. (min)	-7.3 (-5.9 / -12.0)	-10.0 (-3.3 / -20.0)	3.3 (0.0 / 10.0)
	false alerts	9 (6 / 3)	4 (2 / 2)	0 (0 / 0)
ANN _{LS} Flow Short-term	n. observed.	56 (45 / 11)	11 (7 / 4)	2 (1 / 1)
	n. predicted.	34 (31 / 3)	7 (4 / 3)	2 (1 / 1)
	predicted %	60.7 (68.9 / 27.3)	64.7 (57.1 / 75.0)	100.0 (100.0 / 100.0)
	a.w.t. (min)	35.9 (36.4 / 30.0)	22.9 (22.5 / 23.3)	45.0 (30.0 / 60.0)
	a.p.d. (min)	0.0 (0.3 / -3.3)	5.7 (15.0 / -6.7)	5.0 (20.0 / -10.0)
	false alerts	16 (10 / 6)	2 (1 / 1)	0 (0 / 0)
ANN _{FL} Flow Long-term	n. observed.	56 (45 / 11)	11 (7 / 4)	2 (1 / 1)
	n. predicted.	36 (32 / 4)	9 (5 / 4)	2 (1 / 1)
	predicted %	64.3 (71.1 / 36.4)	81.8 (71.4 / 100.0)	100.0 (100.0 / 100.0)
	a.w.t. (min)	71.4 (69.7 / 85.0)	73.3 (98.0 / 42.5)	100.0 (70.0 / 130.0)
	a.p.d. (min)	8.9 (8.4 / 12.5)	5.6 (2.0 / 5.0)	15.0 (30.0 / 0.0)
	false alerts	15 (5 / 10)	2 (2 / 0)	0 (0 / 0)

a.w.t.: average warning time; a.p.d.: average prediction delay.

- Predicted crossing: signalled to occur at least once in the available time horizon
 - Average warning time: first alert of impending crossing with respect to actual crossing
 - Average prediction delay: predicted anticipation – actual anticipation at the time of first alert
- ✓ The majority of the most severe threshold crossings are predicted
 - ✓ All the lower threshold crossings at *gz_lt02* are predicted
 - ✓ a.w.t. \approx 25 ÷ 40 min for short-term, up to 120 min for long-term
 - ✓ a.p.d. generally lower than 10 min
 - ✓ Flow predictions slightly outperformed by level predictions

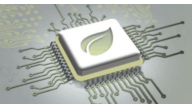


Artificial Neural Networks for level and flow forecasts

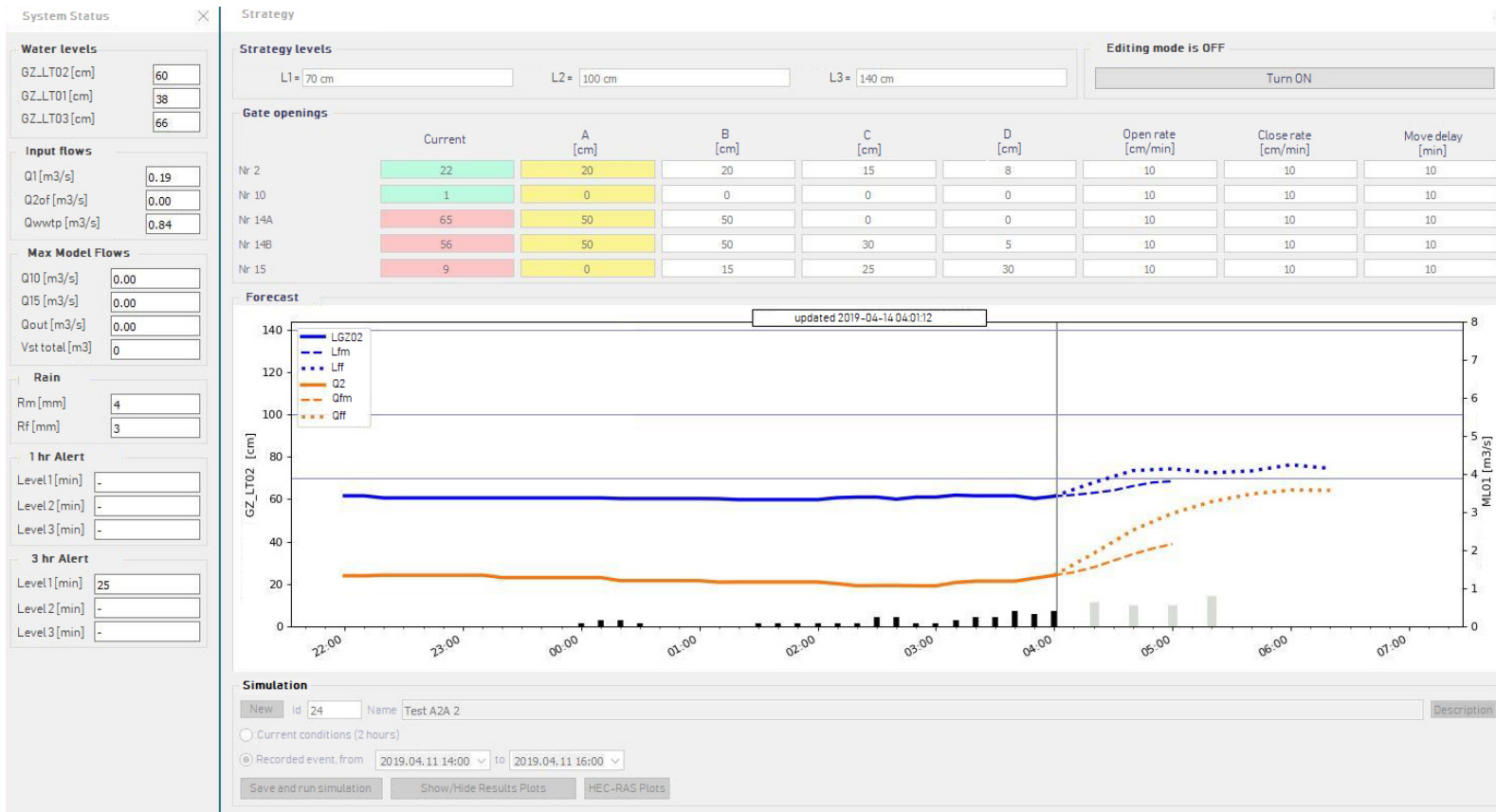


Envelop of +10-min and +20-min level forecast for a given event

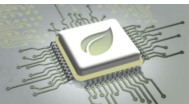
“Snap-shot” of prediction window 40 minutes and 20 minutes before crossing of 100 cm level threshold



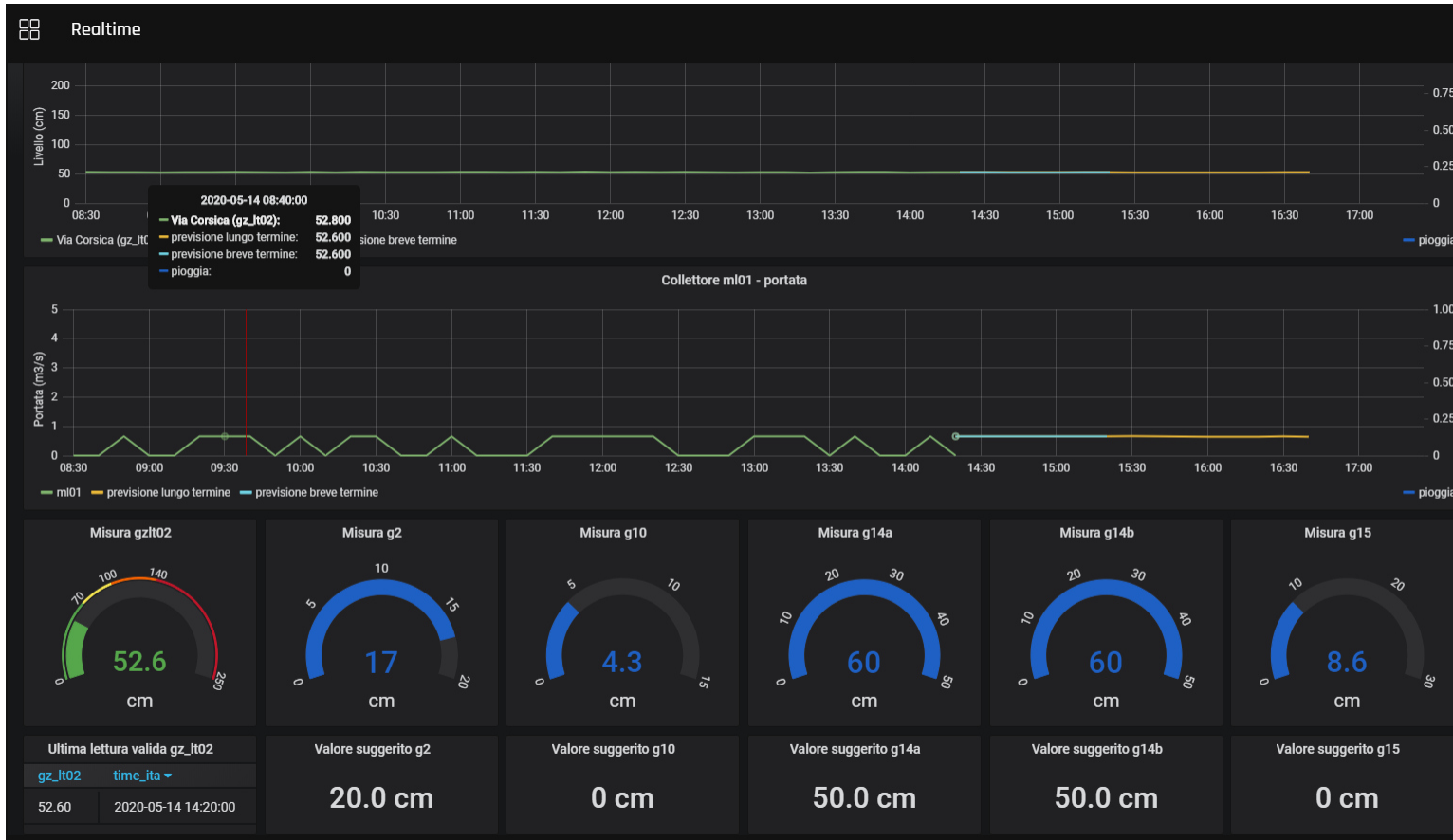
User Interface



- Qgis plugin running on remote desktop
- Measured and forecasted rainfall
- *gz_lt02* level and *ml01* flow in the past 6 hours and forecasts up to +60 and +140 minutes
- Current and suggested gate openings: 4 strategies depending on observed crossings of the defined thresholds at *gz_lt02*
- Embedded HEC-RAS model of VF



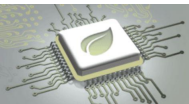
Simplified User Interface



- Visualization-only interface
- Available on desktop and mobile devices
- 3 dashboards:
 - real-time (in figure)
 - past data
 - accuracy of past predictions

Further developments

- **Enhancement of ANNs performance**
 - *more data*
 - *different structures (e.g. LSTM)*
 - *analysis on unseen data (testing set)*
- **Investigation of rainfall forecast accuracy** (perfect forecast hypothesis was used in developing the DSS)
- **Improvement of the current mitigation strategies**, based on long-time experience and triggered by measured *gz_lt02* level
 - *ex-post testing of different gate opening combinations and threshold through the HEC-RAS model*
 - *integration of real-time multi-objective functionalities*
- **Installation of automatic actuators in order to implement a Real-Time Control System**



The presented study is part of the INNOVA EFD3 research project financed by
A2A Ciclo Idrico S.p.A.



Thank you for your attention!