EIP Water Conference 2016

How is water innovation succeeding in Europe?

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CTRL+SWAN Side meeting

SWANP: Smart WAter Network Partitioning and Protection

Activities of

European Innovation Partnership on Water Action Group CTRL + SWAN

Cloud Technologies & ReaL time monitoring + Smart WAter Network

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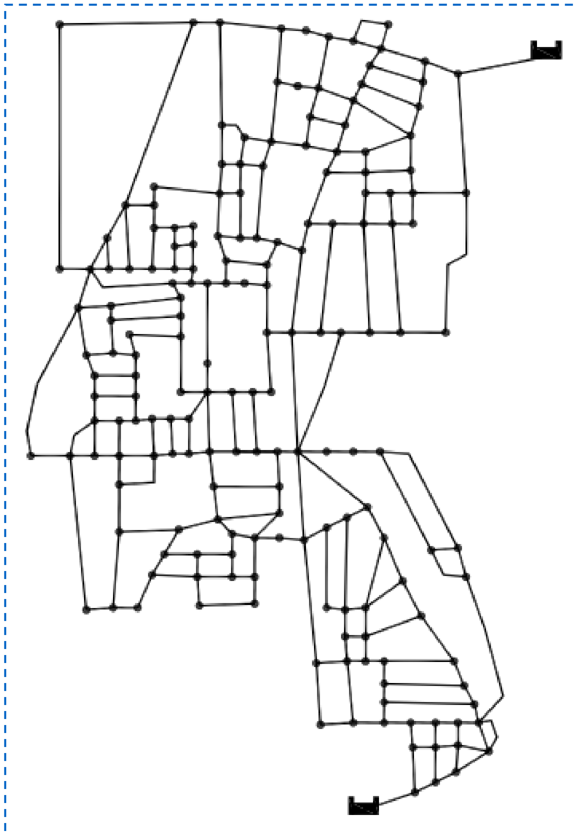
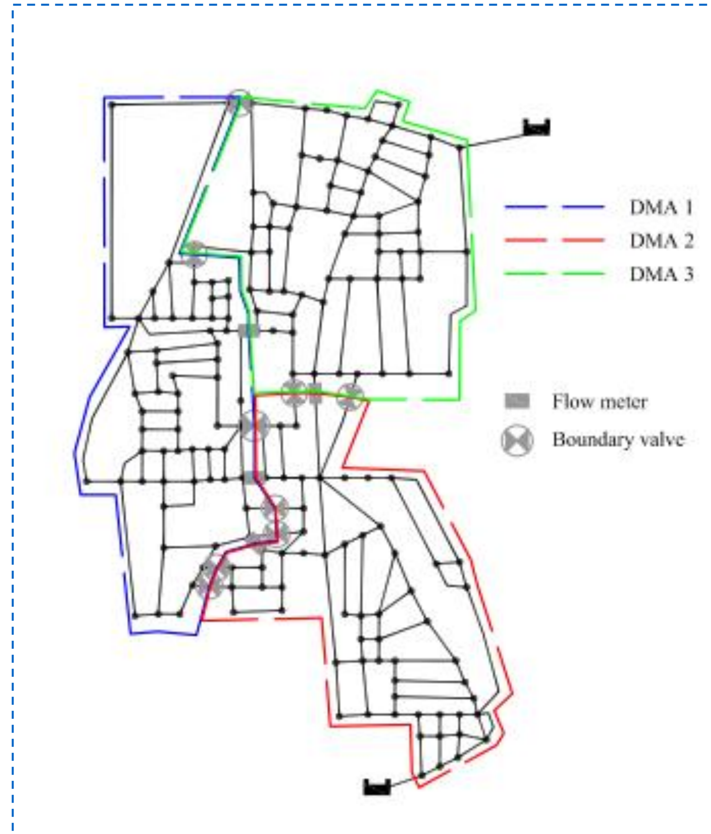
Water Network Partitioning (WNP) is a methodology that consists in dividing a **Water Distribution System (WDS)** in subsystems or District Meter Areas (DMAs) by using ***flow meters*** and ***gate valve*** (boundary valves), introducing the paradigm of Divide and Conquer



Original Water Distribution Network



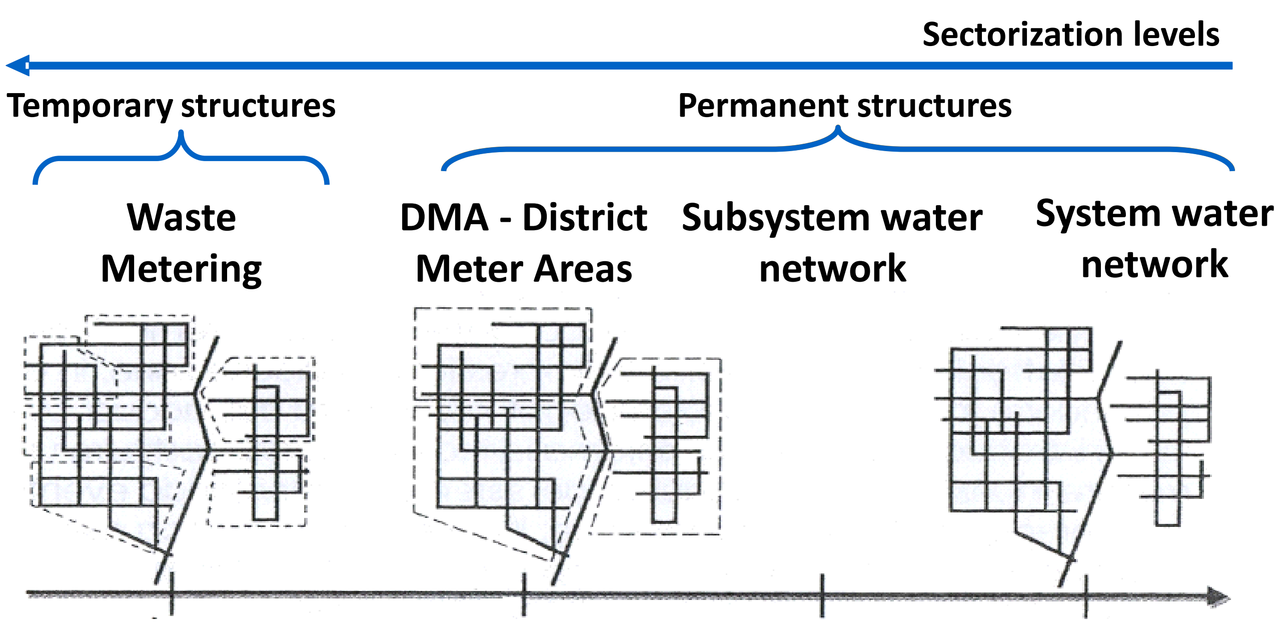
Water network partitioning in DMA

Smart WAter Network – 1. Water Network Partitioning

WNP allows to improve the water network management, in particular to:

- ✓ Evaluation of the **hydraulic balance** in order to recognize network reliability
- ✓ Localization and reduction of **water leakages**
- ✓ **Pressure control** to reduce water losses
- ✓ **Monitoring** network **performances** and water demand
- ✓ **Protection** from **contamination**

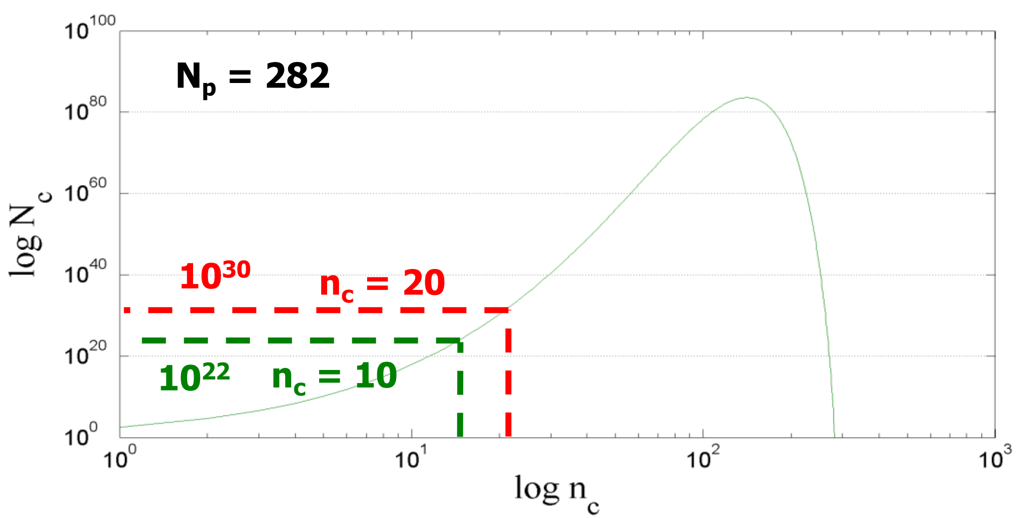
WNP is based on the identification of **District Meter Areas** (**DMA**):



Smart WAter Network – 1. Water Network Partitioning

Main **WNP drawbacks**:

- ✓ **Availability**: the partitioning decreases the network redundancy traditionally used in the design of WDS *(Mays, 2000)*;
- ✓ **Effectiveness**: the partitioning can significantly increase energy dissipations caused by pipe closures *(Di Nardo and Di Natale, 2011)*;
- ✓ **Economy**: it is necessary to contain costs to buy, install and repair flow meters and boundary valves *(Wrc/WSA/WCA Engineering and Operations Committee, 1994)*
- ✓ **Computational complexity**: it is necessary to decrease the number of possible partitioning of a water network that is huge *(Di Nardo and Di Natale, 2011)*



$$N_c = \binom{N_p}{n_c}$$

- *Binomial coefficient*
- N_c= layouts; N_p= pipes; n_c= pipe closed

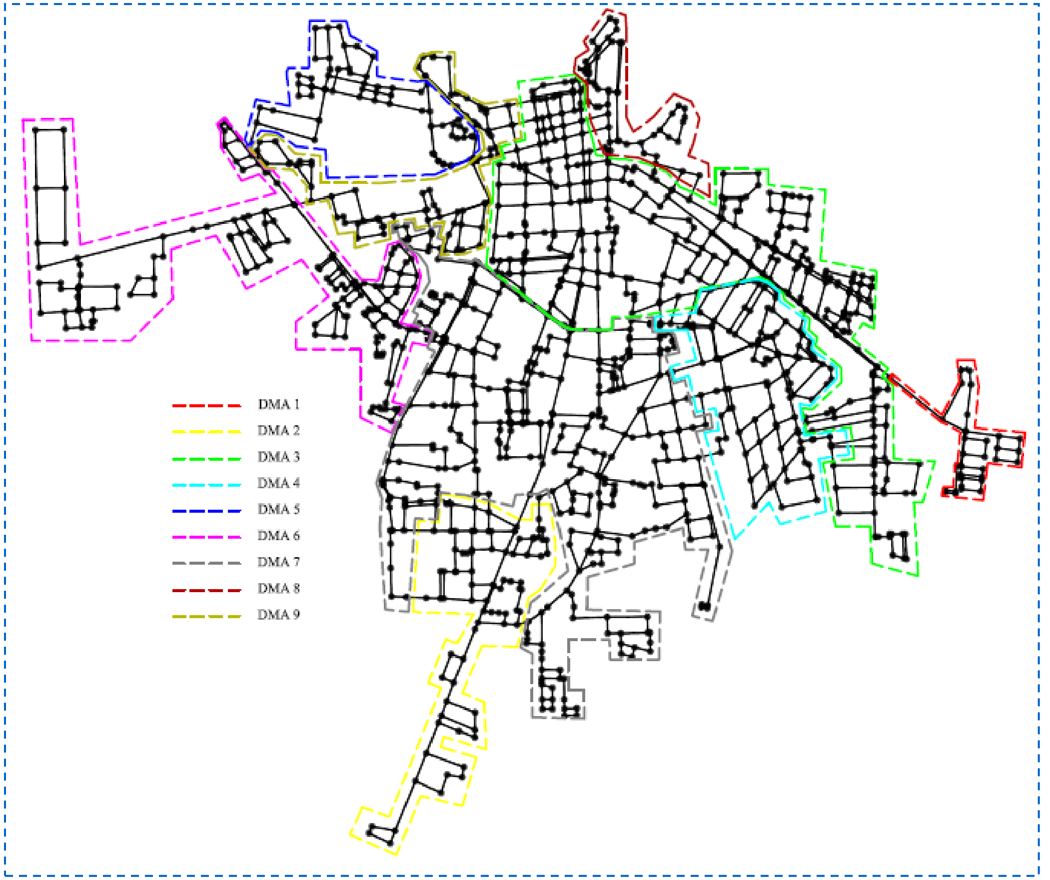
Smart WAter Network – 1. Water Network Partitioning

Our research group has developed a tool for the **automatic definition** of **shape** and **dimension** of **permanent DMAs** or, in other terms, of the number of nodes belonging to each DMA and the **positioning** of **flow meters** and **boundary valves**.

The software has been tested on several case-study real WDNs, among which the WDN of the city of **Matamoros** (Tamaulipas, Mexico) .

Number of nodes, *n*	**1,283**
Number of links, *m*	1,651
Number of reservoirs, *r*	9
Hydraulic head of reservoirs [m]	29.0; 31.46; 26.99; 28.14; 36.06; 36.26; 26.12; 30.64; 30.73
Total pipe length, L_{TOT} [km]	376.6
Minimum ground elevation, z_{min} [m]	5.33
Maximum ground elevation, z_{max} [m]	12.9
Pipe materials	PVC and AC
Pipe diameters [mm]	76; 95; 152; 190; 238; 300; 338; 380; 428; 476; 508; 600; 762; 914
Average demand, Q [m^3/s]	0.987
Peak demand, Q [m^3/s]	1.342
Design pressure, h^* [m]	12
h_{FP} [m]	5

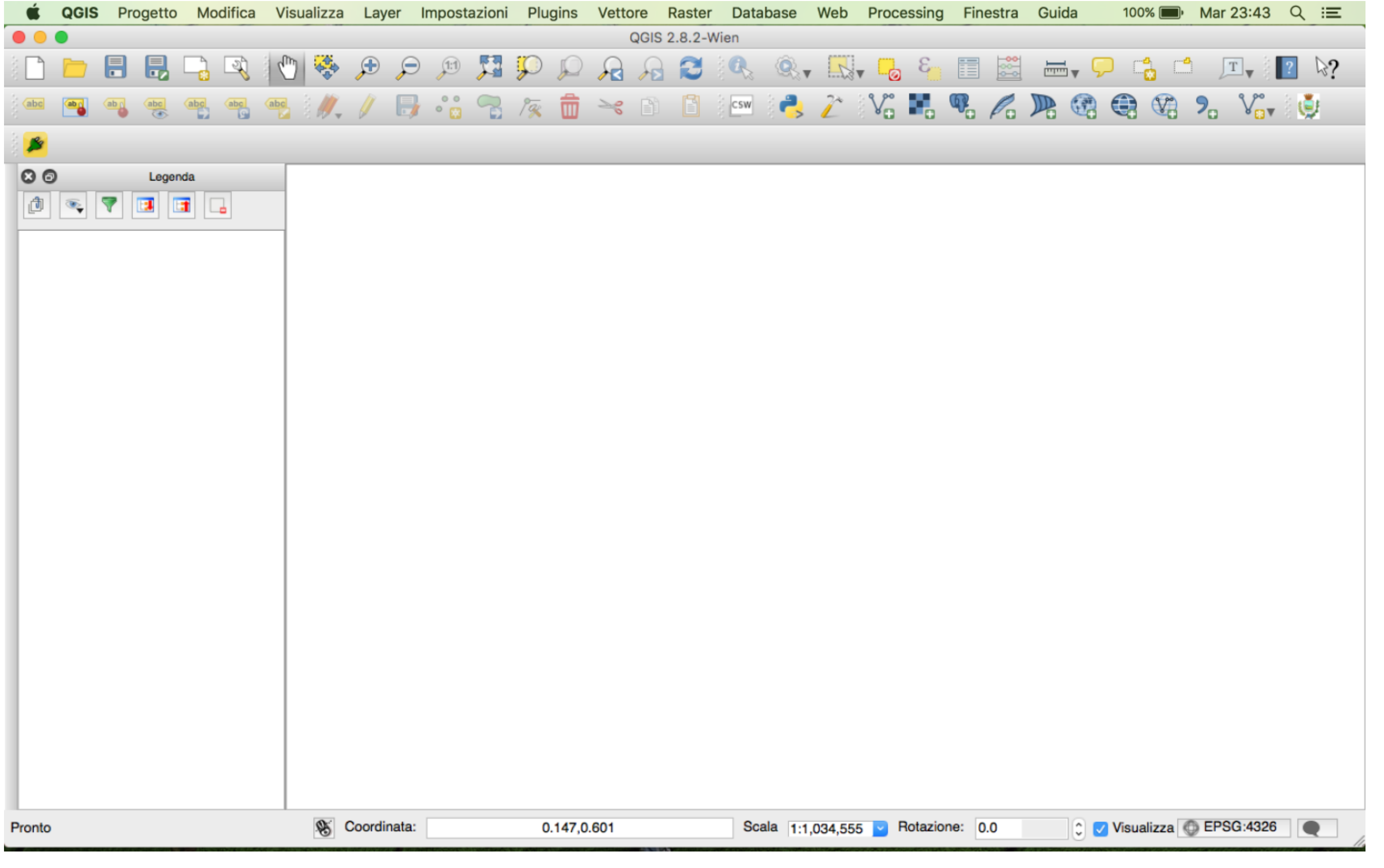
AC, asbestos cement; PVC, polyvinyl chloride.



SWANP 3.0 is the 3rd release of an hydraulic software devoted to water network modelling, analysing, partitioning and protecting. Its acronym stands for ***Smart WAter Network Partitioning and Protection.***

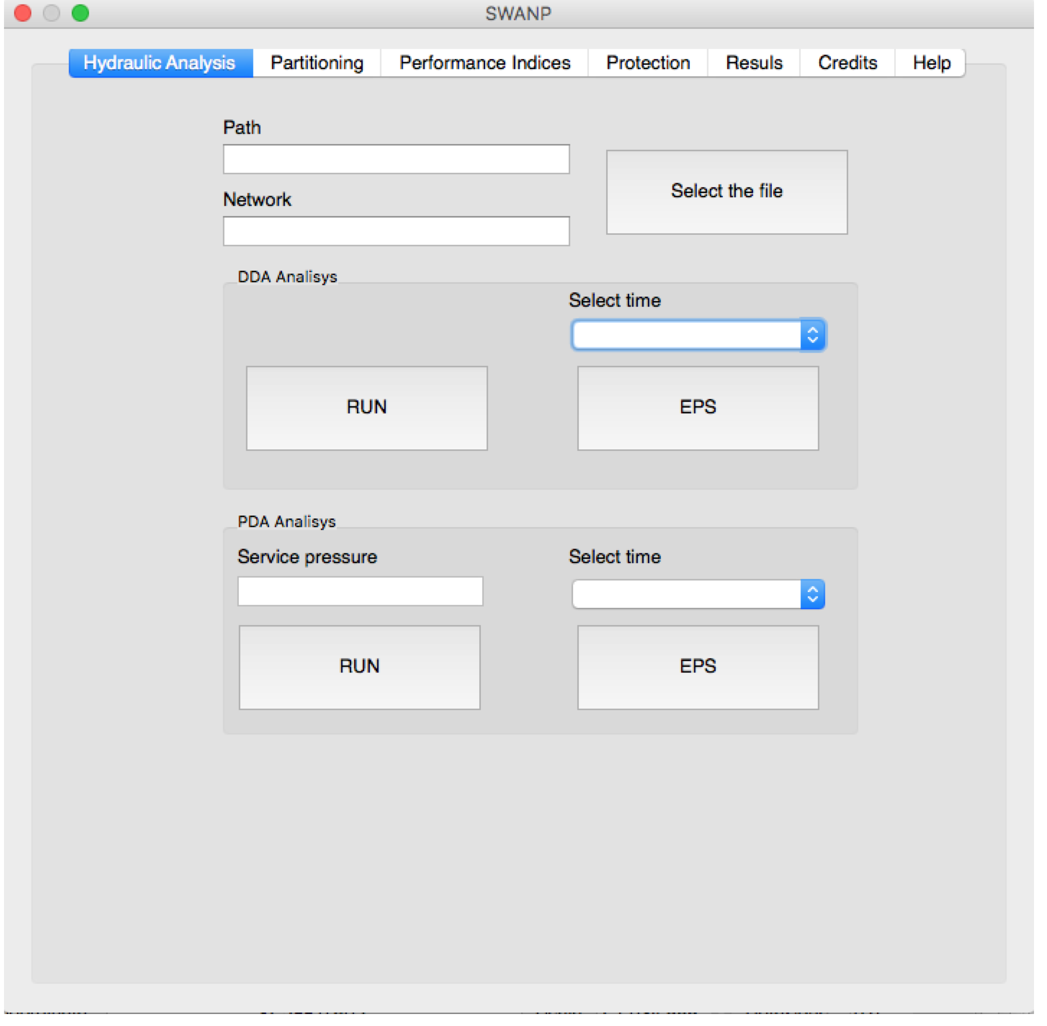
- ✓ the **decision-maker** that provides different solutions comparing network layouts with some hydraulic and protection performance indices;
- ✓ integrating two different algorithms based on multilevel and edge betweenness community techniques **for water network partitioning**;
- ✓ novel algorithm based on a multi-objective function, for **water network protection** from accidental or intentional contamination based on backflow attack model.

The SWANP software is integrated in a **QGIS software**, which is open source software to manage, visualize, modify and analyse the geographic data. By installing the SWANP plug-in for QGIS it is possible use all SWANP functions and, simultaneously, all analysis and visualization instruments provided by the QGIS. The GUI (graphic user interface) of SWANP tools for QGIS uses the QT4 graphic libraries while the functions of the SWANP are developed in Python 2.7.



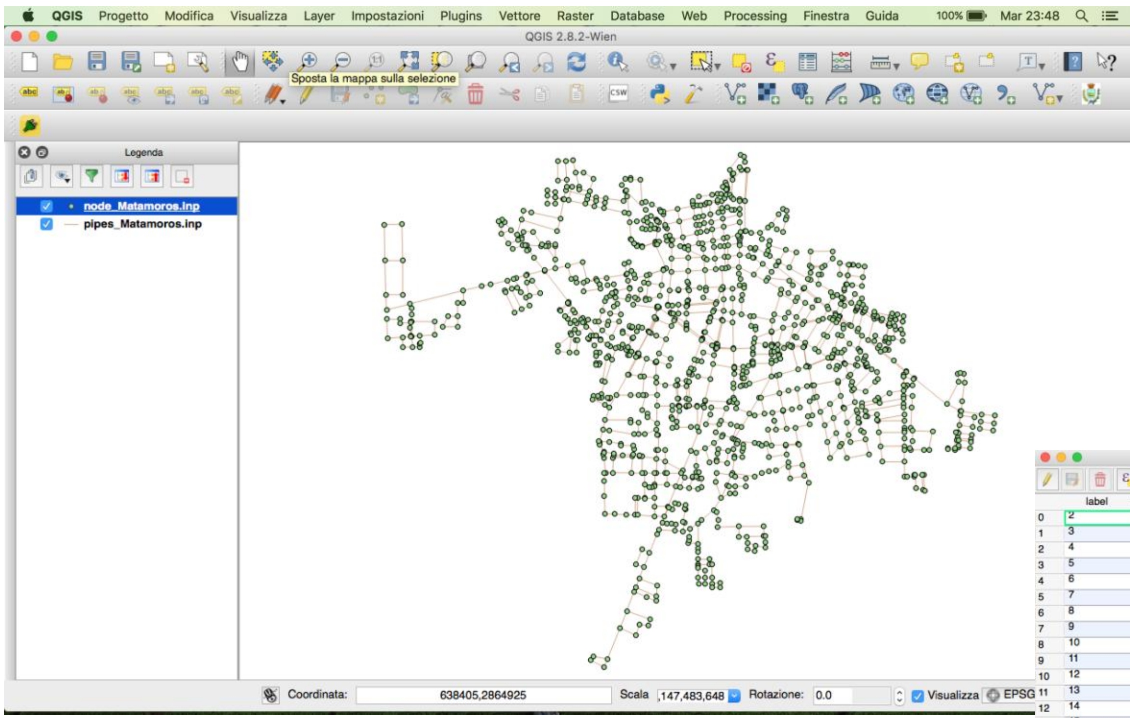
The GUI (Graphic User Interface) of SWANP is composed by 5 main sections:

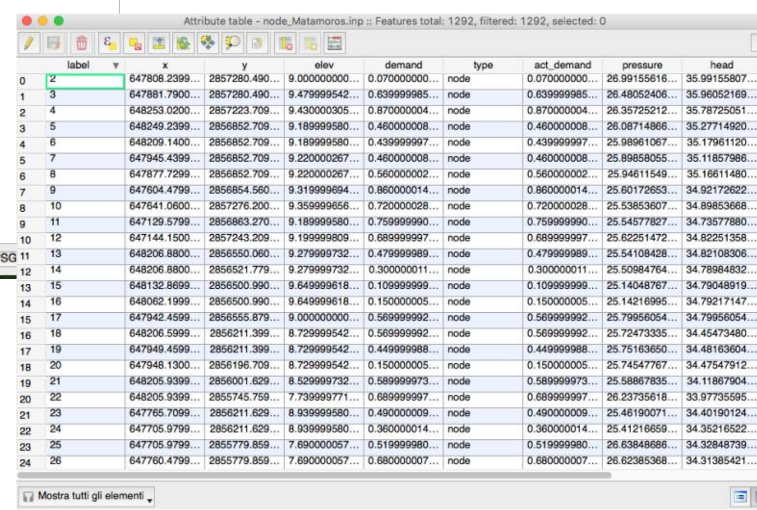
- ✓ **Hydraulic analysis**
- ✓ **Partitioning**
- ✓ **Protection**
- ✓ **Results**
- ✓ **Performance Indices**



SWANP 3.0 can performs the steady-state simulation of a Water Network Distribution by integrating the dynamic library of the EPANET 2.0 software.

It is possible using a **Demand Driven Analysis (DDA)** or **Pressure Driven Analysis (PDA)** approach in which, starting from topologic and hydraulic and water demand INPUTs, pressure nodes and pipe flow are provided.





Attribute table - node_Matamoros.inp :: Features total: 1292, filtered: 1292, selected: 0

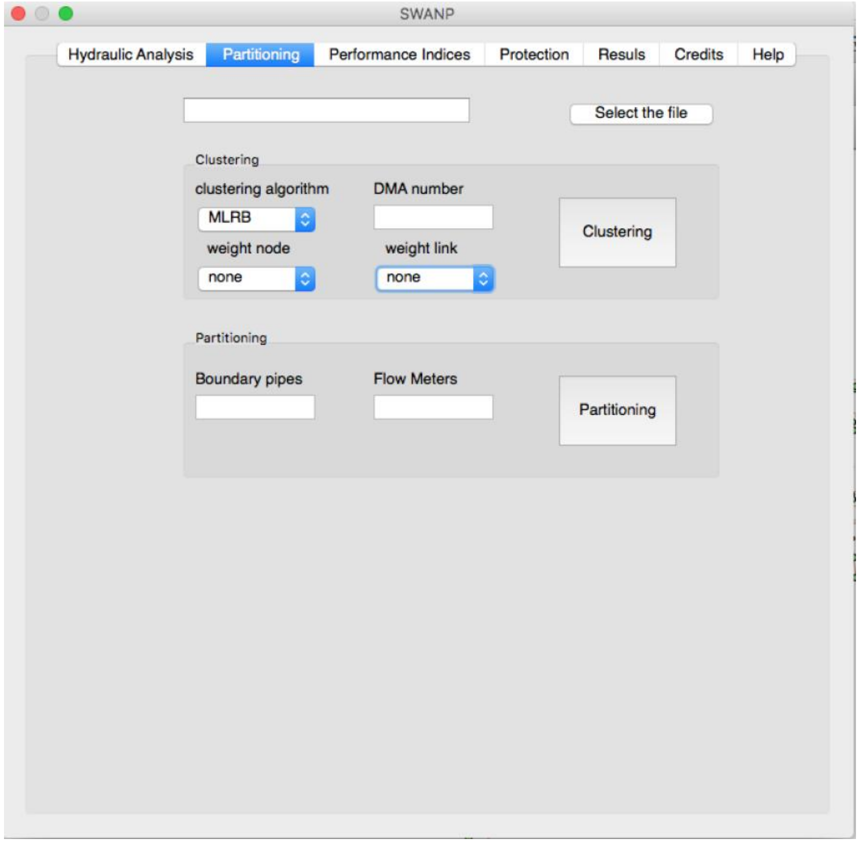
	label	x	y	elev	demand	type	act_demand	pressure	head
0	2	647808.2399...	2857280.490...	9.000000000...	0.070000000...	node	0.070000000...	26.99155616...	35.99155807...
1	3	647881.7900...	2857280.490...	9.479999542...	0.639999985...	node	0.639999985...	26.48052406...	35.96052169...
2	4	648253.0200...	2857223.709...	9.430000305...	0.870000004...	node	0.870000004...	26.35725212...	35.78725051...
3	5	648249.2399...	2856852.709...	9.189999580...	0.460000008...	node	0.460000008...	26.08714866...	35.27714920...
4	6	648209.1400...	2856852.709...	9.189999580...	0.439999997...	node	0.439999997...	25.98961067...	35.17961120...
5	7	647945.4399...	2856852.709...	9.220000267...	0.460000008...	node	0.460000008...	25.89858055...	35.11857986...
6	8	647877.7299...	2856852.709...	9.220000267...	0.560000002...	node	0.560000002...	25.94611549...	35.16611480...
7	9	647604.4799...	2856854.560...	9.319999694...	0.860000014...	node	0.860000014...	25.60172653...	34.92172622...
8	10	647641.0600...	2857276.200...	9.359999656...	0.720000028...	node	0.720000028...	25.53853607...	34.89853668...
9	11	647129.5799...	2856863.270...	9.189999580...	0.759999990...	node	0.759999990...	25.54577827...	34.73577880...
10	12	647144.1500...	2857243.209...	9.199999809...	0.689999997...	node	0.689999997...	25.62251472...	34.82251358...
11	13	648206.8800...	2856550.060...	9.279999732...	0.479999989...	node	0.479999989...	25.54108428...	34.82108306...
12	14	648206.8800...	2856521.779...	9.279999732...	0.300000011...	node	0.300000011...	25.50984764...	34.78984832...
13	15	648132.8699...	2856500.990...	9.649999618...	0.109999999...	node	0.109999999...	25.14048767...	34.79048919...
14	16	648062.1999...	2856500.990...	9.649999618...	0.150000005...	node	0.150000005...	25.14216995...	34.79217147...
15	17	647942.4599...	2856555.879...	9.000000000...	0.569999992...	node	0.569999992...	25.79956054...	34.79956054...
16	18	648206.5999...	2856211.399...	8.729999542...	0.569999992...	node	0.569999992...	25.72473335...	34.45473480...
17	19	647949.4599...	2856211.399...	8.729999542...	0.449999988...	node	0.449999988...	25.75163650...	34.48163604...
18	20	647948.1300...	2856196.709...	8.729999542...	0.150000005...	node	0.150000005...	25.74547767...	34.47547912...
19	21	648205.9399...	2856001.629...	8.529999732...	0.589999973...	node	0.589999973...	25.58867835...	34.11867904...
20	22	648205.9399...	2855745.759...	7.739999771...	0.689999997...	node	0.689999997...	26.23735618...	33.97735595...
21	23	647765.7099...	2856211.629...	8.939999580...	0.490000009...	node	0.490000009...	25.46190071...	34.40190124...
22	24	647705.9799...	2856211.629...	8.939999580...	0.360000014...	node	0.360000014...	25.41216659...	34.35216522...
23	25	647705.9799...	2855779.859...	7.690000057...	0.519999980...	node	0.519999980...	26.63848686...	34.32848739...
24	26	647760.4799...	2855779.859...	7.690000057...	0.680000007...	node	0.680000007...	26.62385368...	34.31385421...

Mostra tutti gli elementi

SWANP 3.0 allows defining automatically an optimal partitioning of a water network (**WNP**) using different algorithms. The proposed procedure is subdivided in two phases:

a) the **clustering**, aimed to define the shape and dimension of network subsets based on graph theory;

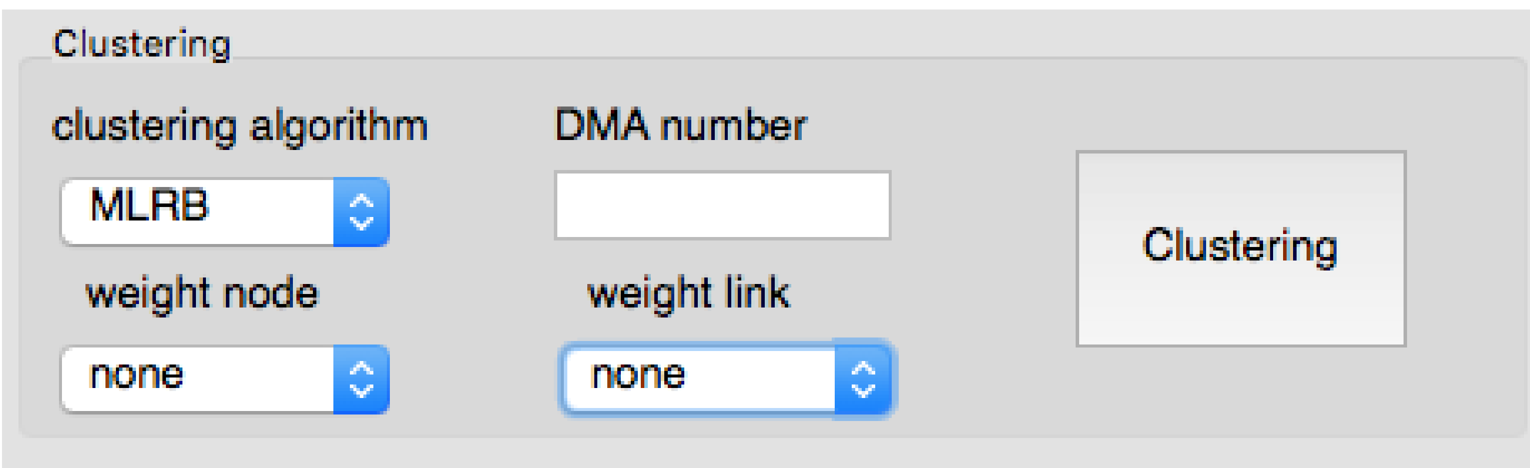
b) The **partitioning** that consists in the definition of the best position of the flow meters and the boundary (or gate) valves.



To perform the **clustering** phases, two different algorithms are proposed based on **graph partitioning** and **community structure.**

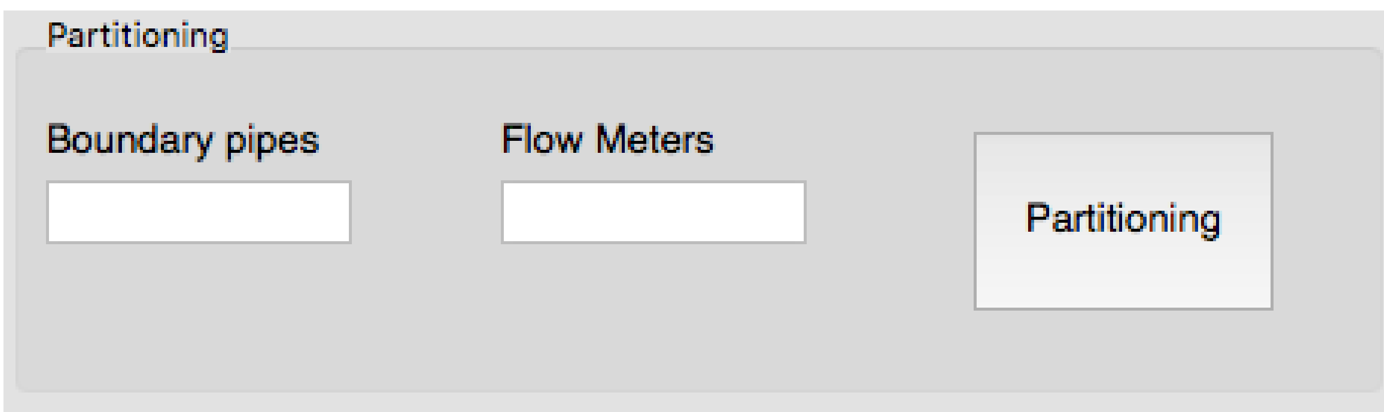
1) MLRB (MultiLevel Recursive Bisection): a **graph partitioning** algorithm borrowed from a technique of Computer Science, developed in order to solve problems that need huge computational power like, for example, simulations based on finite element methods that require distribution of the finite element mesh among different processors.

2) EBC (Edge Betweenness Community): a **community structure** algorithm borrowed from social network theory (SNT). As in a social network, the importance of each element of water network depends on the interrelation degree with other elements.



The **partitioning** phase consists in to define the best position of the **flow meters** and **boundary (or gate valves)** to insert in the boundary pipes (or edge-cuts) between DMAs previously obtained by clustering algorithms. This goal is obtained by using a heuristic optimization method based on a Genetic Algorithm (GA) is used maximizing the total node power of the network.

$$FO = \max\left(\gamma \sum_{i=1}^{n} Q_i H_i\right)$$



Water distribution networks are exposed to different potential sources of accidental and intentional contamination.

Accidental contamination

- ✓ occasional bad source water quality
- ✓ dysfunction of chlorine stations
- ✓ pipe breaks
- ✓ etc.

Malicious attack

- ✓ intentional introduction of a contaminant at the network sources
- ✓ backflow attack (injection of a contaminant in a network pipe through a pump system that allows to overcome the pressure gradient of network pipes)

terrorist

+

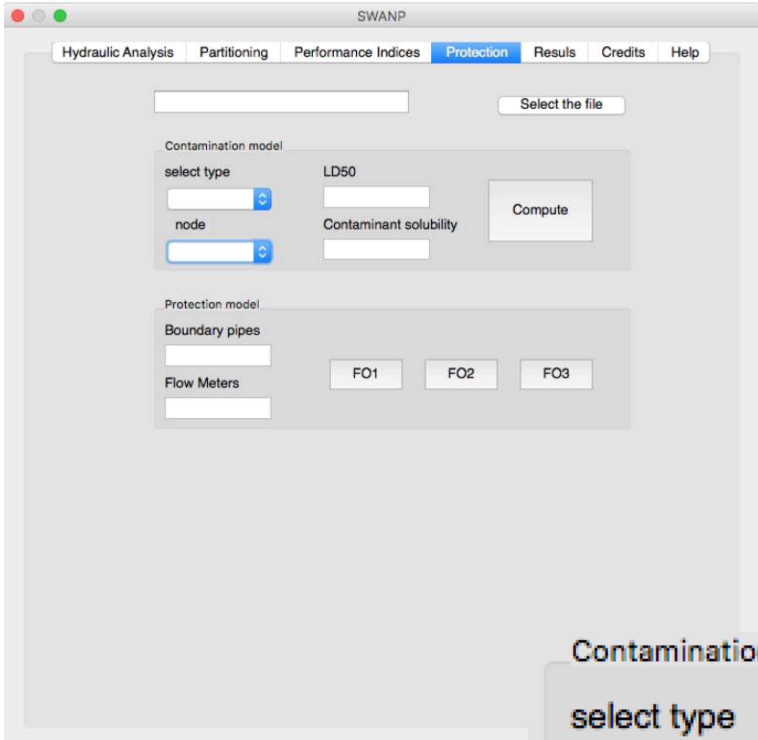
backpack

+

bathroom tub

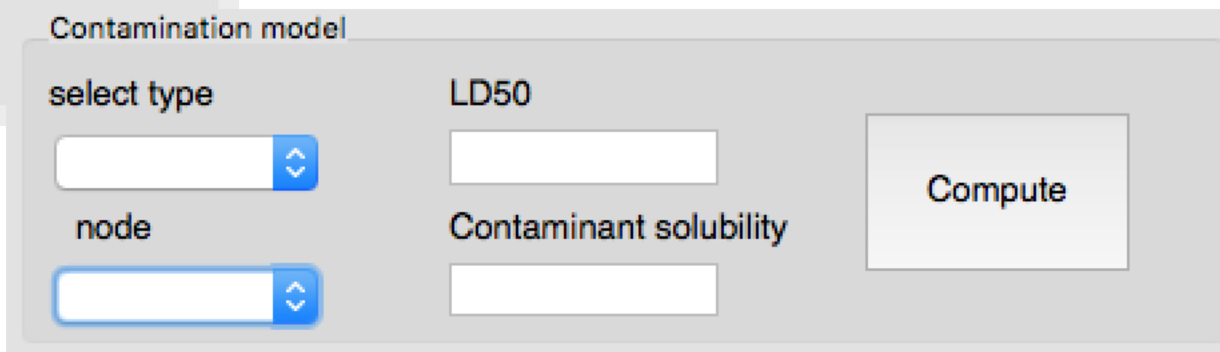
+

pump



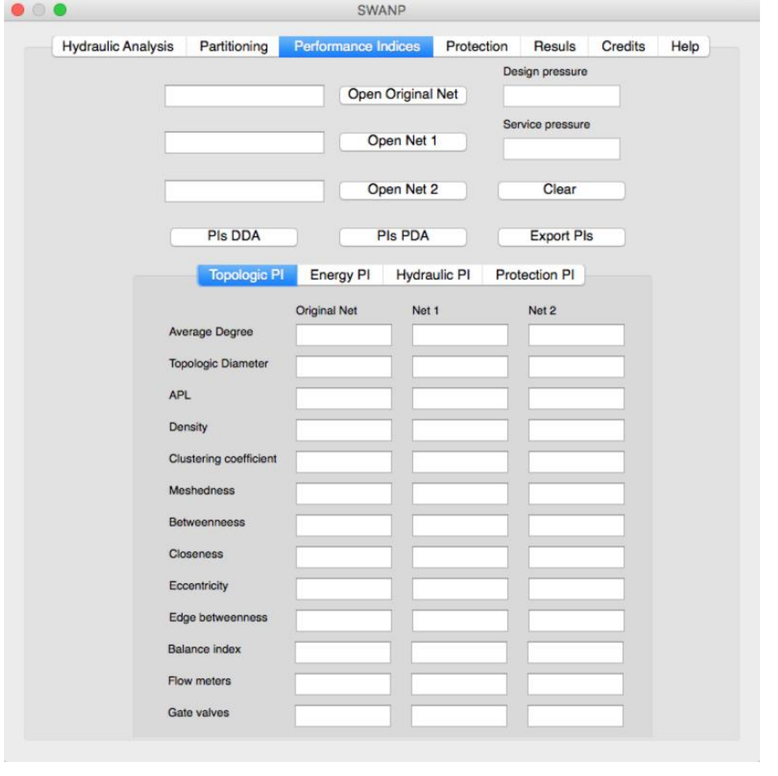
The contamination impact is measured by some Protection Performance Indices:

- ✓ the total number of exposed users (**Neu**),
- ✓ the number of exposed users that consumed more than the LD50 (**Neu50**);
- ✓ length of the contaminated pipes.

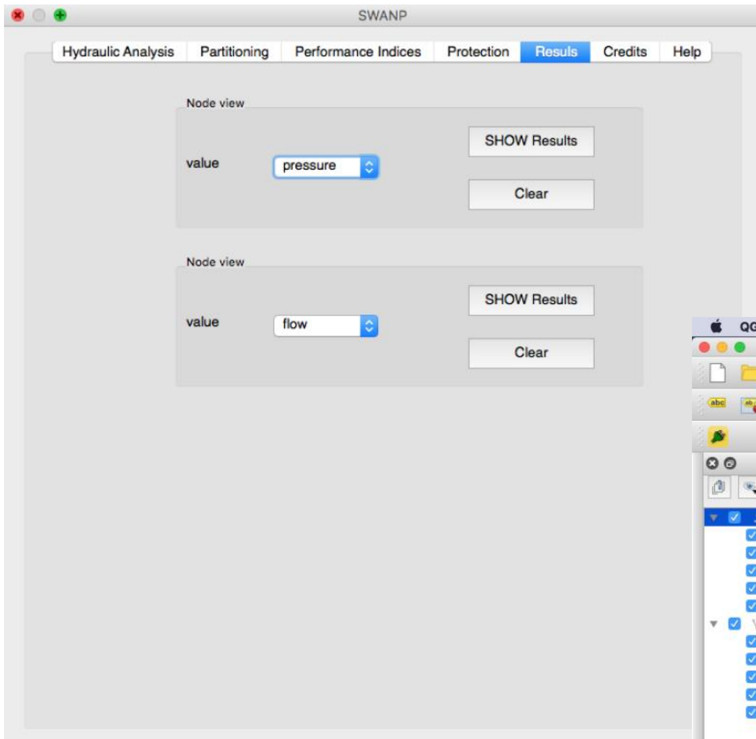


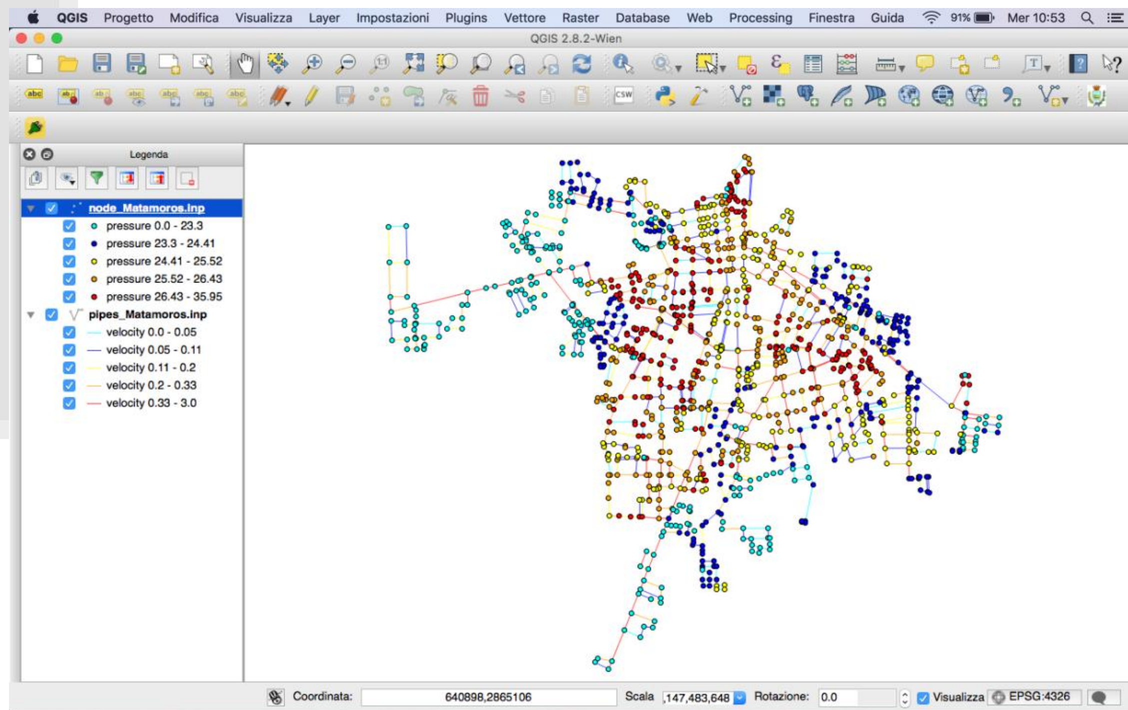
SWANP 3.0 allows to compute some traditional and innovative Performance Indices (PI) that provide information both on the whole network and on a sub-system or DMA.
PI are organized in four category and tested in different publications:

1) Topological PI
2) Energy PI
3) Hydraulic PI
4) Protection PI



SWANP 3.0 uses also the visualization instruments provided by the QGIS, to plot the result of hydraulic analisys, partitiong etc.





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Pooling resources – Innovating water

Thank you for your attention