BEtter Water-management for Advancing Resilient-communities in Europe

Action D1 – Monitoring water flows and climate impacts

First annual monitoring report

Covering the project activities from 01/01/2019 to 31/12/2020

Project Data	
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1 Glossary, Abbreviations, Acronyms

BEWARE	BEtter Water-management for Advancing Resilient-communities in Europe
COMSAN	Municipality of Santorso
COMMAR	Municipality of Marano Vicentino
NWRMs	Natural Water Retention Measures as classified by the Office International de l'Eau (www.nwrm.eu)
SUDS	Sustainable Urban Drainage Systems
TESAF	Dipartimento Territorio e Sistemi Agro-Forestali, Università degli Studi di Padova
Floods	All events in which water inundates lands not normally covered by water (directive 2007/60/EC, 2007) (Salvati et al., 2014)
RG1	Rain gauge number 1, located in Santorso
RG2	Rain gauge number 2, located in Giavenale di Schio

2 Executive summary

Action D1 focuses on the monitoring of the water flows managed by some of the interventions realized in the context of the BEWARE project (Actions C3 and C4).

The action includes two types of monitoring:

- Quantitative monitoring concerns measurements of inflows and outflows from the monitored interventions. The measurements will provide a precise estimation of the effectiveness of the interventions in accumulating and infiltrating water and, consequently, in flood mitigation.
- Qualitative measurements that analyses the improvements in water-quality determined by the realization of the interventions.

The monitored interventions are the following:

- The water retention basin (Action C3, Figure 2.1a) realized on a private agricultural land in Giavenale locality (Municipality of Schio, Vicenza Province) in order to *i)* mitigate the flooding risk of a downstream residential area located in the municipality of Marano Vicentino, *ii)* provide water for irrigation during the dry season to the nearby crops.
- The rain garden (Action C4, Intervention 1, Figure 2.1b) realized in Piazza della Libertà (Santorso Municipality) in order to manage the water runoff produced by the paving of the parking lot of the square.
- The grassed swale and the bioretention area (Action C4, Intervention 2, Figure 2.1c) realized in the Grumo hill (Santorso Municipality) in order to mitigate the flood risk in a down-stream residential area.
- The rain garden (Action C4, Intervention 5, Figure 2.1d) realized in the parking lot of the graveyard located in Via dei Prati (Santorso) in order to manage the water runoff coming from the paved and cultivated upstream areas.

Figure 2.1. Pictures of the interventions monitored by the Action D1 of the BEWARE project: a) water retention basin realized in Giavenale di Schio locality; b) autumn flowering at the intervention of Piazza della Libertà (Santorso); c) the rain garden located in Via dei Prati (Santorso); d) the bioretention area located on the eastern side of the Grumo hill (Santorso).

3 Project BEWARE overview

3.1 Background and justification

The consequences of climate change are exacerbated by land-use changes which affect the control of rainfall-runoff relations, and the impact on flood risk. Effectively, urbanisation is steadily contributing to the increase of impervious areas and reducing the time-to-peak. This actual scenario is fostering the debate on sustainable climate-adaptation strategies in line with the requirements of the EU Strategy on adaptation to climate change, adopted by the European Commission in 04/2013. The pressure that European countries are facing is demonstrated by scientists' modelling disaster scenarios, which evidenced that, in absence of adaptation measures in place, river flooding could affect about 300,000 people per year in the EU by 2050 and 100,000 more by 2080 (doubling the affected people in the period 1961–1990) (Rojas R. et al., 2012). Scientists showed a consistent increase of flood risk in the British Isles, western Europe and northern Italy, mainly due to the population increase.

The Italian Institute for Environmental Protection and Research (ISPRA), in a study published in June 2018, highlighted that 91% of the Italian municipalities is currently under risk of flooding, compared to the 88% in 2015. Nevertheless, in Northern Italy, the consumption of soil is higher than other Italian regions, worsening the already fragile hydrogeological conditions of the country. The effects of soil sealing and climate changes on the flood dynamics, in the Veneto Region (North-Eastern Italy), has been demonstrated in a recent paper published by TESAF (one of the project partners). The paper provides a regional screening of land-use, rainfall regime and flood dynamics in Veneto Region, covering the timeframe 1900–2010. This analysis suggests that both climate and land-use changes contributed (in synergy and individually) to a significant increase in the flood occurrence. Moreover, Sofia et al. (2017) demonstrated that floods are usually of short duration while the number of flooded areas is higher than in the past. In accordance, several flood events occurred in the region during the last decades and the most severe ones had been recorded in 1966, 1982 and in 2010, between October 30th and November 2nd (called the *All Saints* flood). During this last event, heavy rainfalls occurred in the lower mountain belt, between the provinces of Verona and Vicenza simultaneously, favoured by multiple negative atmospheric conditions (e.g. an increase of the temperatures melting the snow and southern winds contrasting the regular water down flow). 140 km^2 of roads were inundated, 130 municipalities and about 500,000 citizens were affected, 3 persons and more than 150,000 animals died. The economic burden reached up to 429 M€. Other moderate events occurred in the same area in 2011, 2012, 2013 and 2014 (the term "water bombs" was used by mass media to describe flood events triggered by intense rainfall events). However, effective disaster management needs an integrated approach to land planning, which promotes sustainable measures to restore the water storage capacity of the soil.

A previous research (Roder, 2019) covering the overall Veneto Region showed that people has a medium-low perception of flood risk, neglecting the future probability of occurrence and undertaking few individual mitigation actions. The lack of knowledge of the inhabitants is the main cause of their lack of preparedness: in fact, they usually delegate the responsibility of their safety to public authorities in charge. Results justify the need of increasing citizen's awareness and good practices adoption for collective welfare. The study area of the present study is the upper Vicenza province, included in the Bacchiglione–Brenta river system. In this area, and in the rest of Veneto region, green solutions (like the ones promoted by the project) could play a key role in flood mitigation. However, at present time, NWRMs are poorly adopted in the region (and at the National level) and, until now, NWRMs have not been considered/included in the flood risk management plans, drafted by the the *Distretto Idrografico Delle Alpi Orientali* (www.alpiorientali.it). Currently, all the public investments are placed for structural measures without considering neither green solutions nor non-structural measures for people's empowerment. Moreover, Veneto region, with the law n. 3637 of 13/12/2002, asked for a compulsory 'evaluation of hydraulic compatibility' for all the new building regulations. This technical guidance provides methods for hydrologic evaluations but does not suggest NWRMs adoption to preserve the hydraulic invariance.

The individual's adoption of NWRMs is expected to provide positive benefits at the society level: i) under a bottom-down approach (the setting of new water regulations) and ii) under a bottom-up approach (the implementation of transferable measures in a participative context). In this regard, it is remarkable that the Flood Directive recommends a wide involvement of the civil society when defining the management plans: «The Member States shall encourage active involvement of interested parties in the production, review and updating of the flood risk management plans (...) » (Art. 10 p. 2).

3.2 Project BEWARE objectives

The main project objective is the achievement of a global strategy for climate adaptation to flooding risk, increasing water infiltration and storage in urban and rural areas and involving the local communities actively. BEWARE project aims to increase knowledge, benefits and real implementation of NWRMs (Natural Water Retention Measures) both in the territory of COMSAN and COMMAR (Vicenza, Veneto Region, IT) and also in other EU municipalities, thanks to demonstrative interventions fully coordinated with information, communication and education activities. Specific objectives are:

1. To perform six urban NWRMs to reduce flood risk by increasing water infiltration and storage in COMSAN and COMMAR. Such measures are: i) undertrained bioretention, ii) infiltration trenches, iii) detention basin with an internal bioretention pond, iv) rainwater harvesting plus dry wells, v) rain gardens plus grass swales and vi) SUDS treatment train;
2. To perform one agricultural NWRM, in COMMAR, to reduce the flood risk and to partially solve the drought problems of some agricultural firms during the dry periods;
3. To promote a participative approach to implement local initiatives and measures on water-retention actions, facing climate change challenges;
4. To establish a local administrative, financial, and technical context, supporting the diffuse employment of NWRMs;

5. To enhance the link between European policies and local contexts, actively involving citizens and key-stakeholders, on the EU goals on climate change;
6. To demonstrate that small diffused works and the implementation of best practices can guarantee hydraulic safety, facing climate-change consequences effectively;
7. To favoure the replication of the proposed actions in other geographic areas of Italy and Europe.

The project is innovative for the Communities because it aims to tackle the flood issue on a new participatory perspective. It promotes a set of low-cost measures that municipalities, farms or citizens can manage efficiently. In fact, although in several European Countries a sustainable water-retention approach is still developing, in Italy and in Veneto Region a substantial delay exists. Similar defective situations have been found in Europe, highlighting the need for modern water-retention techniques (Flood Directive, art.7) to be rapidly translated into practice, inside the EU territory.

The participation is the key to develop a favourable background for effective climate adaptations initiatives. Through active involvement, BEWARE aims to promote a public responsibility for facing hydraulic risks and proposes a set of best practices to be implemented in a wider context. Indeed, the strategy can also be a shortcut to ensure social acceptance of a more sustainable land-use planning. Although the NWRMs are technically mature, they are poorly spread in Veneto Region and other European countries. Therefore the action panel of BEWARE is a virtuous example, voted to trigger a positive trend in NWRMs employment.

In addition to the strong demonstrative character of the project, the involvement of all public and administrative authorities at local level that are considered by the Covenant of Mayor's framework (Mayors Adapt) is a real innovation, if considering such a wide area (the project will involve, in the definition of a common water strategy, all 33 municipalities - *Intesa Programmatica d'Area IPA Altovicentino*).

The project is providing insights for the building code's revision in the two involved municipalities that will include mandatory norms for climate change adaptation improving the resilience of new buildings. Through the network provided by different stakeholders, the code will be proposed as a model; in particular, BEWARE will involve other Italian and European municipalities and local governments. A Permanent Centre for Resilient Communities has been launched by the Consortium and hosted by COMSAN providing:

- training activities for local administrators, civil servants, farmers, technicians;
- educational activities for pupils.

Furthermore, seminars and workshops planned by BEWARE are going to be organized. The knowledge spread with these activities will help the dissemination and replication of such measures. In addition, the transformative impacts of the other actions will strongly contribute to the community awareness to cope with climate problems, taking individual practical actions both in private and public territory (e.g. contrasting the soil sealing).

BEWARE is supported by the Italian Ministry of the Environment and the Protection of the Territory and the See (see support letters). A specific agreement will be proposed to involve the Ministry as permanent observant; the agreement will foresee the national dissemination of the project's results.

4 Monitoring methods and devices

4.1 Rainfall measurement

Two rain gauges continuously monitor the rainfall generating the inlet runoff of the interventions. The first rain gauge (RG1) is located on the roof of the secondary school "A. Cipani" in Santorso (Figure 4.1a). This rain gauge allows to measure the rainfall affecting the three monitored interventions located in Santorso (Interventions 1, 2 and 5 of Action C4). The second rain gauge (RG2, Figure 4.1b) is located in Giavenale di Schio locality, on the bank of the water retention basin (Action C3).
RG1 is the model HD2015 produced by Delta Ohm S.r.l. It is a reliable and sturdy bucket rain gauge, entirely constructed of corrosion resistant materials in order to guarantee its durability. The rain gauge is formed by a metal base on which a tipping bucket is set. The rain collector cone, fixed to the aluminum cylinder, channels the water inside the tipping bucket: once the predefined level is reached, the calibrated bucked rotates under the action of its own weight, discharging the water. During the rotation phase, the normally closed reed contact opens for a fraction of a second, sending an impulse to the counter.
The quantity of rainfall measured is based on the count of the number of times the bucket is emptied: the reed contacts, normally closed, open at the moment of the rotation between one bucket's section and the other. The number of impulses is detected and recorded by a data logger HD33-M.GSM provided by a built-in 4G/3G/GPRS modem to set the datalogger and download the recorded data remotely[1].
The second rain gauge (RG2) is located in the vicinity of the water retention basin located in Giavenale di Schio locality (Figure 4.1b), in order to characterize the rainfall affecting this intervention (Action C3) located about 5 km south of the other three monitored interventions of Santorso.

Figure 4.1. Rain gauges installed in Santorso (a), on the roof of the secondary school, and in Giavenale di Schio (b), on the bank of the water retention basin.

[1] Delta Ohm (2020). Operating manual - Tipping bucket rain gauge HD2015.

The RG2 is the model RG50 produced by SEBA Hydrometrie GmbH. The RG 50 is a highly accurate precipitation gauge with a pulse output for data collection systems. It has a one-sided ball-bearing tipping bucket made from plastic with a spirit level and adjusting screw[2]. The rain gauge is provided by a Unilog-Light data logger fully operating with pulse input for measuring rainfall with a current supply of an internal 9V-battery. Measured values and status information can be registered and read out easily on site at the LC-display by means of a 3-buttons display-panel. The 8MB storage (approx. 560,000 measured values) can be programmed, adjusted and read out via RS 232 interface by means of an interface-cable[3].

Figure 4.2 reports the location of the rain-gauges respect to the monitored interventions.

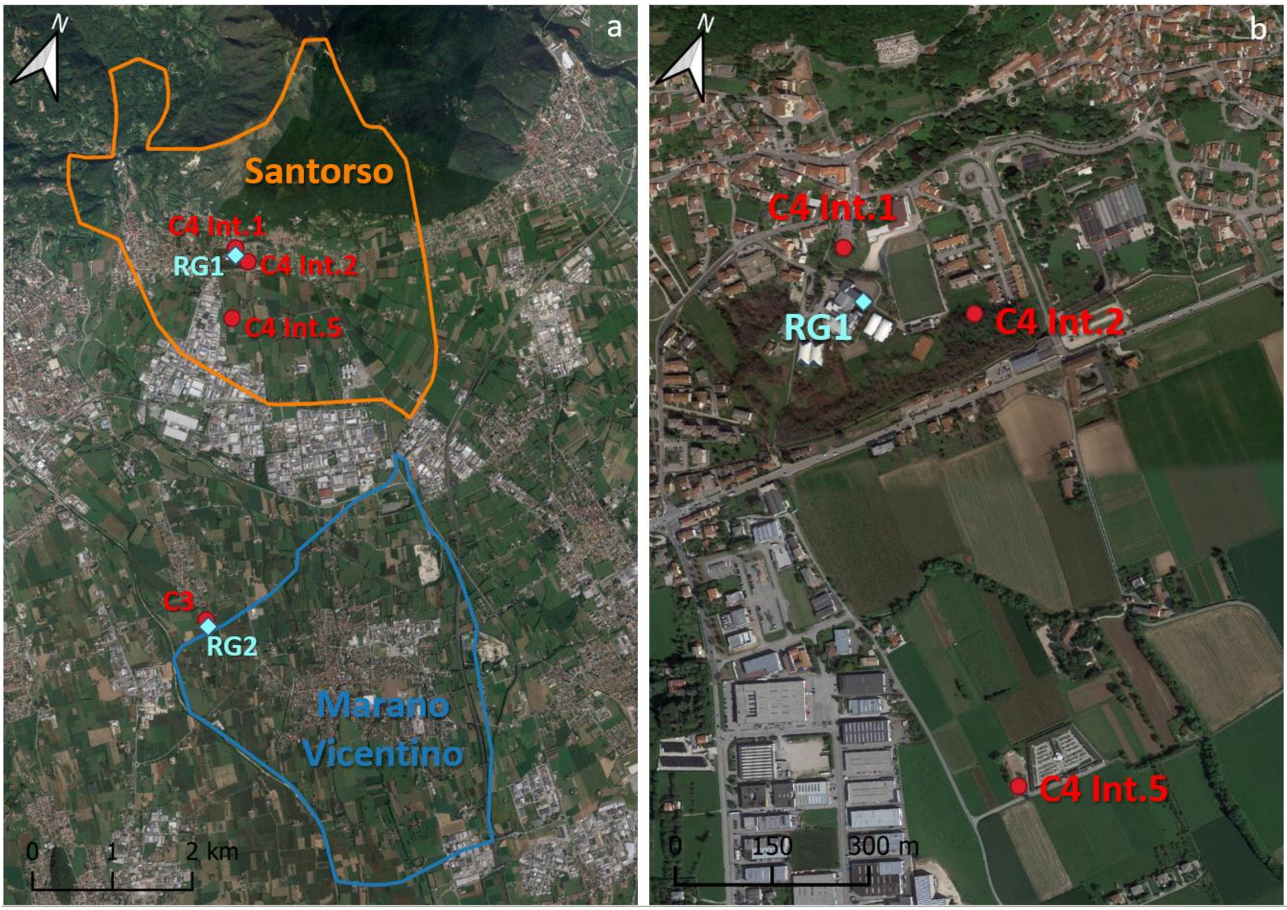

Figure 4.2. Location of the monitored interventions (red dots) and rain gauges (light blue rhombus) respect to the municipalities of Santorso and Marano Vicentino (a); figure b reports a

[2] SEBA Hydrometrie (2020). RG 50 User Manual Version 2.00.

[3] SEBA Hydrometrie (2020). Unilog-Light User Manual Version 1.51.

4.2 Inlet runoff measurement (interventions in urban areas, Action C4)

An *ad hoc* device has been designed and produced in order to monitor the runoff inlet of the three monitored interventions realized in the urban context (Action C4, Interventions 1, 2 and 5, location in Figure 4.2). The device consists of a water collection concrete pit provided by an aluminum sharp-crested weir.

The concrete pit is composed by two chambers: in the first chamber the runoff is intercepted and pre-treated (siphon) in order remove debris that might clog the second chamber that function as weir pond.

Figure 4.3 explain the general functioning of the inlet runoff measurement using as example the intervention 1 of Action C4.

Figure 4.3. Graphic scheme of the functioning of the inlet runoff measurement, with the positioning of the inlet device that collect the runoff from the drainage area (red polygon) measuring the discharges before it enters the intervention (blue polygon).

The weir installed in the concrete pit is necessary for the discharge measurement and it has been designed considering the range of expecting inlet discharges. This discharge was calculated by using the Rational Method and a Runoff Coefficient selected considering the ground cover of the drainage area. Table 4.1 reports the results of this preliminary analysis. Information about the precipitation analysis and the parameters used in the calculation are reported in the design of the interventions, deliverable of the Action C4 of the project.

Table 4.1. Expected inlet discharges Q for the three monitored interventions realized in the urban context for different rainfall return periods (Tr) and rainfall height (h). Table reports the parameters used in the application of the Rational Method: time of concentration (Tc), drainage surface area (A), and Runoff Coefficient (C).

Intervention	***Tc*** [min]	***A*** [m^2]	***C*** [-]	***Q*** [l/s]				
				Tr = 2 yr	**Tr = 5 yr**	**Tr = 10 yr**	**Tr = 30 yr**	**Tr = 50 yr**
				h = 25.8 mm	**h = 33.8 mm**	**h = 39.2 mm**	**h = 47.2 mm**	**h = 50.9 mm**
1 (Piazza della Libertà)	7.8	783.5	0.9	20.9	26.2	29.7	35.0	37.5
2 (Grumo hill)	25.7	4200	0.2	14.0	18.4	21.3	25.7	27.7
5 (New graveyard)	1.5	700	0.9	41.2	48.5	53.5	61.1	64.6

In order to accurately measure the wide range of expected discharges and limit the head flowing through the notch, a compound rectangular-rectangular sharp-crested weir (CRRSC weir) has been designed. Figure 4.4 reports the dimensions of the weir and a picture of its installation in the field (Intervention 5, Action C4).

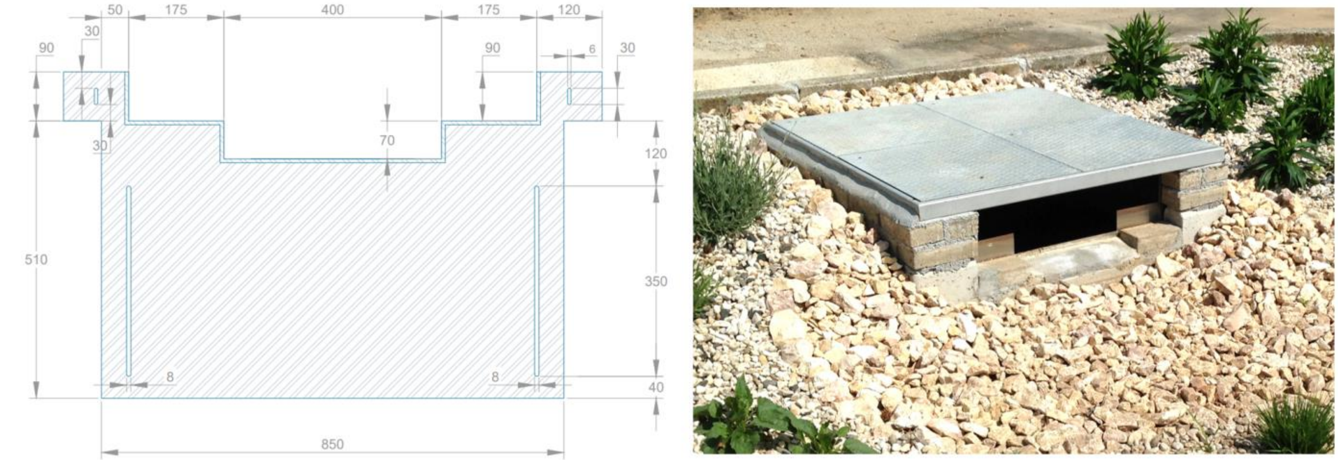

Figure 4.4. Perspective drawing of the weir (on the left, values in millimeters), and picture of its installation into the concrete pit that function as weir pond (on the right).

The CRRSC weir can be considered as a linear combination of two simple rectangular sharp-crested weirs (Jan et al., 2005). Therefore, from the linear combination, the discharge relation for the symmetric CRRSC weir can be written as:

$$Q = C_{d1}\sqrt{2g}(2b_1)h_1^{3/2} + C_{d2}\sqrt{2g}(b_2)h_2^{3/2}$$

Where C_{d1} and C_{d2} are the discharge coefficients and can be set equal to 0.415 if the upstream flow velocity is equal to zero (Ferro, 2011), b_1 is the width of the first left rectangular weir (equal to 175 mm in Figure 4.4, that is equal to the symmetrical right weir), and b_2 is the width of the middle rectangular weir (400 mm in Figure 4.4). An experimental calibration of the weirs has been carried out using a full-scale prototype (Figure 4.5). Experimental data confirmed the validity of the theoretical coefficients, and the final relation adopted to convert flow head values into discharge values is reported in Figure 4.6.

Figure 4.5. Full scale prototype used for the calibration of the CRRSC weir.

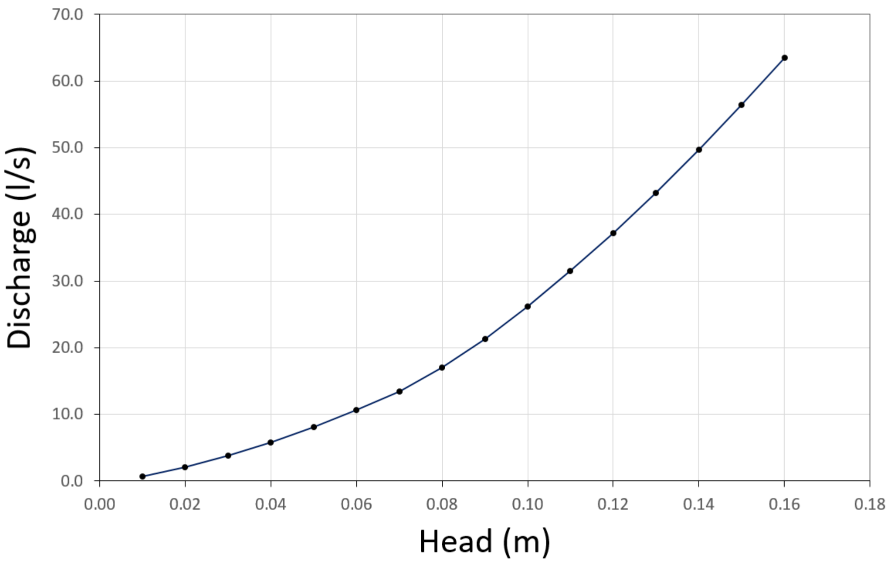

Figure 4.6. Graph of head vs discharge for the compound rectangular-rectangular sharp-crested weir used to monitor the inlet discharge to the monitored urban interventions of Action C.4.

In order to constantly measure the flow head over the crest weir and consequently know the flow discharge inlet of the interventions, a pressure transducer has been installed inside the concrete pits hosting the weirs. The adopted device is a Datalogger Dipper PT produced by SEBA HYDROMETRIE GmbH equipped with an external battery compartment (Power-pack module: Power supply with 4 x 1.5 V replaceable C-type batteries alkali-manganese), Figure 4.6. The SEBA Data Loggers type Dipper-PT are used for digital data recording of water level in ground water and surface water. The Dipper-PT/PTEC has a RS485 interface for configuring and calibrating the probe, retrieving measurement values and reading data storage. All these functions can be executed with software SEBAConfig. The robust ceramics pressure measuring cell makes it possible to measure the water level above the probe (hydrostatic pressure). The combination of the referential pressure sensor and the special measuring cable with integrated air pressure compensation capillary compensates air pressure fluctuations[4].

Figure 4.7. The pressure transducer SEBA Dipper-PT used to monitor the flow head over the weir crest (on the left), and a picture of its installation in the Intervention 2 of Action C4 (Grumo hill, Santorso).

[4] SEBA Hydrometrie (2020). Dipper-PT User manual Version 2.84.

4.3 Outlet runoff measurement (interventions in urban areas, Action C4)

In case the intervention stops to retain runoff waters (this means that its storage and infiltration capacities are exhausted), an overflow pipe collects the excess water to a second concrete pit that measure the outlet volumes before they reach the urban drainage system (Figure 4.8). Knowing the pit dimensions (1m^2 of planimetric section), the outlet volumes are measured through the monitoring of the flow level inside the pit.

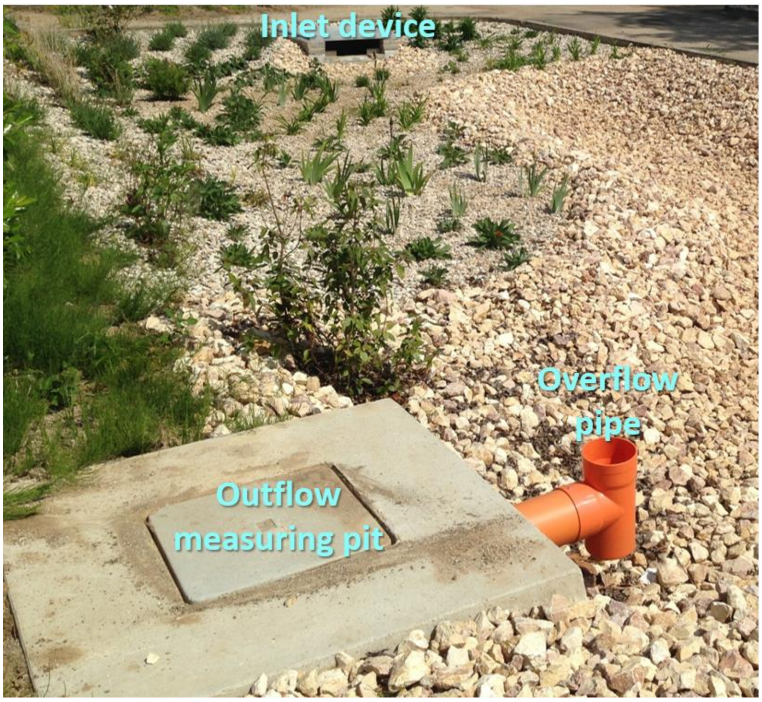

Figure 4.8. Picture of the Intervention 5 of Action C4 showing the position of the outlet measuring devices.

The flow level inside the pit is measured using the same device used in the inlet pit: the pressure transducer SEBA Data Loggers type Dipper-PT. In this case, the Dipper-PT is not provided by an external battery pack as in the inlet measuring device because the recording rate (30 min) does not require the installation of an external power supply.

Differently from Interventions 1 and 5 (Piazza della Libertà and Via dei Prati), in the intervention 2 (Grumo hill) the outlet runoff is monitored through the installation of a piezometer in the downstream bioretention area: the intervention consists of two bioretention areas organized in a cascade (details in the intervention design, Action C4 deliverable). The pressure transducer installed in this PVC pipe allows to detect the activation of the second bioretention area (i.e. define when the water accumulation and infiltration of the first bioretention area was not able to manage the inlet runoff), and to provide evidences in its functioning, included the documentation of the outflow.

4.4 Monitoring the water volumes managed by the retention basin (intervention in an agricultural area, Action C3)

In the agricultural area of Giavenale di Schio locality (Vicenza Province), a retention basin has been built with a double aim: reduce the flooding risk of a residential area in the municipality of Marano Vicentino, and guarantee, even in times of drought, the water resource to the agricultural activities of the area.

As a consequence, during the summer period the basin is maintained full of water in order to provide water for irrigation, while during the winter season the basin is empty in order to receive and accumulate the water runoff generated by prolonged rainfall.

The basin effect in reducing the flooding risk is measured in terms of volume of water retained during rainfall events that may result in potential flooding.

In order to accurately measure the water volume retained by the basin, a UAV flight has been carried out the 8th October 2019, after the conclusion of the construction works, using a DJI Phantom 4 Pro (Figure 4.9), a consumer-grade quadcopter with a 20 Megapixel camera. The flight provided high resolution imagery and a high-resolution topographic reconstruction of the basin based on Structure-from-Motion (SfM) photogrammetry. Twelve ground targets were used to georeference the UAV SfM data. The easting, northing, and elevation of each target was recorded using two Topcon HiPer V differential GPS (Rover and base receivers, Figure 4.9) with a centimetric accuracy. Agisoft™ Metashape PC software was then used to create a orthophoto mosaic and a digital terrain model (DTM) with a resolution of 10 cm (Figure 4.10) from the 92 photos taken during the flight.

Figure 4.9. Devices used for the high-resolution topographic survey of the empty retention basin (on the background): the DJI Phantom 4 Pro and the Topcon HiPerV differential GPS (used as base station in the picture).

Figure 4.10. Orthophoto mosaic (on the left) and the digital terrain model (hillshade view on the right) obtained by the UAV survey of the empty water retention basin (Action C3).

The geoprocessing toolbox of ESRI ArcGIS has been used to analyze of the digital terrain model. The Surface Volume algorithm, available on of the 3D Analyst extension of the toolbox, calculates the area and volume of the region between a surface and a reference plane. Using the DTM of the basin as reference plane, the tool has been used to calculate the volumes of water retained by the basin for different elevations of the water level inside the basin. The data obtained by this analysis is reported in Figure 4.11. The linear interpolation between the points of the graph in Figure 4.11 has been used to obtain a value of volume retained for each possible water level measured inside the basin.

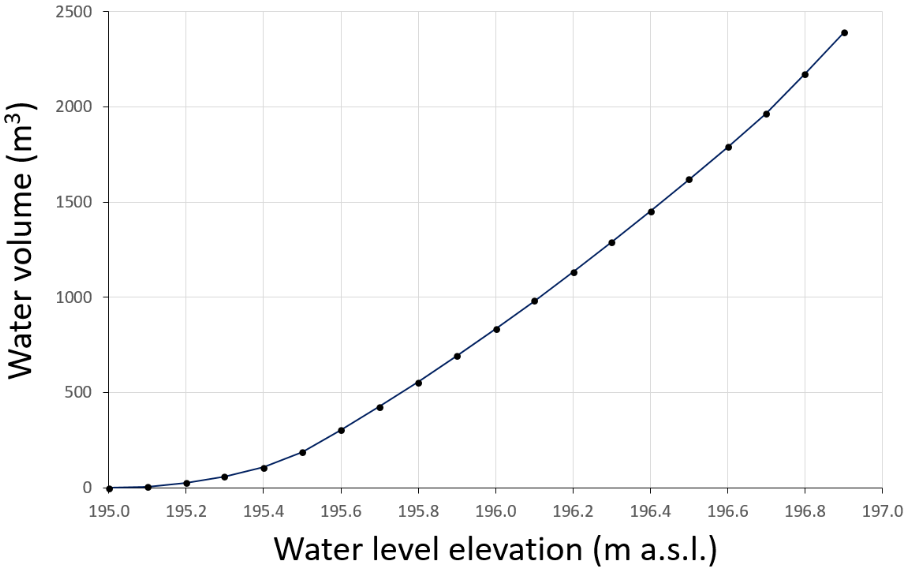

Figure 4.11. Water volume retained by the retention basin (Action C3) Vs. elevation of the water level inside the basin.

The water level is constantly monitored by a pressure transducer SEBA Dipper-PT (description of the device in the previous section; picture of the installation site in Figure 4.12). The application of the identified relationship of Figure 4.11 to the measured water levels allows to know the volume retained by the basin through time. Consequently, the adopted methods allow to measure the water retained by the basin after potentially flooding rainfall events.

Figure 4.12. The perforated PVC pipe installed on bank of the basin that host the pressure transducer in order to measure the water level.

5 Monitoring results

5.1 Rainfall

Table 5.1 reports the monthly rainfall recorded during the year 2020 by the two rain gauges (description of the devices in Section 4.1) installed in Santorso (RG1) and Giavenale di Schio locality (RG2).

The pattern of the precipitation over the year is similar in the two locations, and the annual cumulative rainfalls differs by about 150 mm.

Figure 5.1 reports the graph of the daily rainfall recorded by the rain gauges.

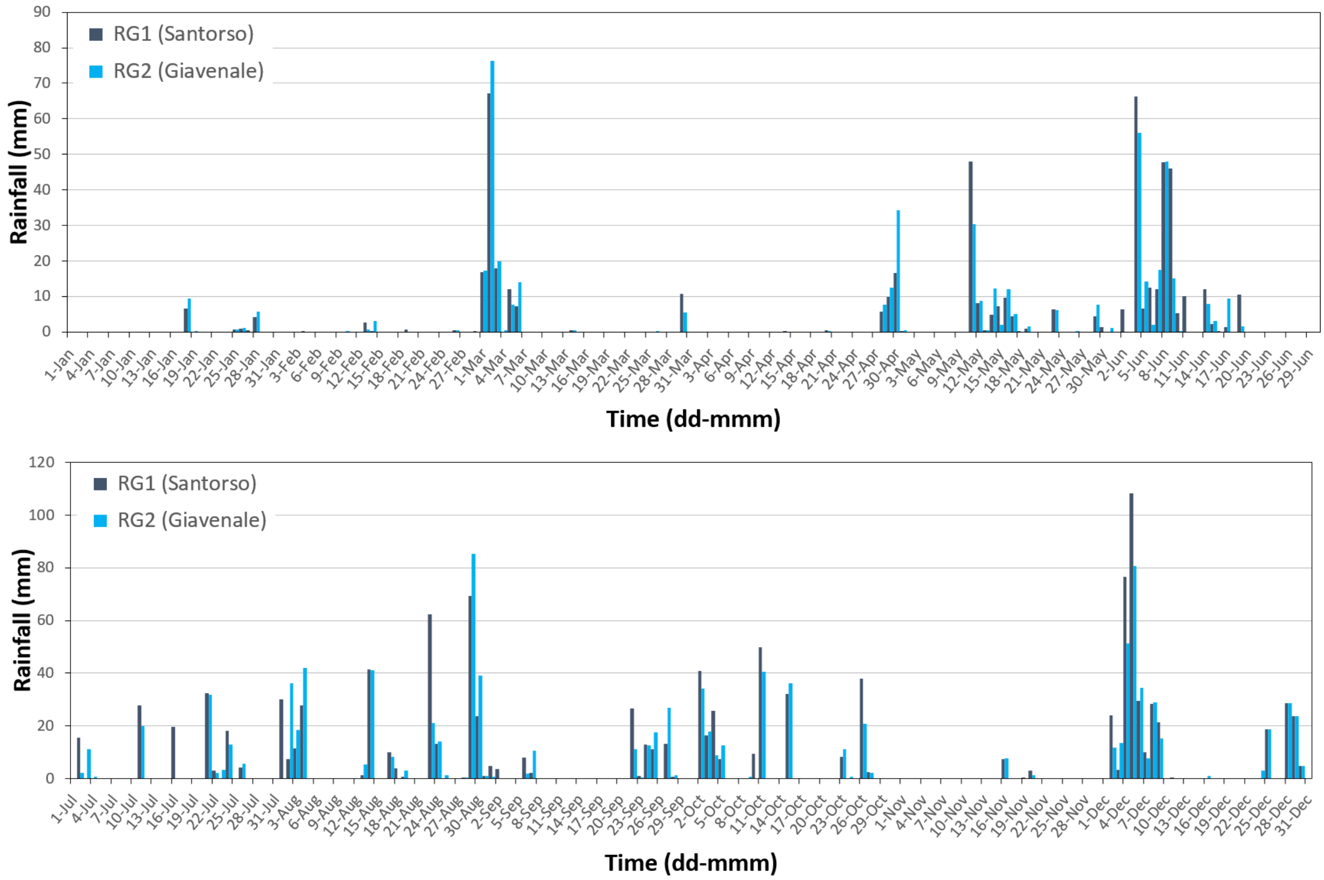

Figure 5.1. Bar charts showing daily rainfall recorded by the two rain gauges during the year 2020.

Table 5.1. Monthly rainfall collected by the two installed Rain Gauges in the 2020.

Month	RG1 (mm)	RG2 (mm)
Jan	12.9	17.4
Feb	4.4	4.4
Mar	132.3	141.2
Apr	33.0	54.4
May	95.9	88.0
Jun	239.6	174.8
Jul	122.2	90.3
Ago	305.5	317.7
Sep	85.2	83.8
Oct	231.2	186.9
Nov	11.1	9.4
Dic	378.1	324.2
Annual Rainfall	**1651.5**	**1492.5**

5.2 Interventions in urban area (Action C4)

The methods described in Section 4 are providing data in order to monitor the functioning and the efficiency of the rain garden realized in Piazza della Libertà (Santorso Municipality, Action C4, Intervention 1), of the grassed swale and the bioretention area realized in the Grumo hill (Santorso Municipality, Action C4, Intervention 2), and of the rain garden realized in the parking lot of the graveyard located in Via dei Prati (Santorso Municipality, Action C4, Intervention 5).

For each monitored rainfall event, the fielded actions provided the data graphically displayed in the graphs of Figure 5.2: the rainfall affecting the drainage area managed by the intervention, the inlet discharge and volume, and the cumulative outlet water volume after each rain shower.

This is for each of the monitored interventions except for the intervention of the Grumo hill where, as described in the Section 4, the probe at the outlet does not provide information about the outlet volume, but give information about the functioning of the bioretention system, i.e the outlet activation from the first and from the second bioretention areas.

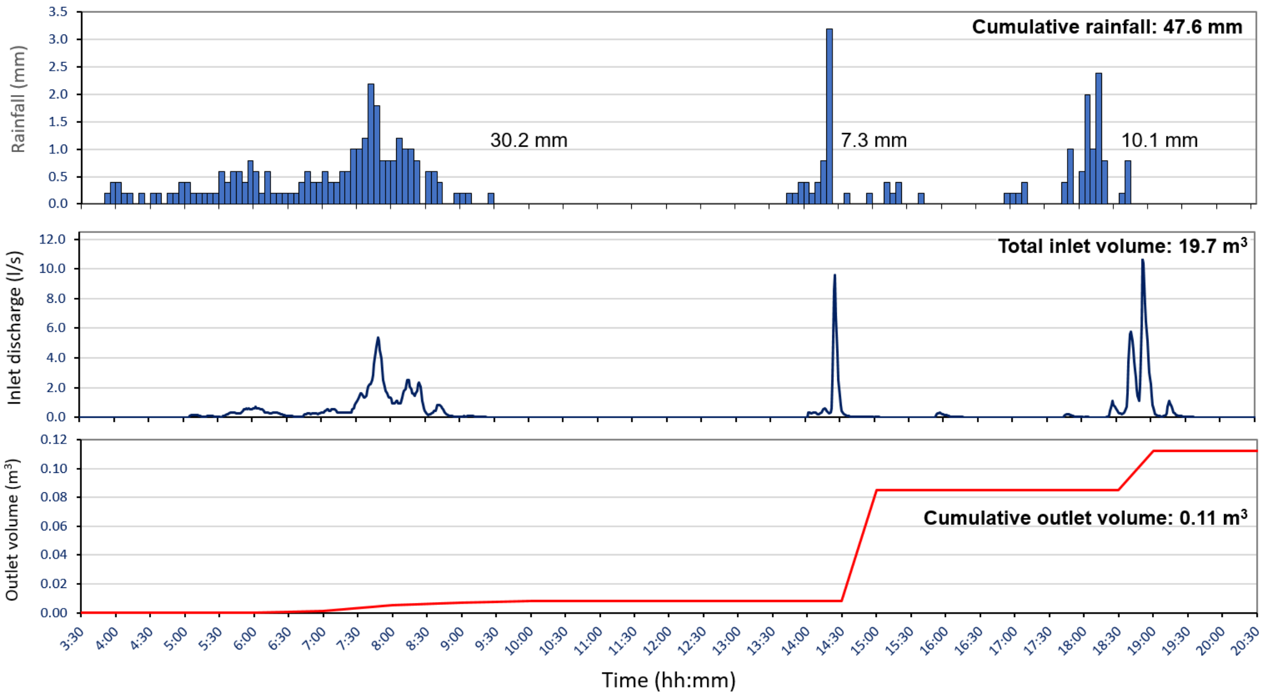

Figure 5.2. Rainfall affecting the urban area of Santorso Municipality the 11[th] of May 2020 (first graph), and the consequently measured inlet and outlet runoff from the Intervention 1 of Action C4 (rain garden located in Piazza della Libertà).

The following tables summarize the data showed in the graph of Figure 5.2 for each rainfall event able to generate inlet runoff in the monitored interventions. Respect to the interventions of Piazza della Libertà and via dei Prati, fewer events are documented for the Grumo hill (Table 5.4). This is because of the drainage area that in the Grumo hill is constituted mainly by a forest that intercept and infiltrate most of the precipitation (low or no inlet runoff occurs).

Data recorded during the first year of monitoring highlight that all the monitored interventions were able to manage almost all the rainfall events occurred in 2020. The fraction of the rainfall runoff that reached the outflow (overflow pit; see e.g. Figure 4.8) was always less than 2%; in addition, for the intervention of the Grumo hill, outflow runoff has never been observed, and only during one rainfall event, the second bioretention area has been activated (for all the other events, the first bioretention area was able to accumulate and infiltrate all the inlet water volume).

Table 5.2. Inlet and outlet volume measured in the intervention of Piazza della Libertà.

Date	Daily rainfall (mm)	Maximum rainfall intensity in the 5 min (mm/h)	Inlet volume (m^3)	Outlet volume (m^3)	Fraction of the inlet volume managed by the intervention (%)
11/05/2020	47.6	3.2	19.7	0.110	99.4
15/05/2020	7.2	1.8	0.9	0.000	100.0
16/05/2020	9.6	0.6	0.1	0.000	100.0
23/05/2020	6.4	0.8	3.5	0.000	100.0
02/06/2020	6.4	2.4	5.6	0.000	100.0
04/06/2020	66.3	2.2	38.2	0.000	100.0
05/06/2020	6.6	0.6	12.1	0.000	100.0
08/06/2020	47.4	4.4	30.7	0.380	98.8
09/06/2020	46.0	9.8	26.0	0.349	98.7
10/06/2020	5.4	1.0	0.3	0.000	100.0
11/06/2020	10.1	3.0	0.3	0.000	100.0
14/06/2020	12.1	4.0	13.6	0.000	100.0
19/06/2020	10.5	3.2	1.9	0.000	100.0
03/07/2020	0.2	0.2	1.0	0.000	100.0
11/07/2020	27.7	2.4	11.3	0.000	100.0
16/07/2020	19.5	4.8	35.2	0.360	99.0
24/07/2020	18.3	2.2	12.3	0.000	100.0
26/07/2020	4.4	2.6	0.7	0.000	100.0
03/08/2020	11.1	0.8	5.6	0.000	100.0
04/08/2020	27.7	2.2	26.3	0.000	100.0
14/08/2020	41.4	11.7	52.0	0.030	99.9
19/08/2020	0.2	0.6	0.6	0.000	100.0
23/08/2020	62.5	10.1	44.2	0.034	99.9
29/08/2020	69.3	4.6	52.6	0.268	99.5
30/08/2020	23.7	3.0	10.5	0.000	100.0
22/09/2020	26.7	7.2	1.7	0.000	100.0
24/09/2020	12.9	1.0	4.5	0.000	100.0
25/09/2020	11.1	2.8	14.0	0.000	100.0
27/09/2020	13.1	0.8	5.5	0.000	100.0
02/10/2020	41.0	1.6	28.7	0.000	100.0
03/10/2020	16.5	1.8	6.6	0.000	100.0
04/10/2020	25.7	1.2	2.2	0.000	100.0
05/10/2020	7.4	1.0	12.5	0.000	100.0
11/10/2020	49.9	1.0	34.7	0.081	99.8
15/10/2020	32.2	0.8	12.7	0.000	100.0
23/10/2020	8.4	0.4	0.3	0.000	100.0
26/10/2020	38.0	1.8	22.1	0.000	100.0
27/10/2020	2.6	1.0	0.8	0.000	100.0
04/12/2020	76.6	2.0	21.6	0.000	100.0
05/12/2020	108.3	2.0	39.4	0.035	99.9
06/12/2020	29.5	1.2	10.9	0.018	99.8
07/12/2020	10.0	0.6	1.9	0.000	100.0
08/12/2020	28.5	0.6	2.9	0.000	100.0
09/12/2020	21.3	0.4	1.3	0.010	99.3
25/12/2020	16.2	0.2	24.9	0.000	100.0
28/12/2020	27.7	0.2	3.8	0.000	100.0
29/12/2020	23.8	0.2	10.3	0.000	100.0

Table 5.3. Inlet and outlet volume measured in the intervention of via dei Prati.

Date	Daily rainfall (mm)	Maximum rainfall intensity in the 5 min (mm/h)	Inlet volume (m^3)	Outlet volume (m^3)	Fraction of the inlet volume managed by the intervention (%)
11/05/2020	48.0	3.2	2.7	0.000	100.0
15/05/2020	7.2	1.8	0.5	0.000	100.0
17/05/2020	4.0	0.4	0.0	0.000	100.0
23/05/2020	6.4	0.8	3.3	0.000	100.0
24/05/2020	6.4	0.8	0.1	0.000	100.0
29/05/2020	4.4	1.0	1.1	0.000	100.0
02/06/2020	6.4	2.4	3.5	0.000	100.0
04-10/06/2020	196.2	3.2	217.6	0.690	99.7
14/06/2020	12.1	4.0	0.9	0.000	100.0
19/06/2020	10.5	3.2	2.8	0.000	100.0
02/07/2020	15.7	4.4	1.4	0.000	100.0
03/07/2020	0.2	0.2	2.4	0.000	100.0
11/07/2020	27.7	2.4	29.0	0.000	100.0
16/07/2020	19.5	4.8	46.8	0.000	100.0
21/07/2020	32.4	8.2	2.0	0.000	100.0
22/07/2020	3.2	0.8	2.9	0.000	100.0
23/07/2020	3.2	0.8	1.7	0.000	100.0
24/07/2020	18.3	2.2	15.0	0.000	100.0
25/07/2020	0.2	0.2	0.4	0.000	100.0
26/07/2020	4.4	2.6	3.2	0.000	100.0
02/08/2020	7.6	0.8	1.7	0.000	100.0
03/08/2020	11.1	0.8	12.9	0.000	100.0
04/08/2020	27.7	2.2	31.3	0.092	99.7
13/08/2020	1.4	0.8	0.2	0.000	100.0
14/08/2020	41.4	11.7	35.9	0.049	99.9
17/08/2020	10.1	5.2	1.4	0.000	100.0
19/08/2020	0.2	0.6	3.4	0.000	100.0
23-25/08/2020	75.8	10.1	60.2	0.059	99.9
29/08/2020-02/09/2020	102.9	4.6	80.1	0.414	99.5
06/09/2020	8.2	1.8	1.9	0.000	100.0
07/09/2020	2.2	0.4	1.6	0.000	100.0
22-25/09/2020	51.9	7.2	66.7	0.018	100.0
27/09/2020	13.1	0.8	17.2	0.000	100.0
02-05/10/2020	90.5	1.8	111.5	0.296	99.7
11/10/2020	49.9	1.0	72.2	0.011	100.0
15/10/2020	32.2	0.8	58.7	0.014	100.0
23-27/10/2020	57.3	1.8	49.3	0.023	100.0
16/11/2020	7.6	0.4	8.8	0	100.0
20/11/2020	3.0	0.4	9.1	0	100.0
02-05/12/2020	212.1	2.0	446.8	0.34	99.9
06/12/2020	29.5	1.2	86.9	0.05	99.9
07/12/2020	10.0	0.6	17.6	0	100.0
08/12/2020	28.5	0.6	41.1	0.05	99.9
09/12/2020	21.3	0.4	26.2	0.03	99.9
25/12/2020	16.2	0.2	38.9	0	100.0
28/12/2020	27.7	0.2	35.6	0	100.0
29/12/2020	23.8	0.2	72.4	0.152	99.8
30/12/2020	23.8	0.2	6.4	0	100.0

Table 5.4. Inlet volume measured for the intervention of the Grumo hill and.

Date	Daily rainfall (mm)	Maximum rainfall intensity in the 5 min (mm/h)	Inlet volume (m^3)	Activation of the second bioretention (yes/no)
01-04/08/2020	77.0	11.3	4.2	no
12-14/08/2020	43.0	11.7	11.6	no
23/08/2020	62.5	10.1	26.0	**yes**
28-30/08/2020	93.5	4.6	30.9	no
22-27/09/2020	65.1	7.2	0.2	no
02-05/10/2020	90.5	1.8	16.1	no
10-11/10/2020	59.5	3.4	7.9	no
15/10/2020	32.2	0.8	2.7	no
26/10/2020	38.0	1.8	2.0	no
02-09/12/2020	301.3	2.0	268.7	no
25/12/2020	16.2	0.2	3.2	no

5.3 Interventions in agricultural area (Action C3)

As described in Section 4.4, the retention basin acts as flood mitigation measure, especially during the winter time when the basin is emptied to receive and accumulate the water runoff generated by prolonged rainfall. During the summer period the basin is maintained partially full of water to provide water for irrigation. To this reason, the following data analysis has been carried out in the two seasons separately.

Figure 5.3 reports the rainfall recorded by RG2 and the water level measured in the basin during the 2020 summer period. The flow level shows a daily fluctuation due to irrigation. Effectively, the “Consorzio di bonifica Alta Pianura Veneta” (CB-APV, project partner) constantly provides water for irrigation that every day partially fills the basin. At the same time, farms take water from the basin for the irrigation. The operations of irrigation are usually carried out during the morning as the decreasing sections of the flow level are generally reported from 8.00 AM to 12.00 AM. As a consequence, in the summer period is not possible to exactly define the contribution of the basin in the flood risk mitigation. Nevertheless, Figure 5.3 shows that for most of the rainfall events, the complete filling of the basin has almost never been reached. An exception is reported in the late summer when maximum water level in the basin was reached because of a reduction in the irrigation withdrawals.

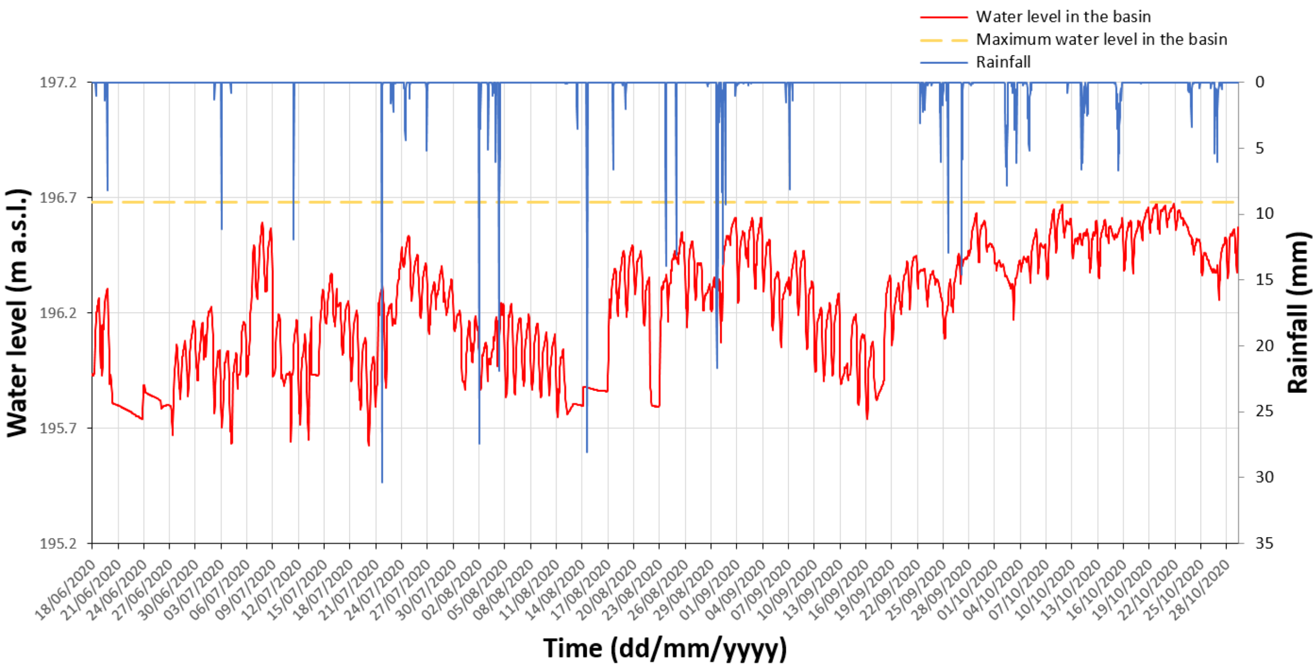

Figure 5.3. Rainfall affecting the Giavenale di Schio area and water level in the basin during the 2020 summer period.

Figure 5.4 reports the rainfall recorded by RG2 and the water level measured in the basin during the 2020 winter period. Differently from the summer period, in the winter period the water inlet is only provided by the flood discharges generated by the rainfall events. As a consequence, the contribution of the basin in flood risk mitigation can be precisely assessed in terms of volume of water stored by the basin. First of all, the graph shows that the basin was able to manage all the flood events occurred in the analyzed period, because the maximum level has never been reached (as reported in Figure 5.4).

Three rainfall events occurred during the analyzed period generated floods able to partially fill the basin. For each event, a rainfall characterization and the volume of water stored in the basin are reported in Table 5.4.

Thanks to these results we can conclude a correct functioning of this intervention, which could certainly manage more severe conditions (e.g. stronger rainstorm events and/or period of more water scarcity) with respect to those observed up to now.

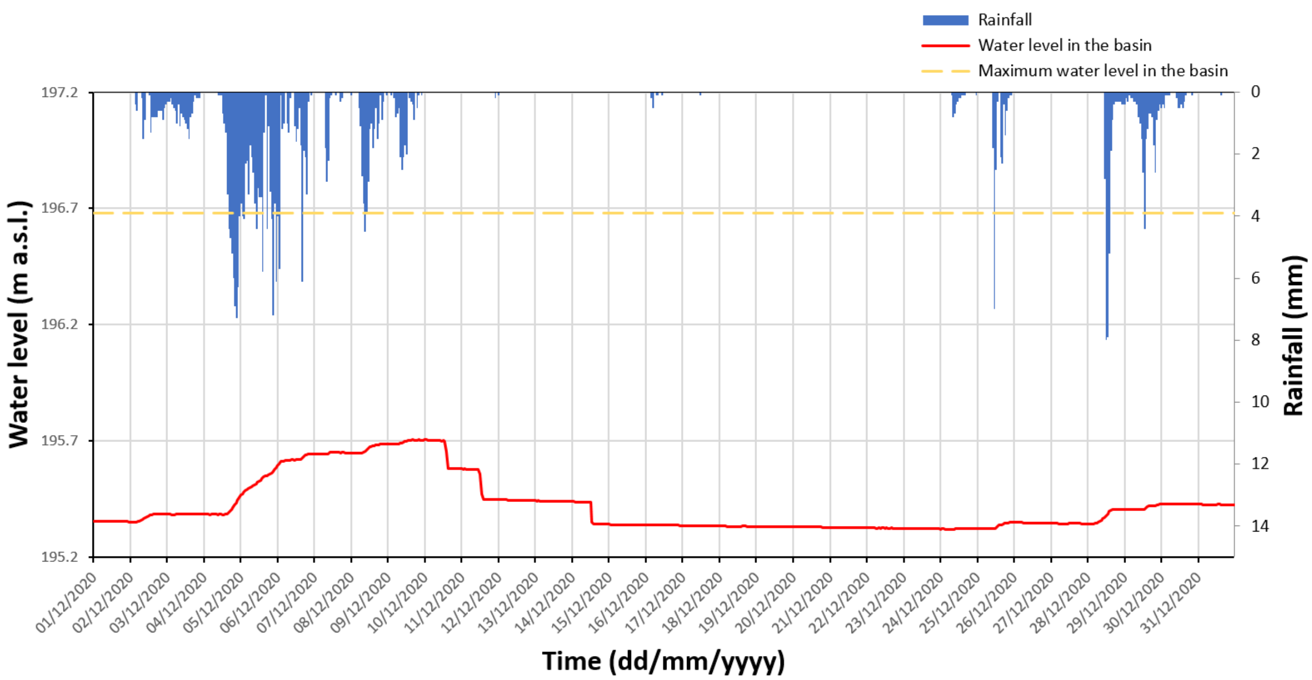

Figure 5.4. Rainfall affecting the Giavenale di Schio area and water level in the basin during the 2020 winter period.

Table 5.5. Rainfall events occurred in the 2020 winter period and corresponding water volume stored in the basin.

Date (dd/mm)	Duration of the rainfall event (days)	Cumulative rainfall (mm)	Maximum rainfall intensity in 5 min (mm/h)	Volume stored in the basin (m^3)
02/12 - 09/12	7.9	243.6	22.8	349.9
24/12 - 25/12	1.6	21.9	10.8	9.7
28/12 - 30/12	2.4	57.2	9.6	50.3

6 References

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