Hydraulic modelling for the rapid assessment of flooding problems in urban area: experimental application in a large urban catchment in Mediterranean Area

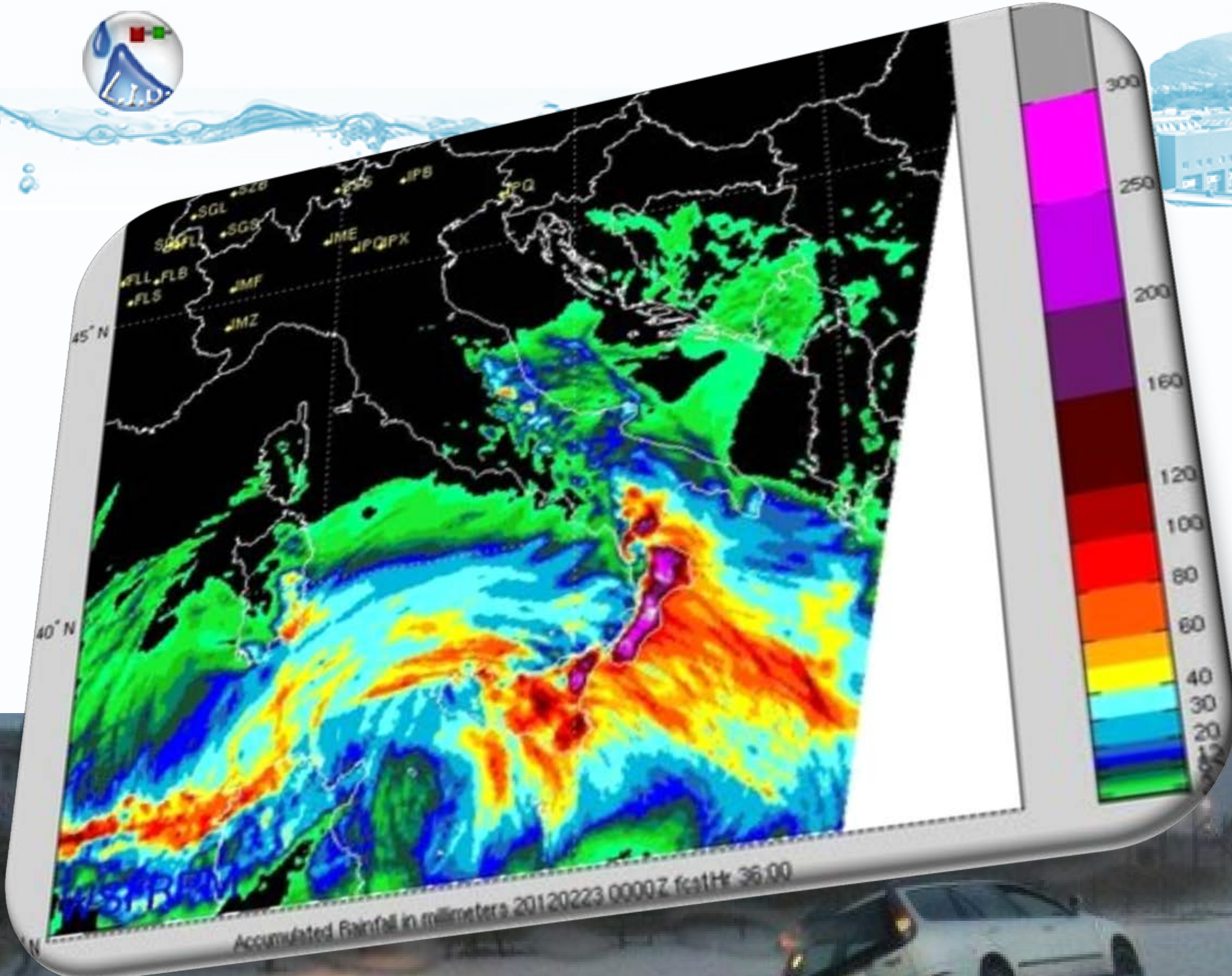
Patrizia Piro, Marco Carbone, Giovanni Tomei, Antonello Mancuso
University of Calabria

Corigliano Calabro, 2009

Roma, 2011

Genova, 2011

Catania, 2012



Sigonella, Feb. 2012

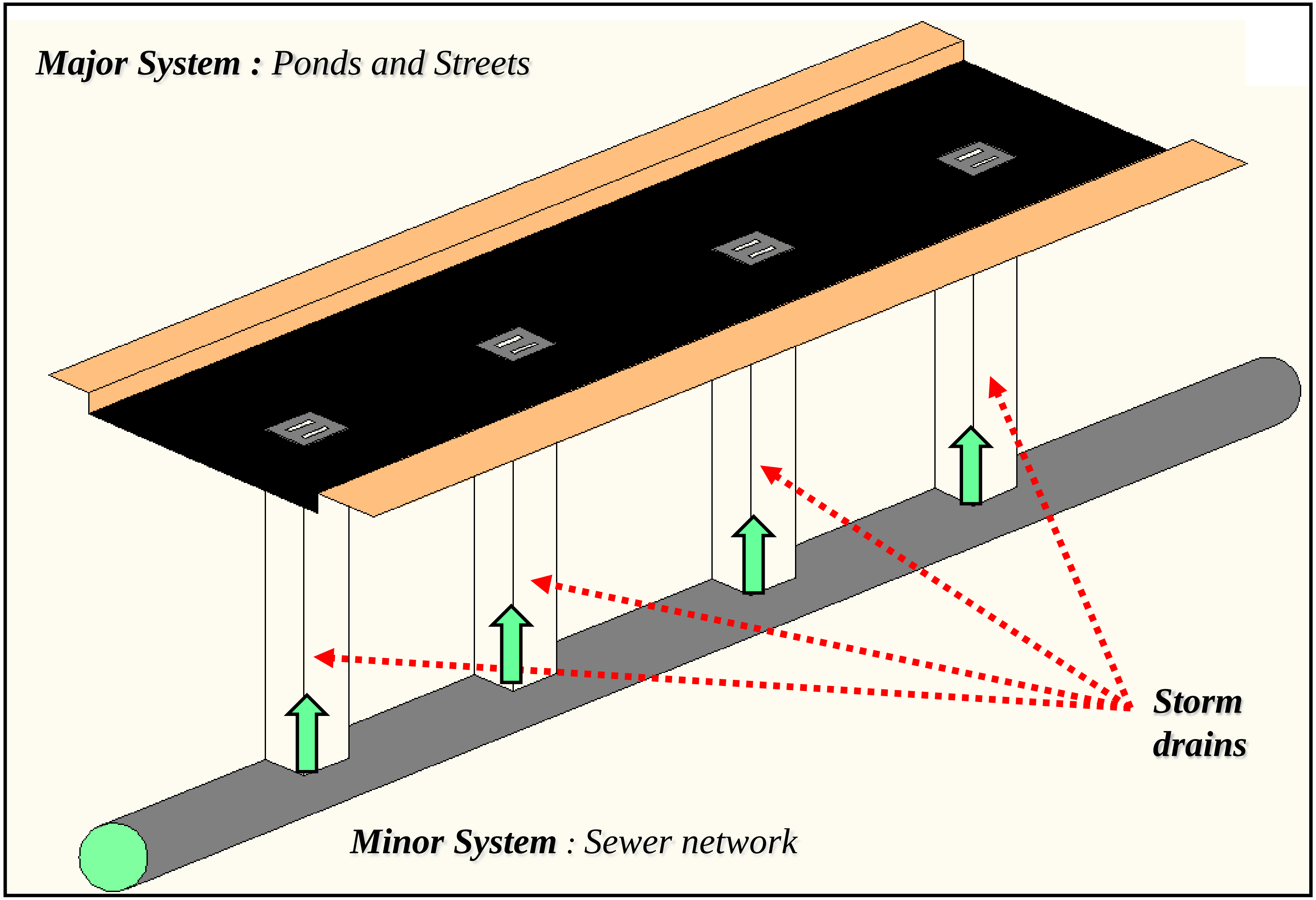
“Although flood risk can never be completely eradicated, its impacts require to be reduced by both improving the modelling of urban drainage systems and deepening the knowledge of flood producing storm rainfalls”

Maksimović et al., 2010

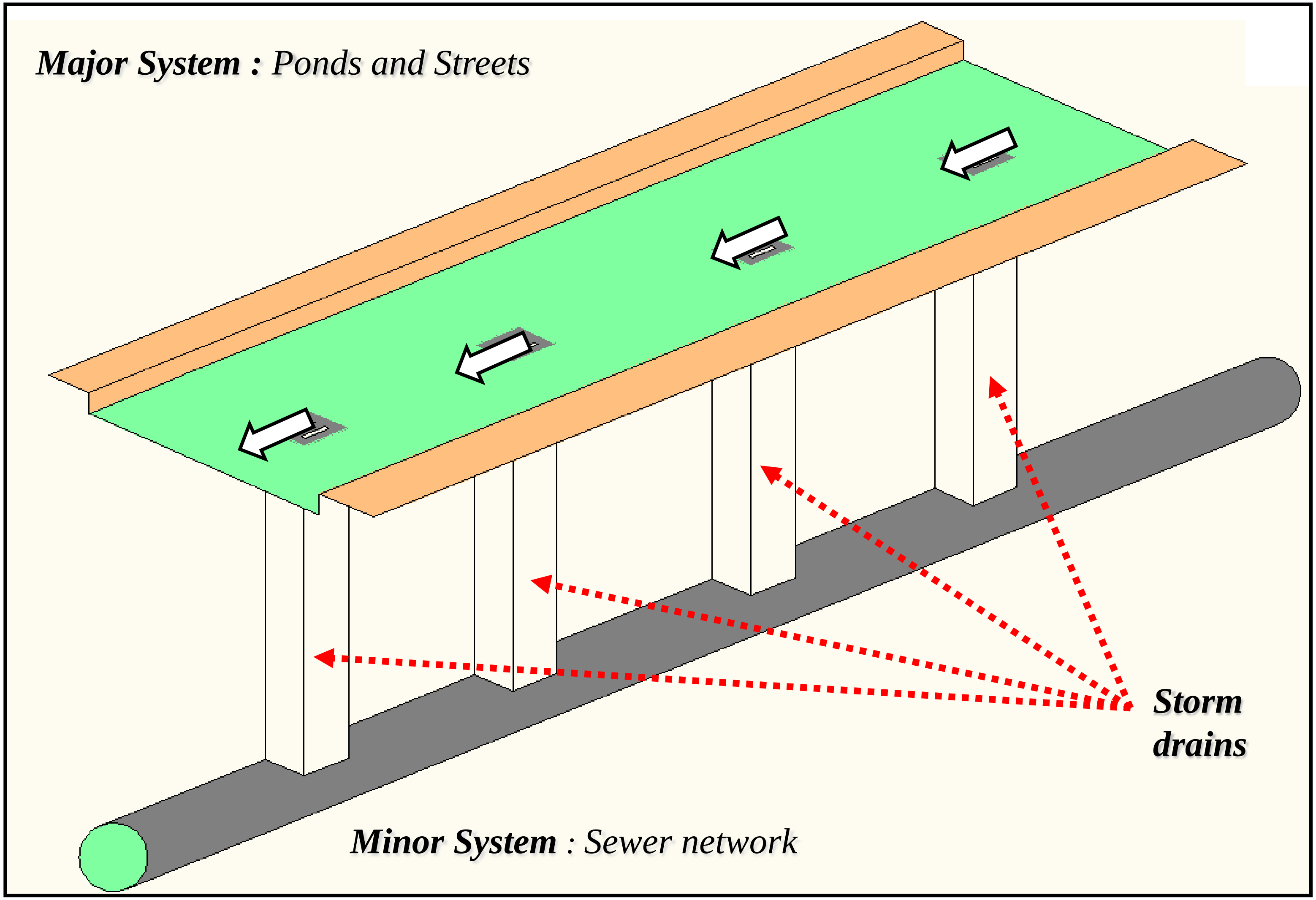
Classical Model	Developed by following the traditional hypothesis according to which the drainage system is composed only by the sewer system, namely considering that storm water, once entered the sewer system, can no longer leave this system by coming back to the surface.
Dual Drainage Model	Based on the dual drainage approach, according to which the urban drainage system is composed of two components: a surface or major system, linked by streets, ditches, and various natural and artificial channels, and a subsurface sewer network or minor system.

These systems are then modelled as two dynamically interconnected networks. Manholes and sewer inlets function as points of flow exchange between sewer and overland systems.

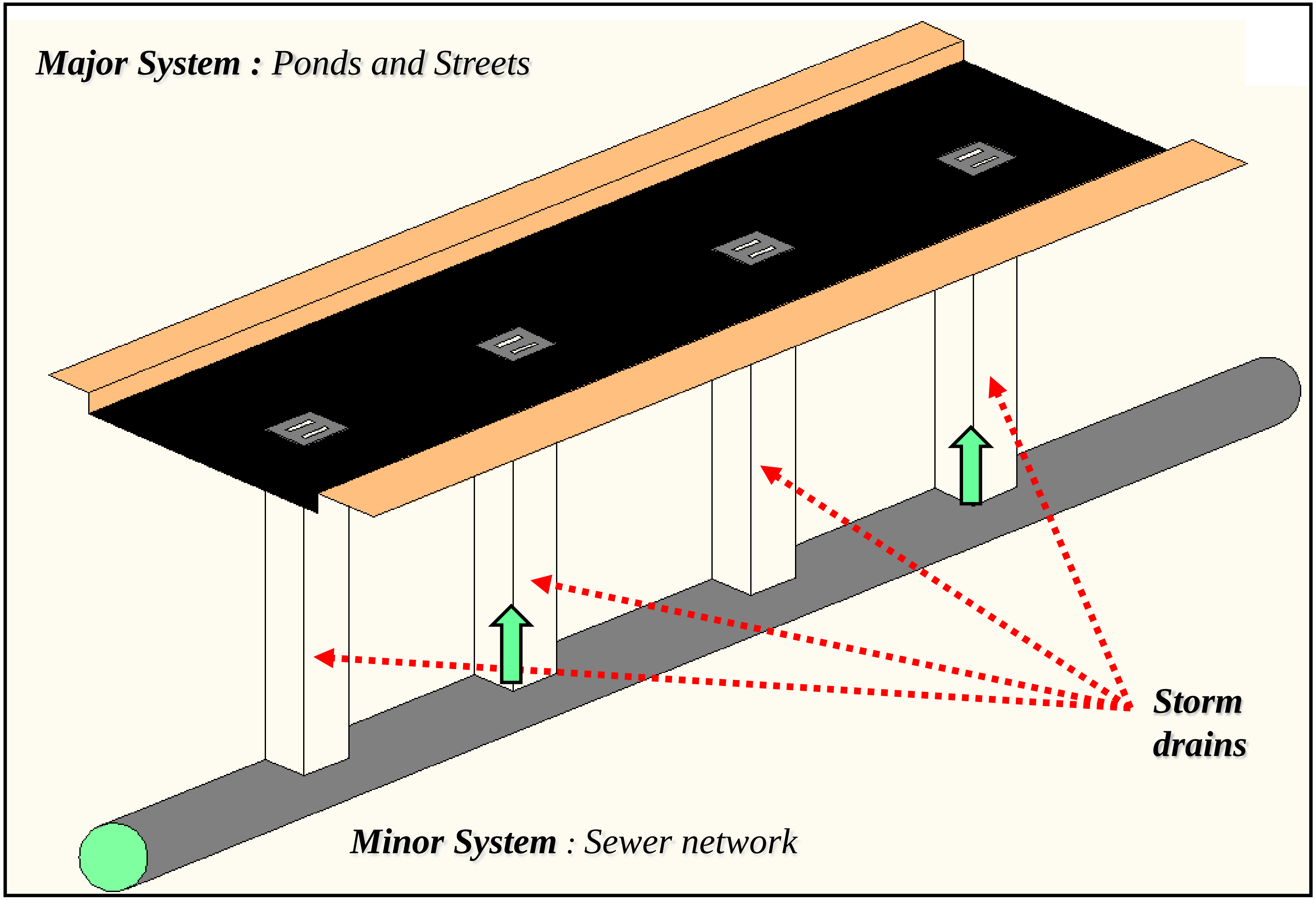
Dual drainage modelling



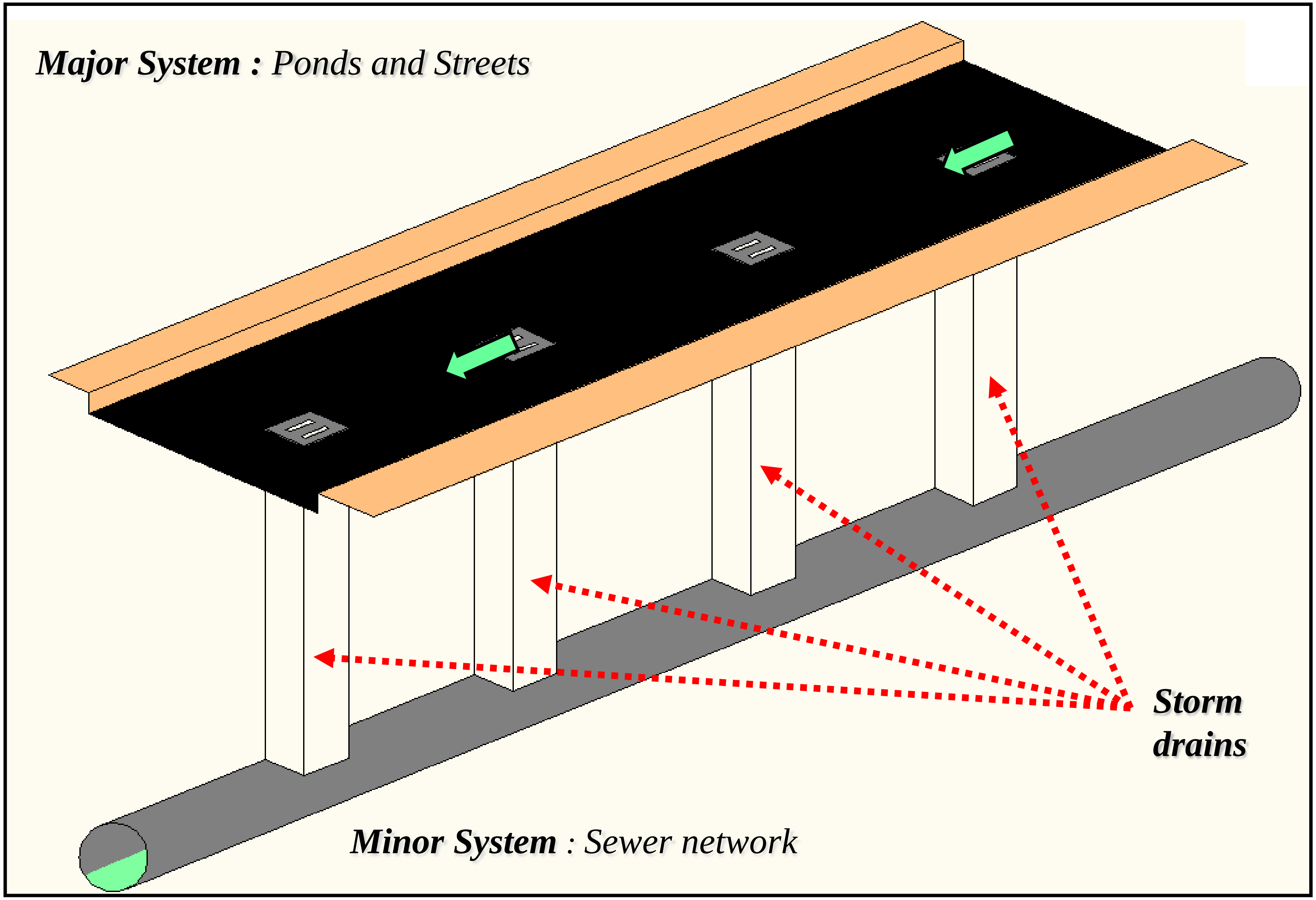
Dual drainage modelling



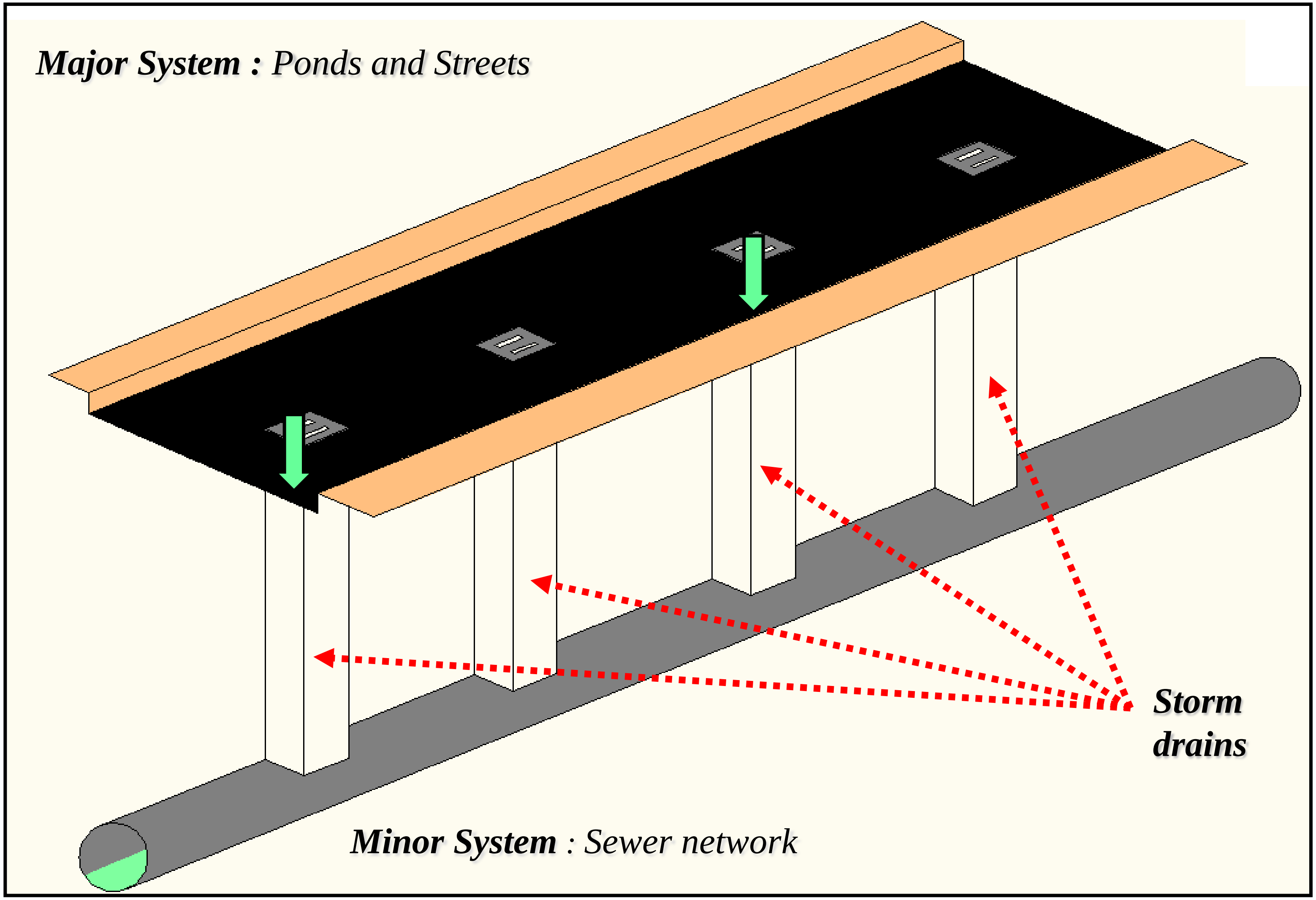
Dual drainage modelling



Dual drainage modelling



Dual drainage modelling



The objective of the study was to demonstrate how conventional methodologies are not suitable for appropriately modelling the behaviour of urban drainage system, above all during extreme rain events.

These considerations will be motivated by comparing the water volume distributions within the two different drainage networks.

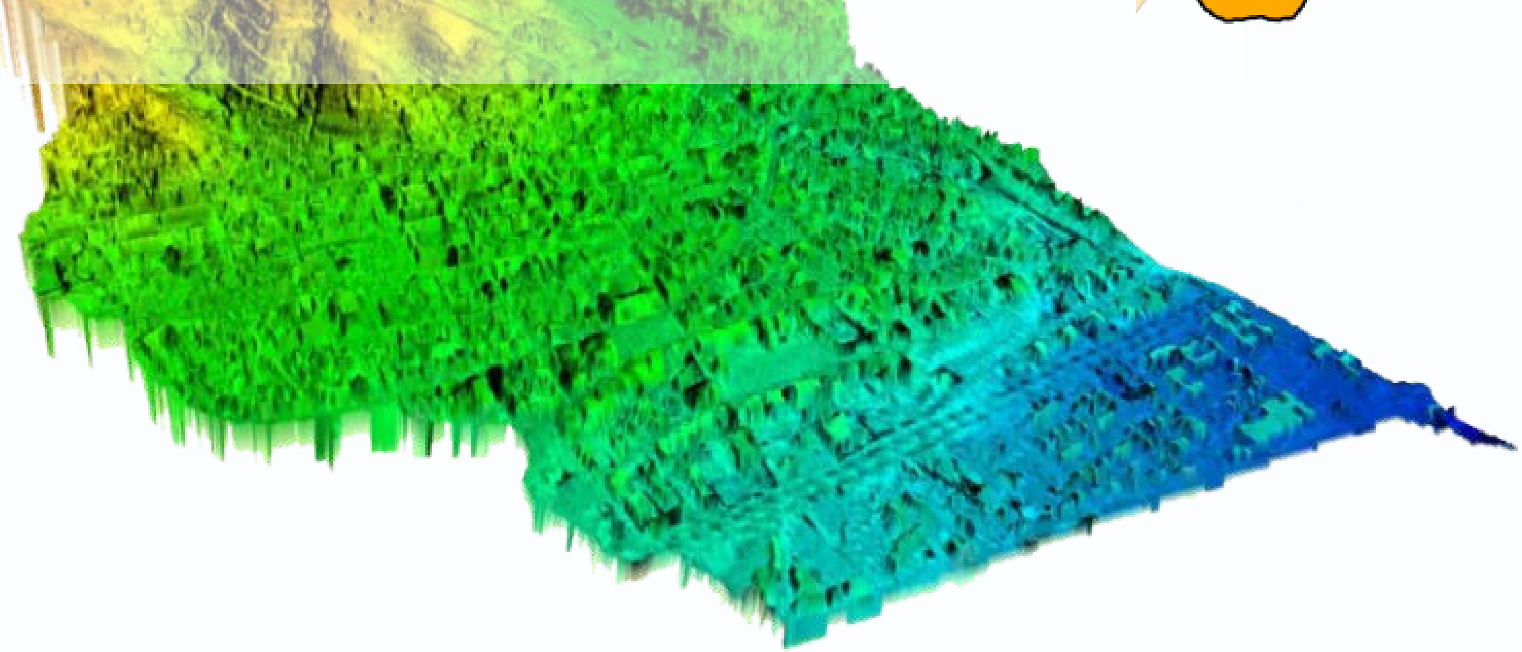
The 1D-1D approach will lead to the reduction of construction and maintenance costs of some parts of the network.

Description of the study area

- The research concerned the modelling of the drainage network of the Liguori catchment, an experimental site that has been studied for several years by the Department of Soil Conservation of the University of Calabria.

The catchment was instrumented by installing a monitoring station, consisting of a tipping-bucket rain gauge and an ultrasonic sensor for measuring water levels (depths) at the sewer outfall.

The drainage network supports a population of 50,000 inhabitants and drains a 400-ha watershed.

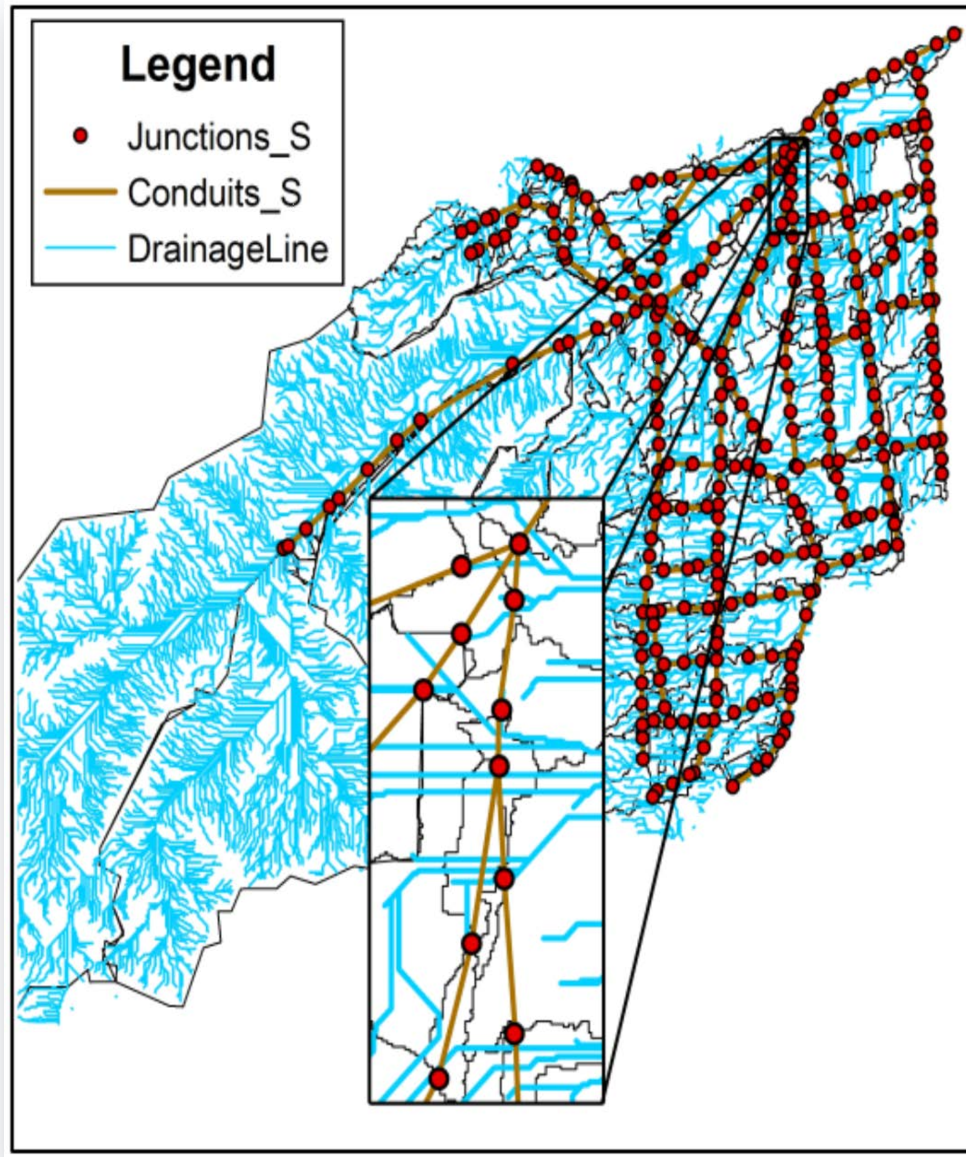


METHOD OF ANALYSIS

ArcGIS software:
physical characteristics of the system to insert into the hydraulic models.

In particular, owing to the lack of information the manhole positions was obtained by considering the intersections between the sewer layout and the natural drainage network generated from the DTM.

A LiDAR DTM, characterized by an horizontal resolution of 1 meter, was used.
The intersections characterized by a Horton's number greater than one, were considered.



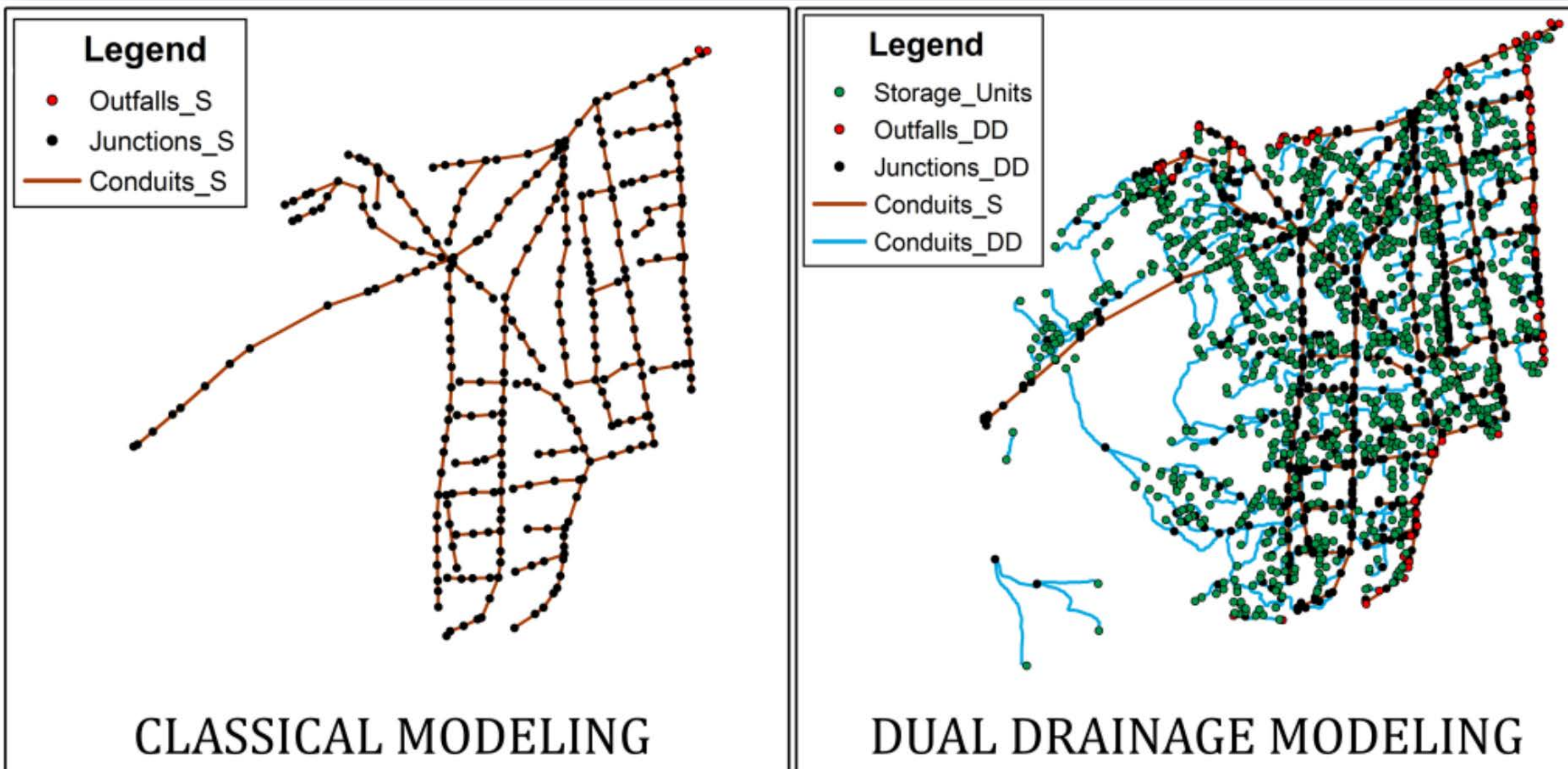
The modelling of a reliable surface network to be coupled with the sewer network model.

The sewer system is generally known,
The surface network must be defined taking into account the geometric characteristics of the study area, such as road slopes, dimensions of sidewalks, buildings, etc.

The AOFD tool (Automatic Overland Flow Delineation). Developed by the Urban Water Research Group (UWRG) of Imperial College London (ICL) in cooperation with the University of Belgrade and the University of Exeter. (Maksimović et al., 2009).

RESULTS

It is evident that the complexity of the hydraulic model increased by passing from a traditional approach to a dual drainage one, as it is possible to observe by comparing the two graphical representation of the networks.



The number of **conduits** increased from **296** to **1625**,

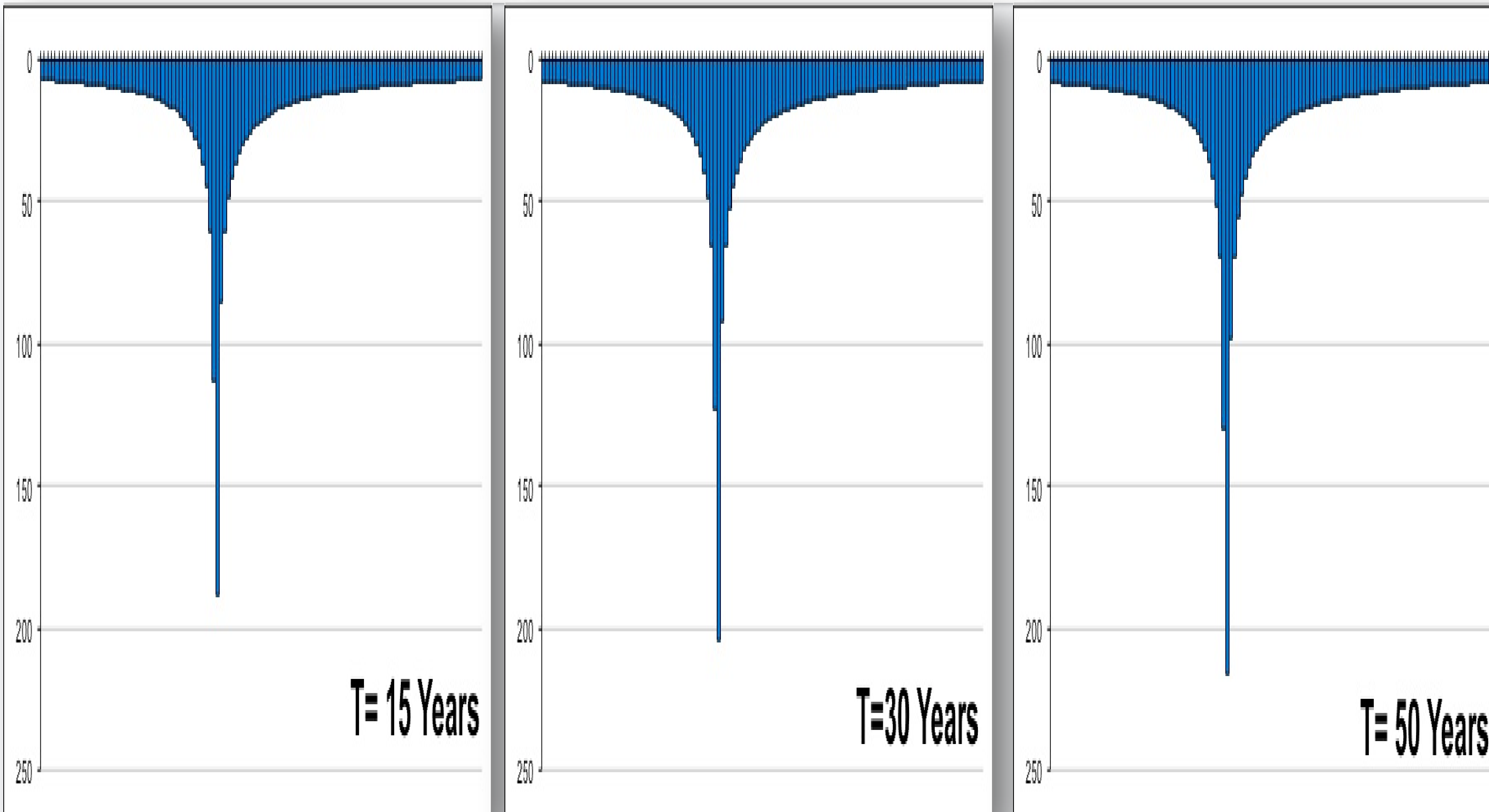
The number of **junction nodes** increased from **296** to **485**,

The number of **outfall nodes** increased from **2** to **55**,
(the consideration of the surface pathways determined the generation of further outfalls inside the catchment).

It was necessary to add about **1000** **storage nodes**, which enabled the simulation of the ponds, and **225** **orifices** to be provided to the surcharged sewer nodes.

This complication of the model was needed in order to simulate the behaviour of the drainage networks more accurately.

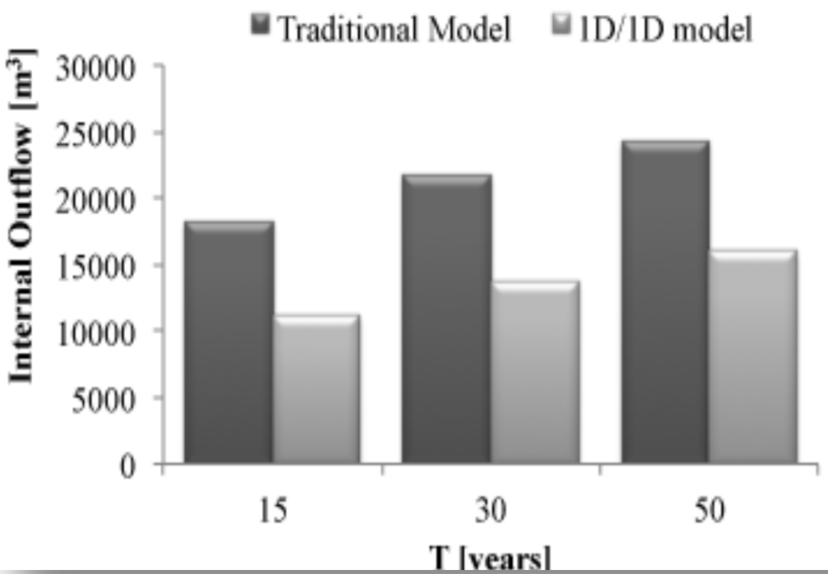
- By subjecting the two hydraulic models to identical rainfall inputs (three synthetic rainfall events with associated return periods of 15, 30 and 50 years), it was possible to note different water volume distributions only when the storm events surcharged the sewer network.

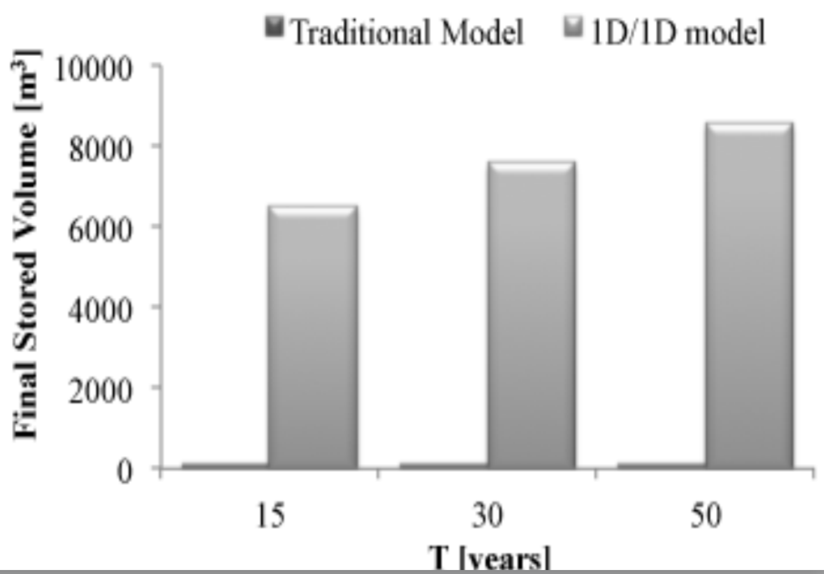


The following Figure reports such outcomes in terms of Internal Outflow and Final Stored Volume relative to the simulations carried out by considering the synthetic rainfall events.

The Internal Outflow is the flow that leaves the system through flooding at non-outfall nodes, whereas the Final Stored Volume is the sum of the volumes stored in nodes and links.

The higher number of conduits and storage nodes in the dual drainage model favoured the definition of a greater storage capacity of the hydraulic model (higher values of the Final Stored Volume).

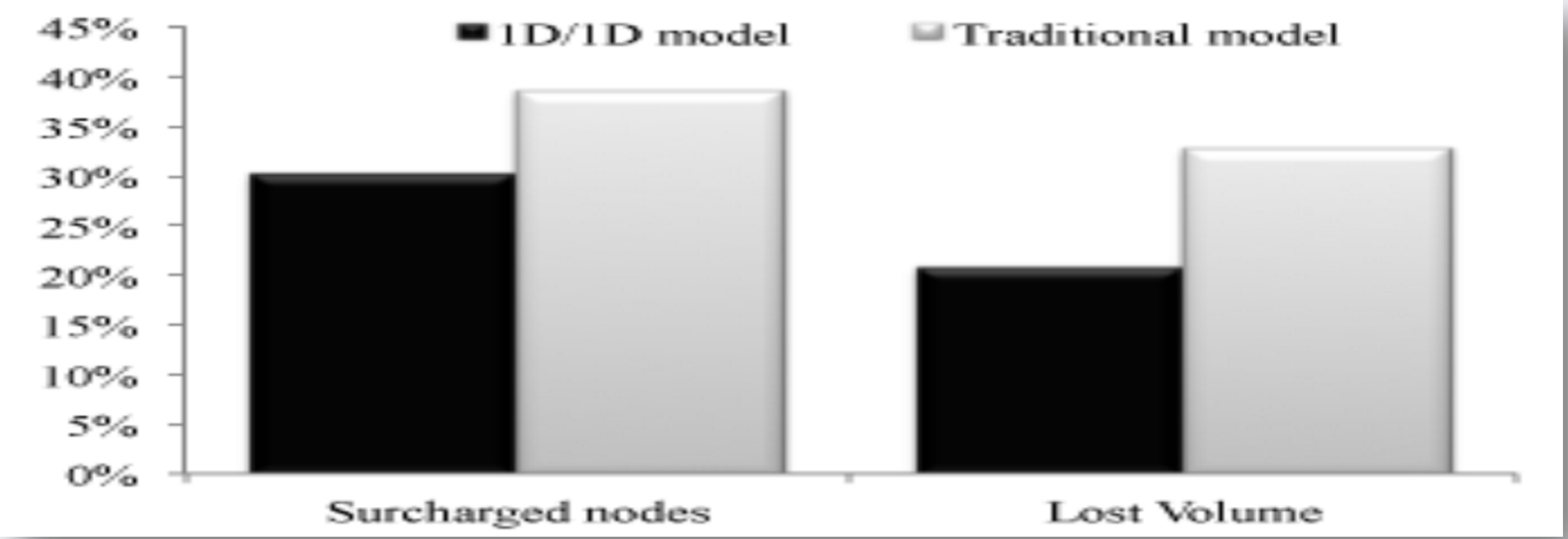




RESULTS

A dual drainage model enabled a more realistic simulation of the sewer flooding, since it was based on a bidirectional interaction between the minor and the major system.

Moreover it was possible to limit the number of surcharged nodes and the associated volume losses.



UNIVERSITÀ DELLA CALABRIA

RESULTS

On average (return periods of 15, 30 and 50 years), 77 % of the surcharged nodes found in the traditional model were also taken into account by the AOFD procedure.

> 94 % were no longer flooded in the dual drainage model thanks to the connections provided with the surface network, whereas a further 5 % was still overloaded, but by a volume reduced by more than 90 %.

Consequently, in such situations, the engineer should solve a significantly reduced number of sewer criticalities, and the cost of the rehabilitation works would tend surely to be decreased.

be decreased.
number of sewer criticalities, and the cost of the rehabilitation works would tend surely to
Consequently, in such situations, the engineer should solve a significantly reduced
by a volume reduced by more than 90 %.

CONCLUSIONS

- This research was focused on comparison of two drainage system models.
  - The first hydraulic model was based on the traditional hypothesis whereby drainage system is composed only by sewer system.
  - The second one was developed following the dual drainage approach 1D/1D, namely considering the system composed by surface and sewer network.
- It emerged that the traditional approach is not adequate to simulate sewer flooding realistically, since it ignores the fundamental concept on which traditional urban hydrology is based, i.e. the interaction between the surface network with the buried drainage system.
- By subjecting both models to identical rainfall inputs, it was possible to note that different volume distributions emerged only in the cases where the storm events determined the surcharge of the sewer network.

CONCLUSIONS

- As expected, the conventional model localized a greater number of surcharged trunks, which would have forced the engineer to increase the dimensions of the pipes involved with consequent repercussions on the cost of the works..

- The dual drainage methodology is suggested to be developed for future applications. In particular it is expected that the use of such an approach will lead to change completely the sewer network design approach. The designer will have to aim at optimizing the use of both major and minor system to manage the resulting excess runoff originated during a storm event.

- An example of this could be the Blue-Green Concept (BGC), that has been developed as a tool to integrate surface water and fluvial flood risk management with green spaces as part of the strategic spatial planning for urban environments.


Thank you
for your attention.