UWOT: The Urban Water Optioneering Tool

Managing the complete Urban Water Cycle

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Presentation structure

A brief history of UWOT

Description of UWOT

- Modelling
- Assessment
- Optimization

UWOT applications

- Water recycling in different climatic conditions
- Natural hydrosystem flow-pattern restoration
- Real world application

Beyond the state-of-art (new UWOT)

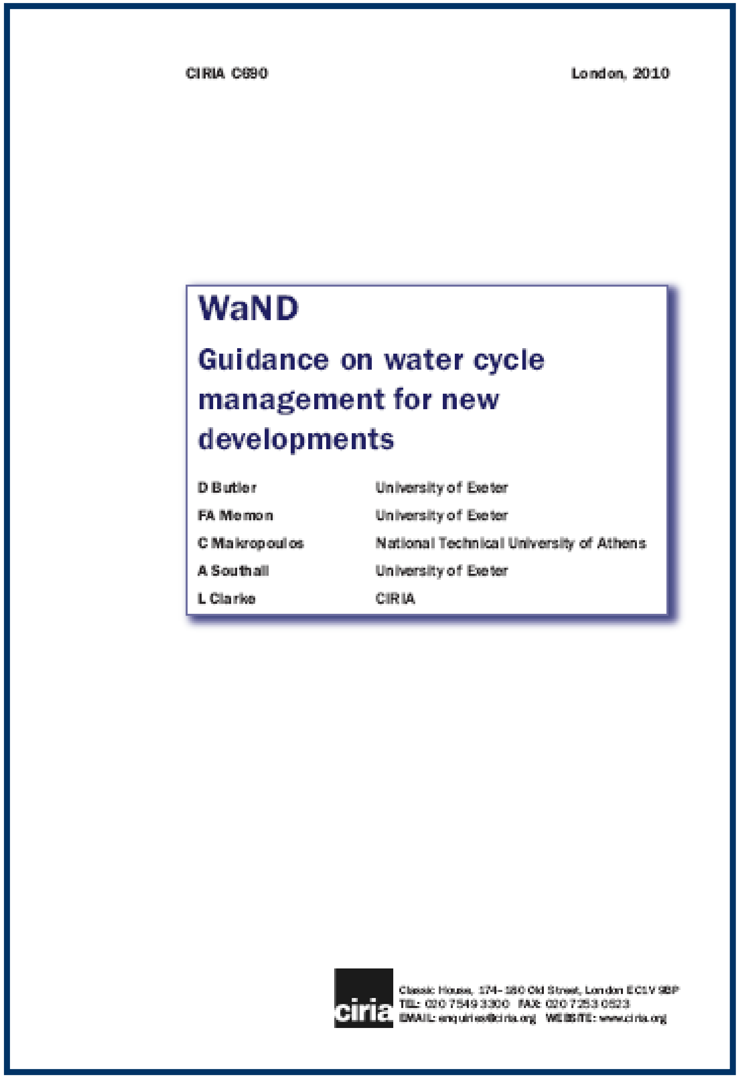
- Topology
- Flexibility
- Openness
- Integration
- Research areas

A brief history

WaND: Water for New Developments Project (EPSRC funded R&D): Focus on urban water management for new urban developments [Imperial College]

Revisions: Regional Visions (EPSRC funded R&D): focus on effects of urban form to environmental resource management (water, energy, waste) [University of Exeter]

TRUST: Transitions to the urban water services of tomorrow (EU FP7): focus on efficiency of urban water services and urban metabolism [NTUA and University of Exeter]



CIRIA C690 London, 2010

WaND

Guidance on water cycle management for new developments

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Description of UWOT

Modelling: UWOT simulates the urban water cycle by modelling individual water uses and technologies and aggregates their combined effects at development scale.

Assessment: UWOT assesses the sustainability of a development water cycle through the use of sustainability indicators.

Optimization: UWOT uses single or multi objective genetic algorithm optimization to suggest sustainable solutions.

Description of UWOT (modelling)

Local technologies

1. Washing Machine
2. Toilet
3. Treatment
4. Shower
5. Bath
6. Hand-basin
7. Kitchen Sink
8. Dish Washer
9. Garden
10. Outside use
11. SUDS local

...

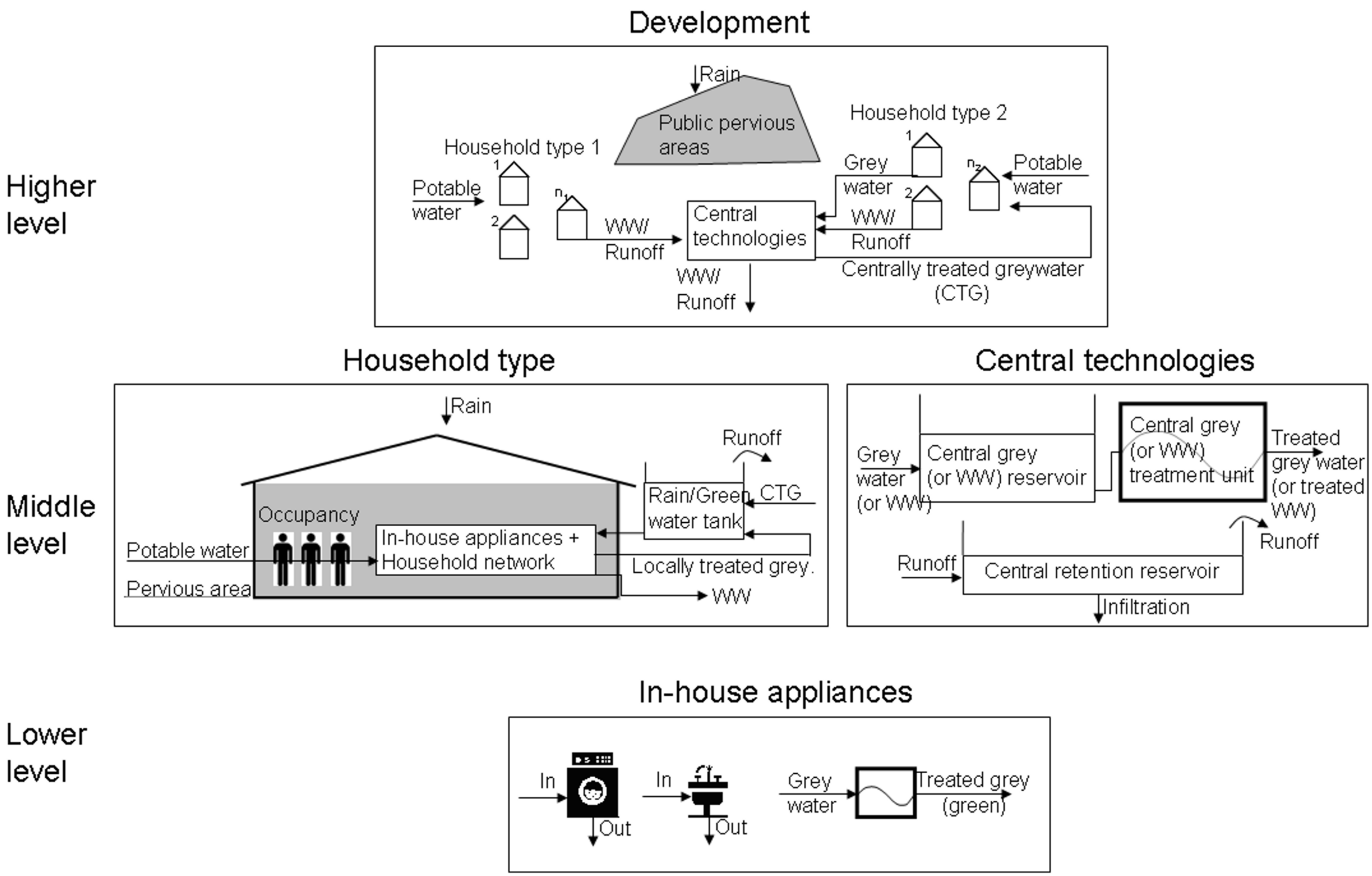
Central technologies

- Central treatment units
- Central SUDS

Technology library

	Specification	Unit
Resources Utilisation	Water Usage	(l/use)
	Water Loss	(%)
	Energy Use	(kWh/use)
	Chemical Use	
	Land Use	(m^2)
Economic parameters	Willingness to pay	
	Capital Cost	(£)
	Operational Cost	(£/use)
Social parameters	Risks to human health	
	Acceptability	
	Public Awareness	
	Social Inclusion	
Technical parameters	Reliability	
	Durability	
Operational Parameters	Frequency of use	(uses/p/d)
	Input Quality (Worst)	
	Output Quality	

Description of UWOT (modelling)



Description of UWOT (assessment)

Assessment indicators

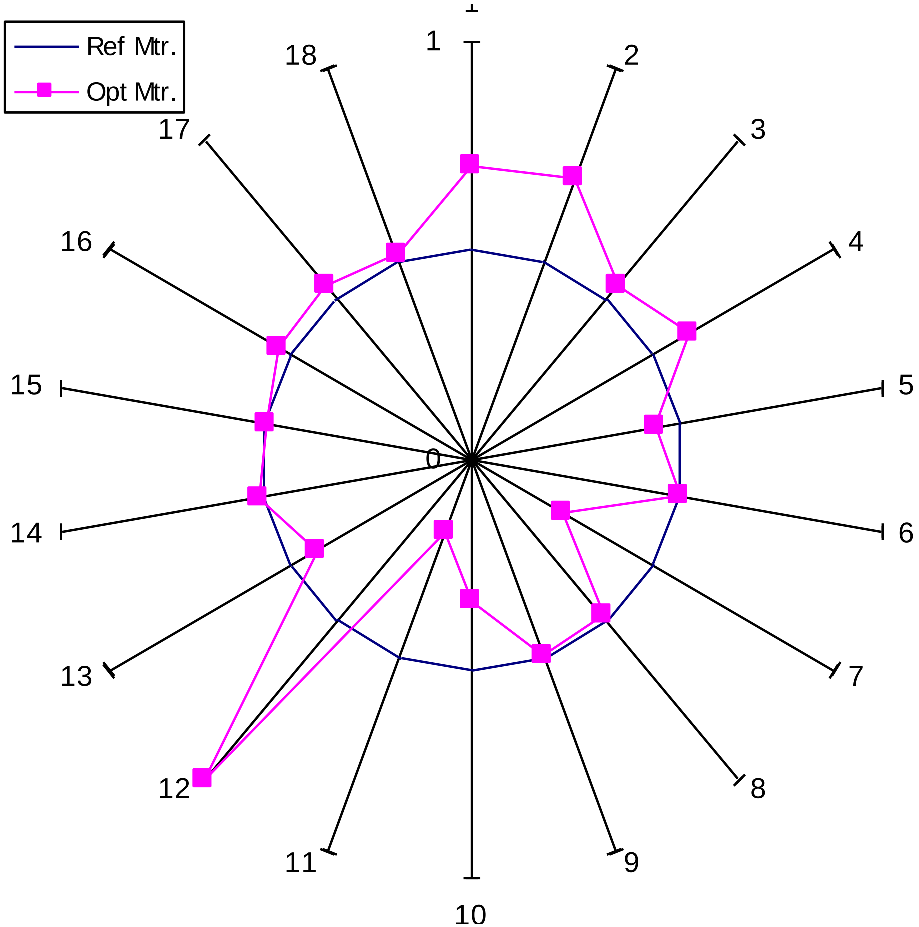
Indicator	Type	Aggregation method
Potable	Quantitative	Summation
Runoff	Quantitative	Summation
WW disch.	Quantitative	Summation
Energy	Quantitative	Summation
Landuse	Quantitative	Summation
Cap. cost	Quantitative	Summation
Op. cost	Quantitative	Summation
WW qual.	Qualitative	Mix
Chemical	Qualitative	Summation
RTI	Qualitative	-
Will. To pay	Qualitative	Summation
Acceptabl.	Qualitative	Summation
Part. Resp.	Qualitative	Summation
Publ. awarn.	Qualitative	Summation
Social incl.	Qualitative	Summation
Reliability	Qualitative	Summation
Durability	Qualitative	Summation
Flexibility	Qualitative	Summation

Description of UWOT (optimization)

Single objective optimization (SOGA)

min $\sum w_i O_i(\mathbf{x})$

Where: **x** is the decision variables vector, **w**=(w_1,w_2,…,w_n) is the preference vector and O_i is the standardize value of the ith indicator.

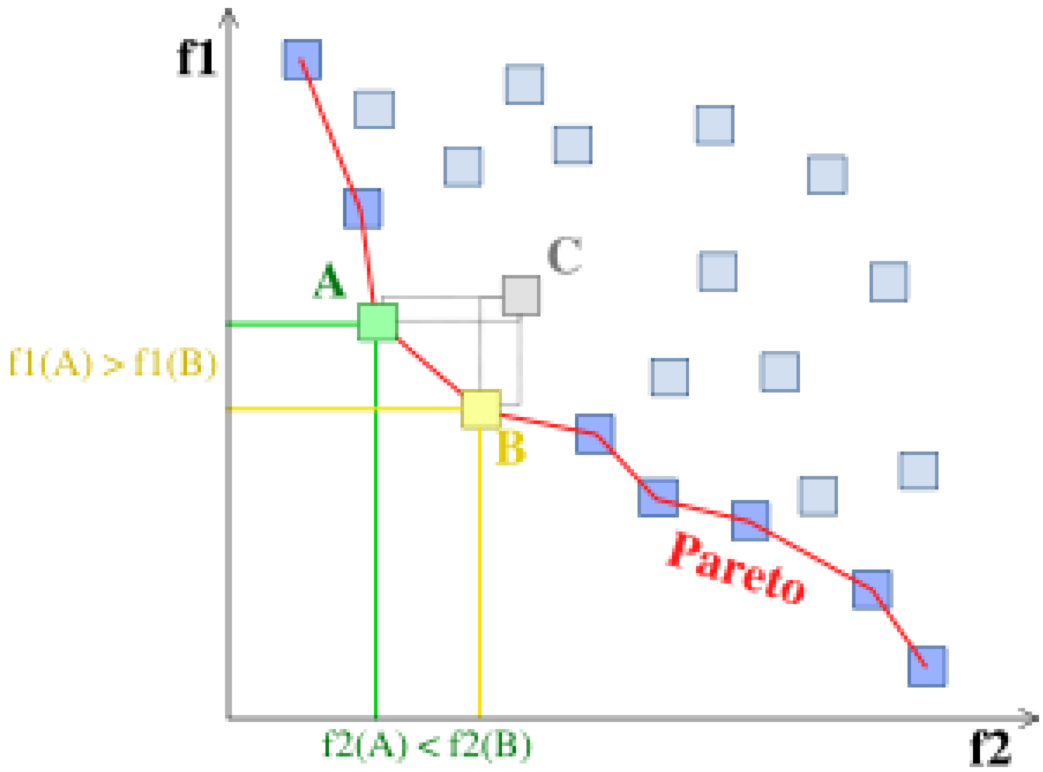


Description of UWOT (optimization)

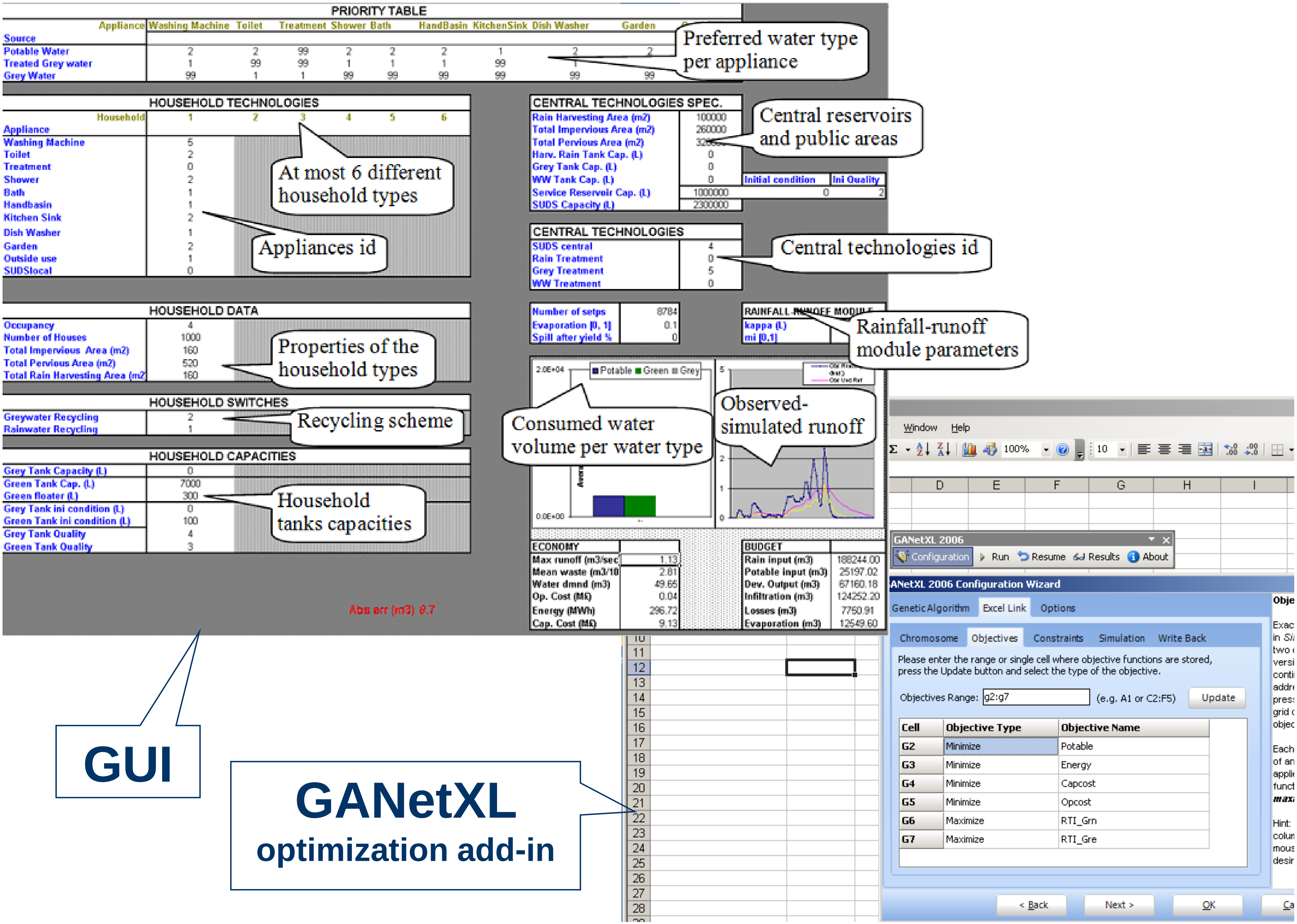
Multi-objective optimization (MOGA)

min [$O_1(\mathbf{x})$, $O_2(\mathbf{x})$,..$O_n(\mathbf{x})$]

The solution to the above problem is a set of Pareto points.



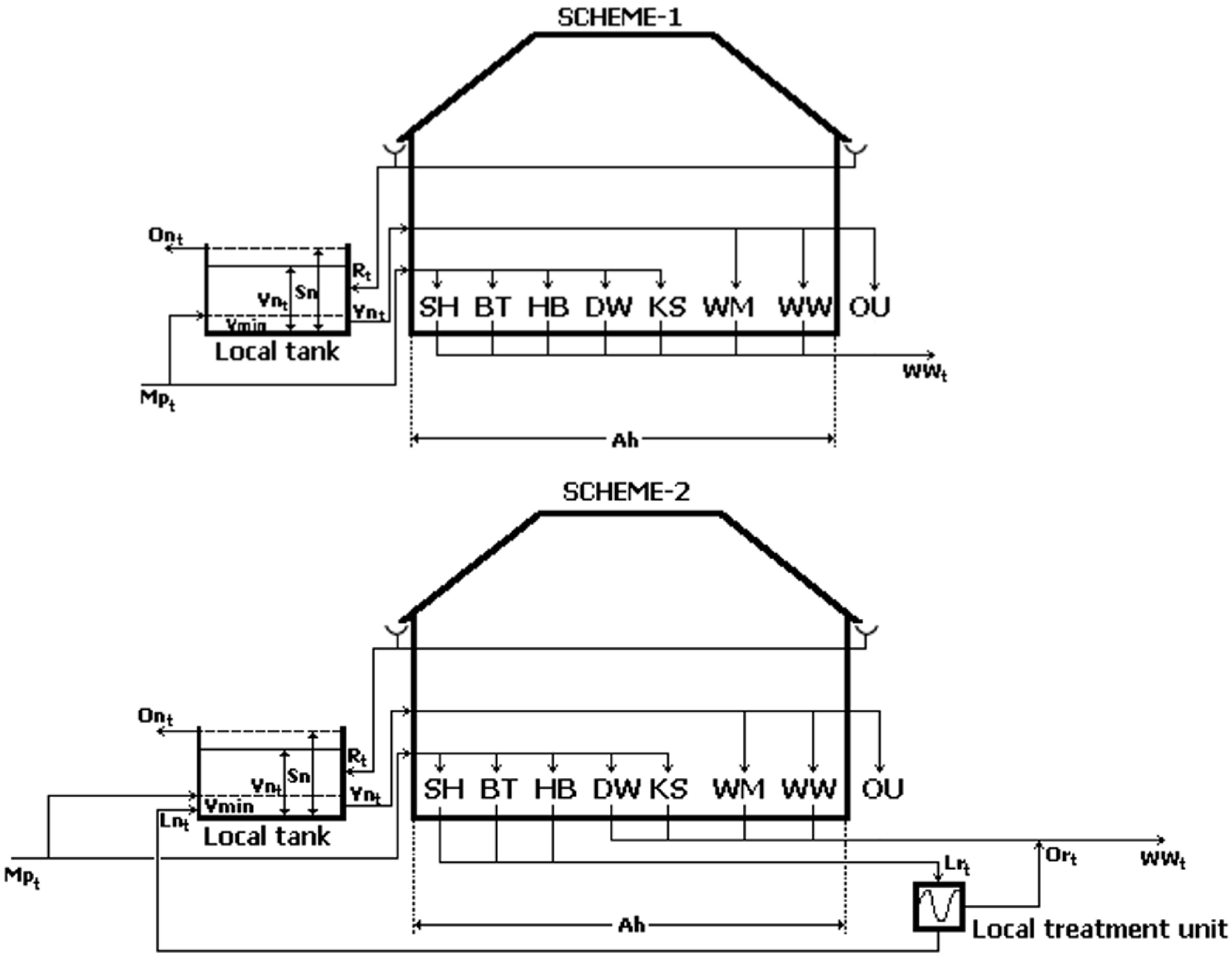
Description of UWOT (GUI)



UWOT application 1

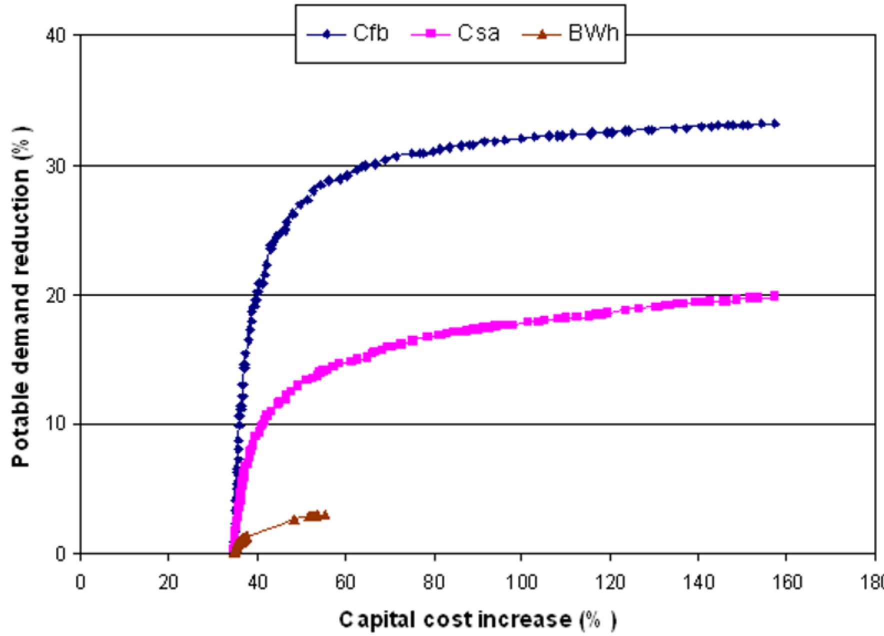
- Two water **recycling schemes** are optimized under three different climatic conditions, humid (Cfb), Mediteranean (Csa) and arid (BWh).
- Parallel Coordinate Plots (PCP) are used to investigate the multidimensional Pareto Front (PF) of the second scheme.
- The potable water demand of the second scheme PF solutions are assessed for a 20% decrease in the annual precipitation.

UWOT application 1 (recycling schemes)

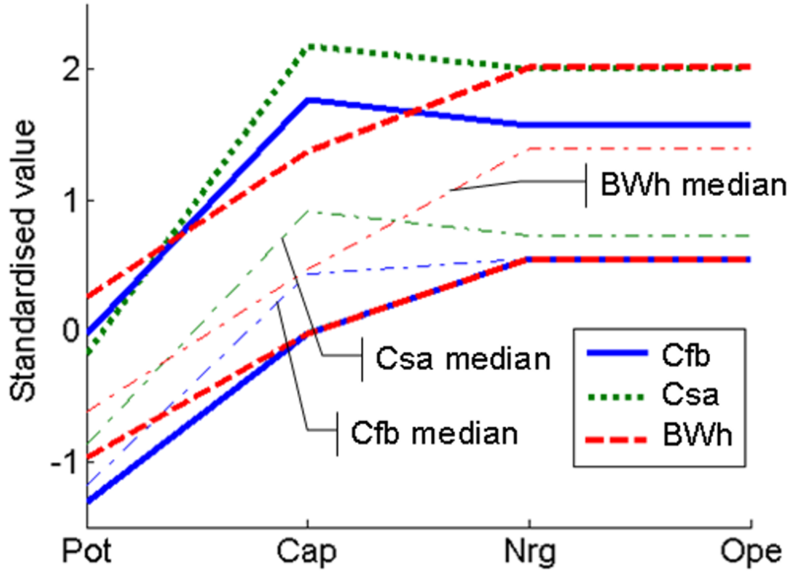


UWOT application 1 (Results)

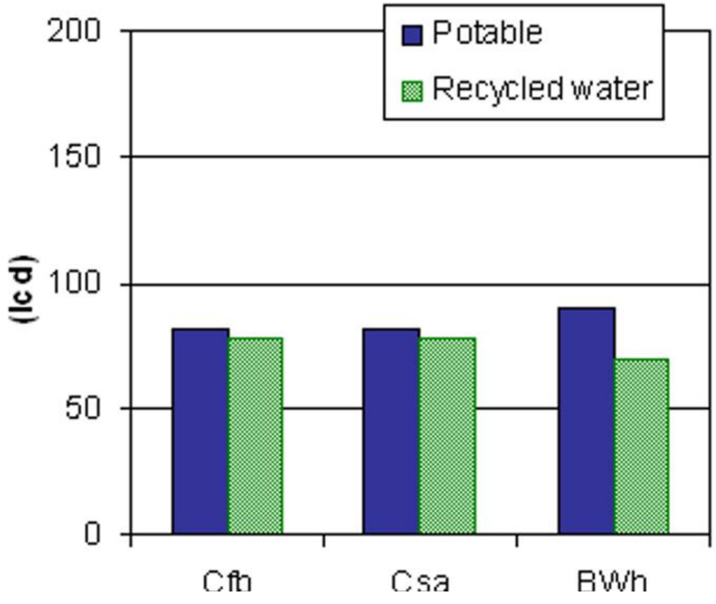
Pareto front of scheme 1



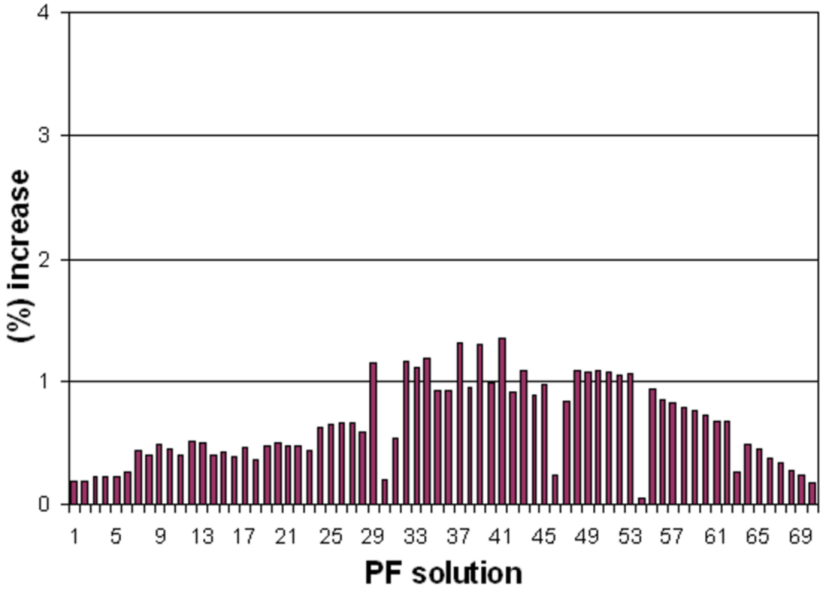
Pareto front (PCP) of scheme 2



Scheme 2 solutions with min potable demand



Scheme 2, 20% reduction of rainfall

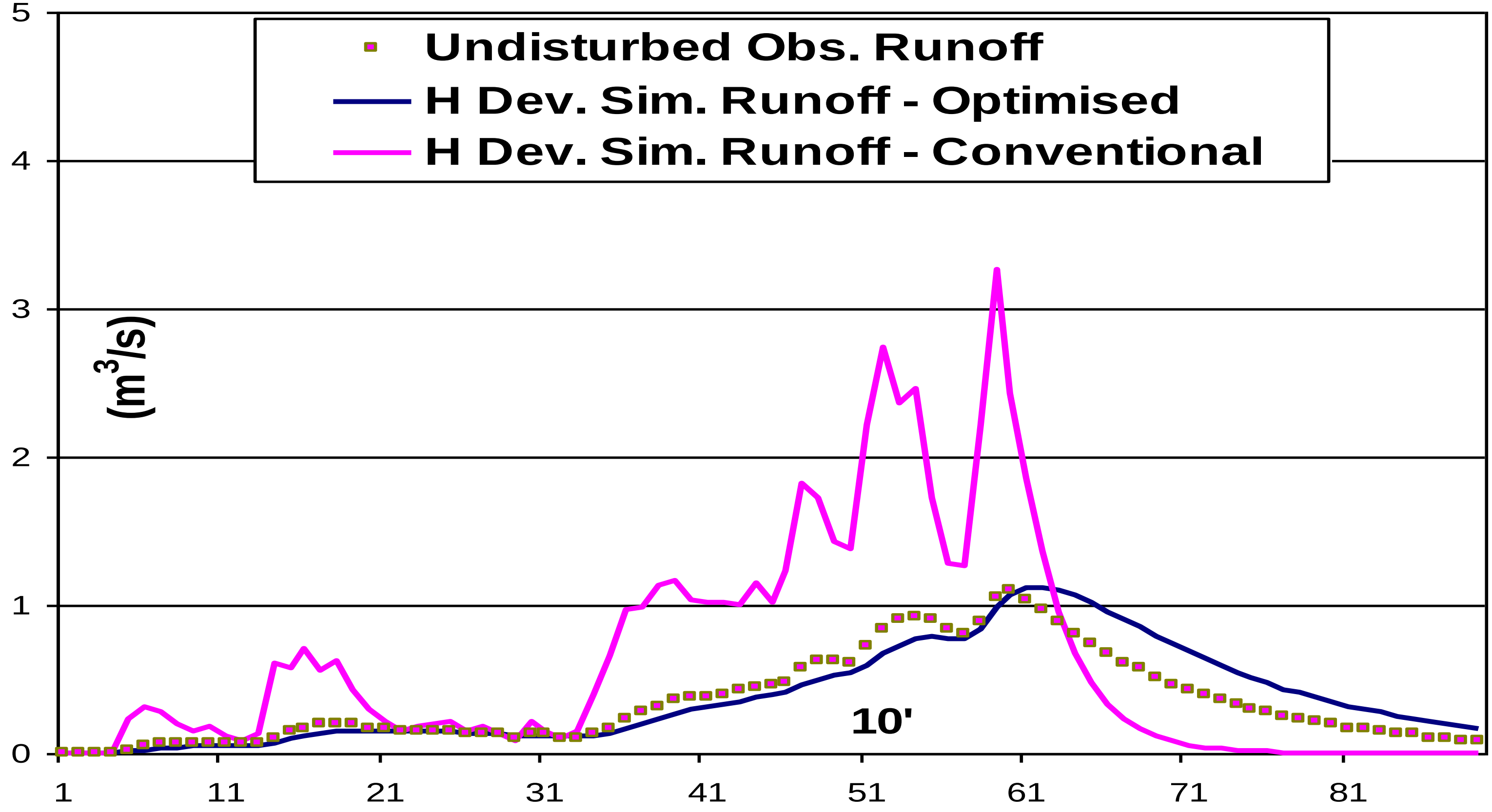


UWOT application 2

- The **runoff** from two hypothetical developments, one with **high (H)** and one with **low (L)** urban density is investigated with UWOT.
- The households of these developments implement a rainwater harvesting scheme (like scheme 1 presented previously).
- The aim is to **restore the rainfall-response** to the pre-urbanization form and to minimize the potable water demand.

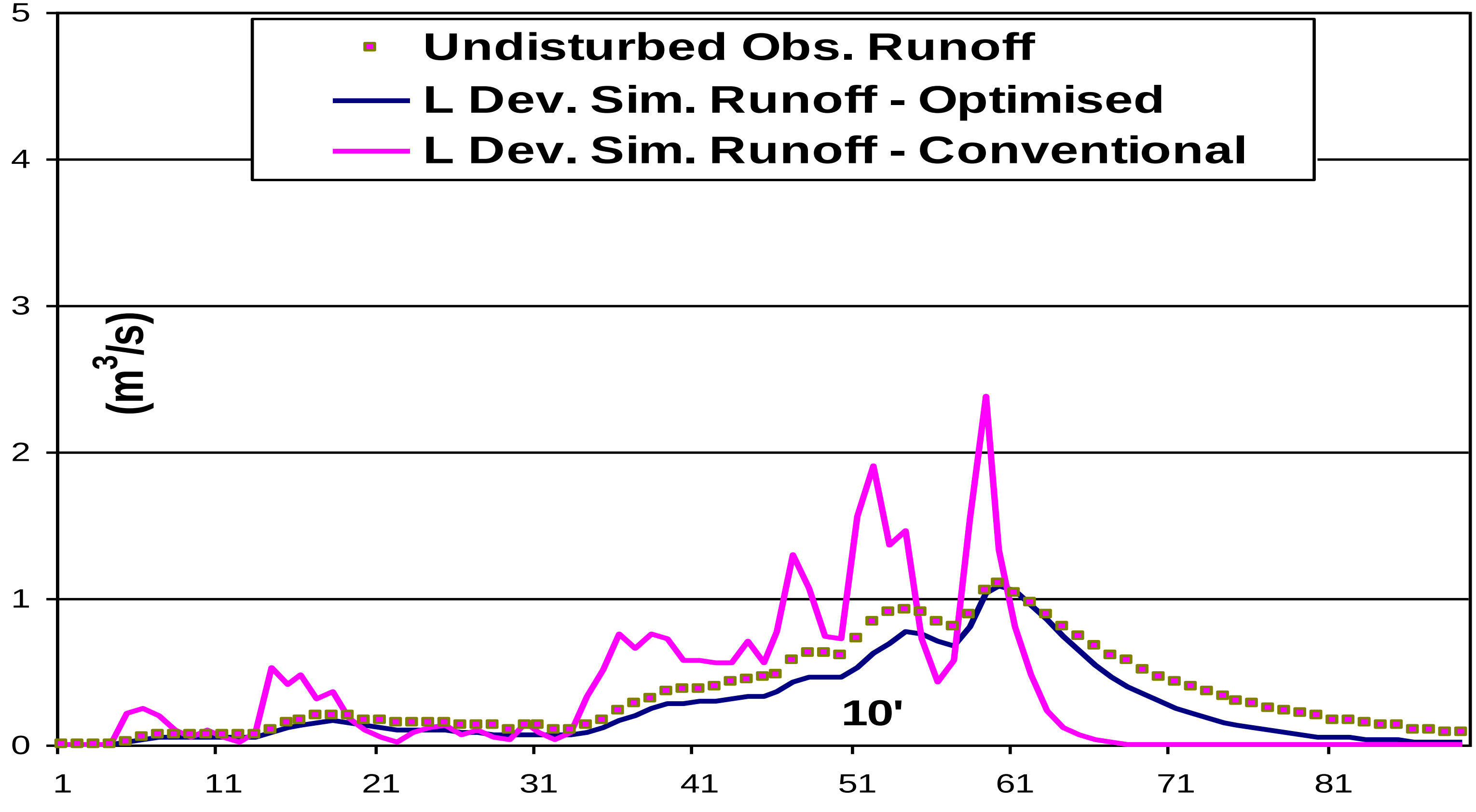
UWOT application 2 (Results)

	Conventional development H	Optimized development H
Maximum runoff (m^3/s)	3.26	1.12
Potable water demand (m^3/d)	1116	834



UWOT application 2 (Results)

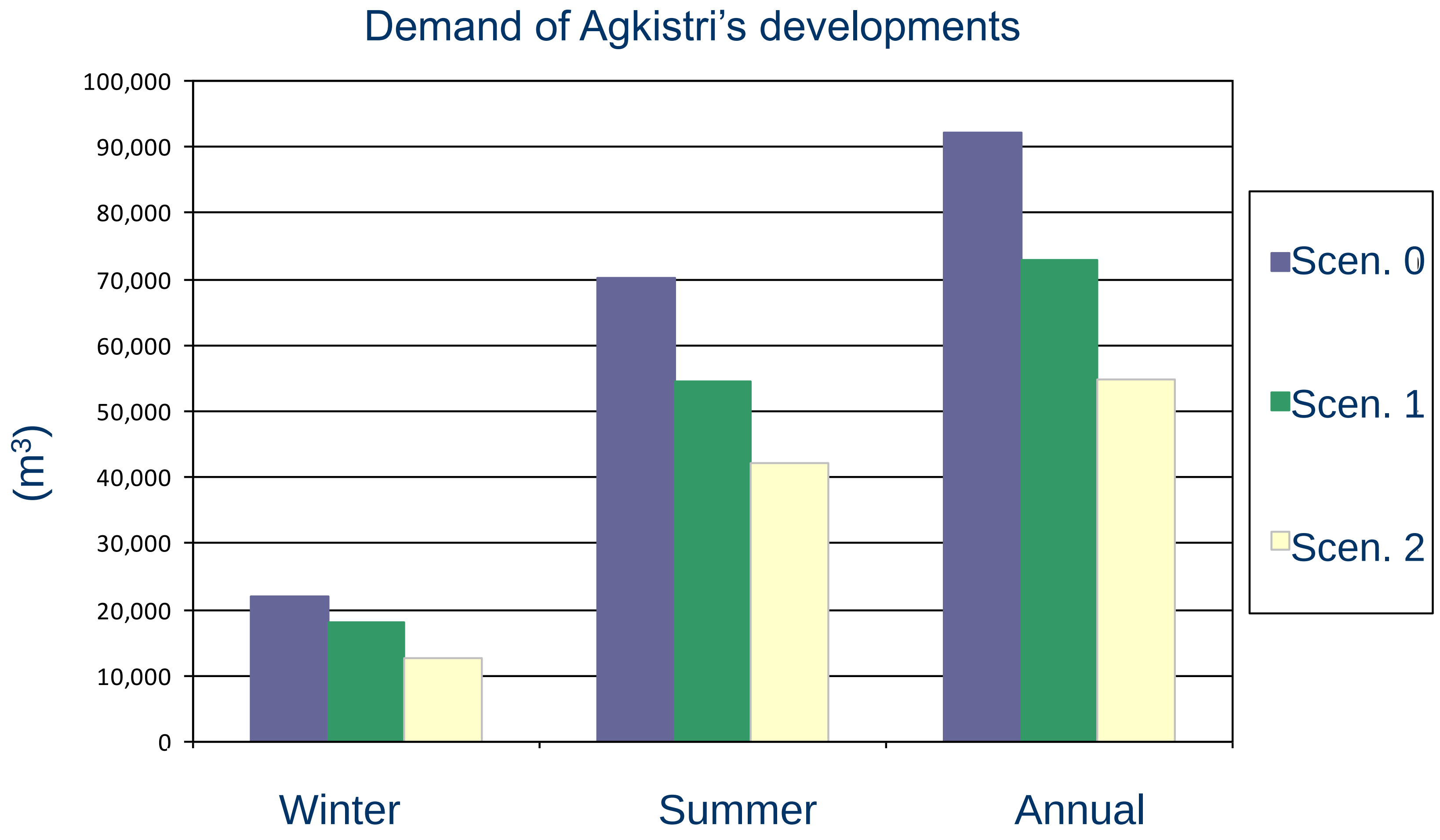
	Conventional development L	Optimized development L
Maximum runoff (m^3/s)	2.38	1.09
Potable water demand (m^3/d)	563	413



UWOT application 3

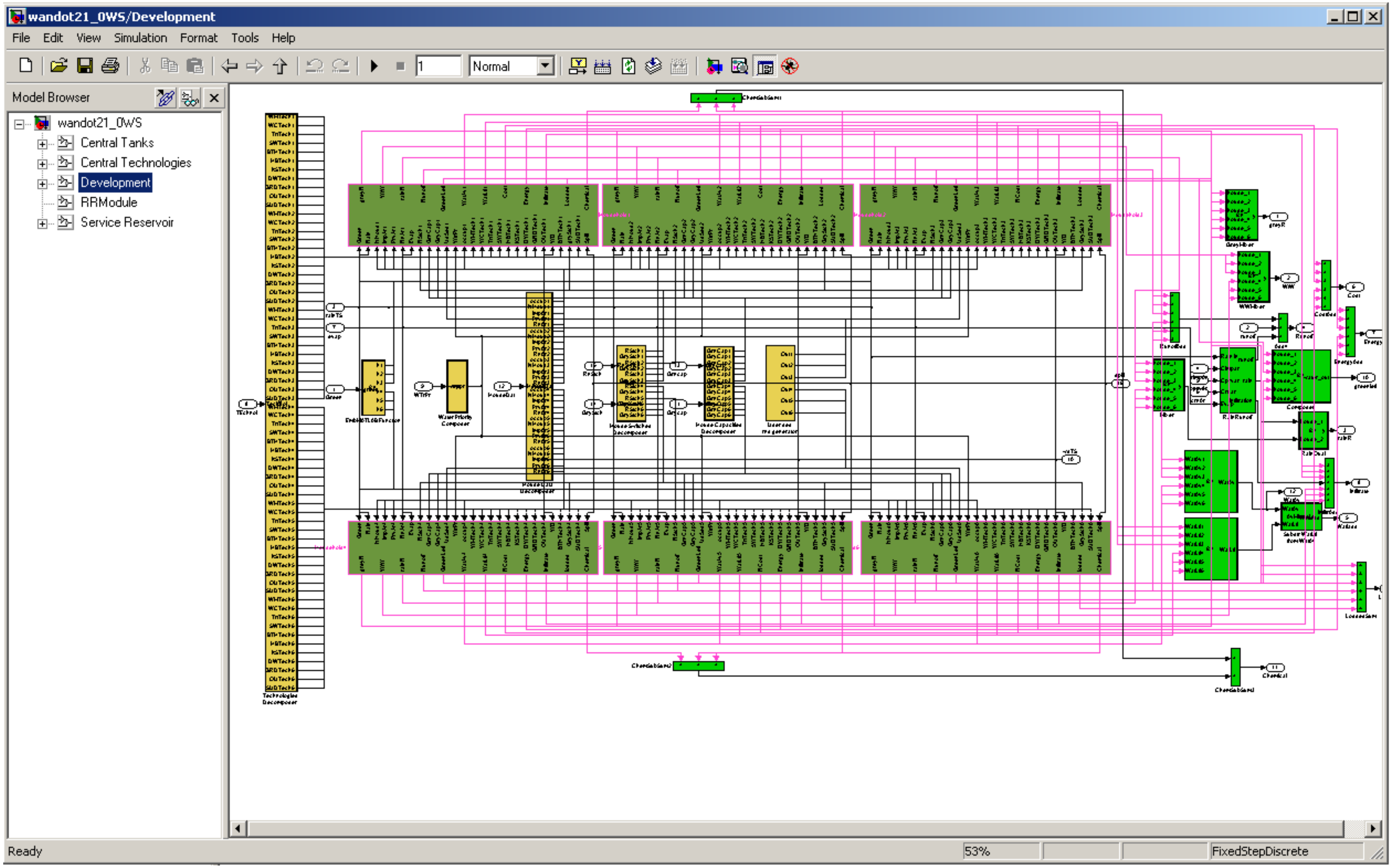
- Retro-fit solutions for potable water demand reduction in a small, water scarce island in Greece (Agkistri) was examined.
- UWOT assessed the benefits of replacing conventional water appliances with low consumption ones (scenario 1) as well as the benefits of implementing greywater recycling (scenario 2).

UWOT application 3 (Results)



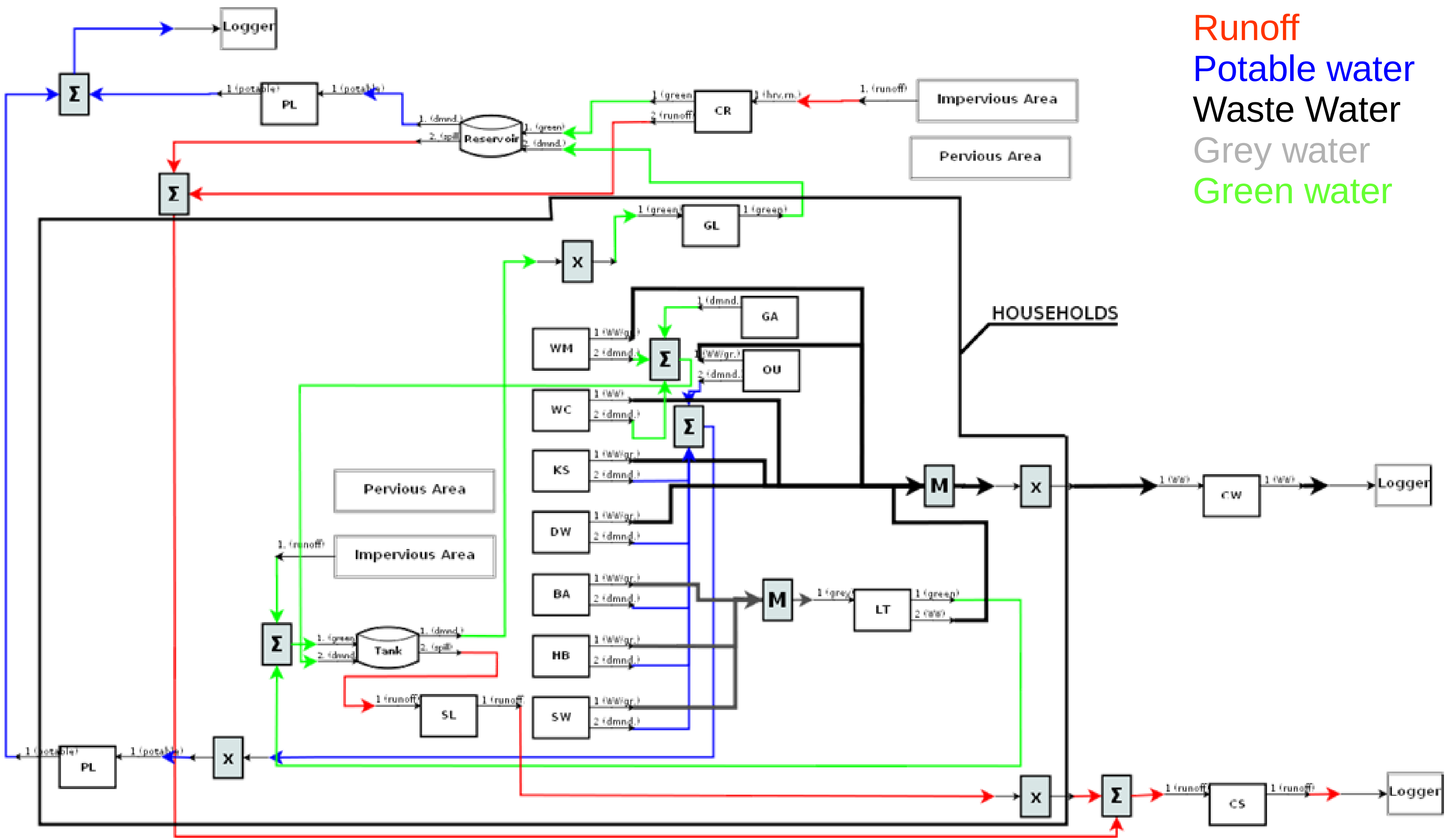
Beyond the state-of-art (topology)

Current version: static pre-designed water network, up to 6 different household types.



Beyond the state-of-art (topology)

New version: tailored design of water network, arbitrary number of household types.



Beyond the state-of-art (flexibility)

Current version: Fixed occupancy, fixed number of households, same input timeseries for all household types, upper limit of maximum time steps (redesign of workbook is required).

New version: Different timeseries per household type for occupancy (touristic units), number of households (expansion of a development), rainfall (spatial heterogeneity) and demand fluctuation (consumer type). Arbitrary number of time steps.

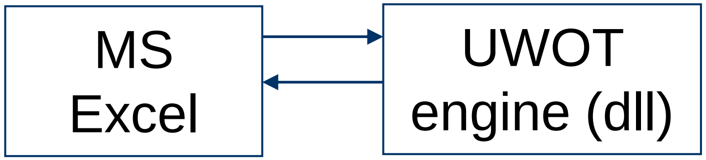
Beyond the state-of-art (openness)

Current version: Engine implemented using MATLAB Simulink. Technology library and project (input and output timeseries, and network topology) stored in Microsoft Excel. Optimization with Excel add-in GANetXL.

New version: Engine implemented with C. Technology library and project stored in SQLite. Optimization with MATLAB’s or Octave’s tools. Compatible with all operating systems.

Beyond the state-of-art (integration)

Current version

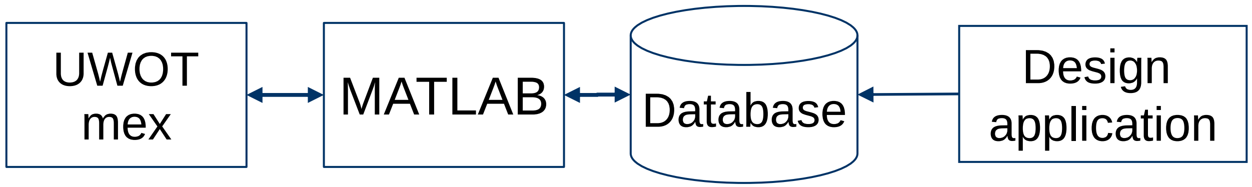


- Limited options of mathematical tools (e.g. optimization algorithms, cellular automata, system dynamic) in the spreadsheet-based environment.
- Integration with other models is hindered by the dependence of engine on MS Excel.
- Deployment as a stand alone application would require significant reengineering.

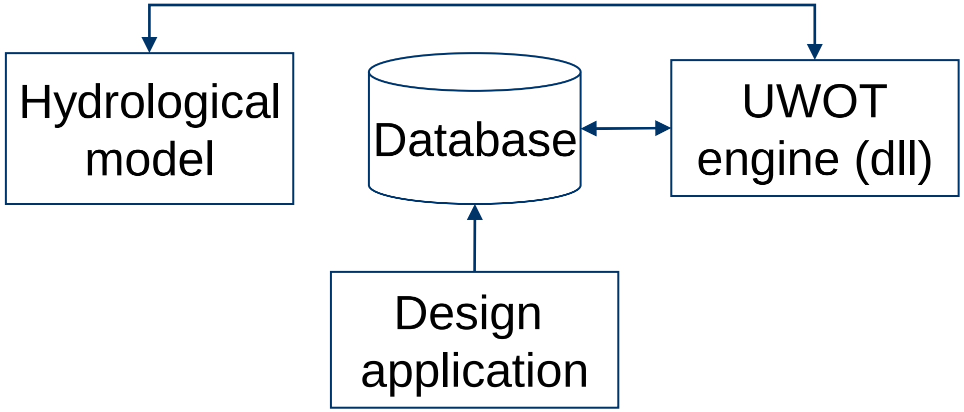
Beyond the state-of-art (integration)

New version

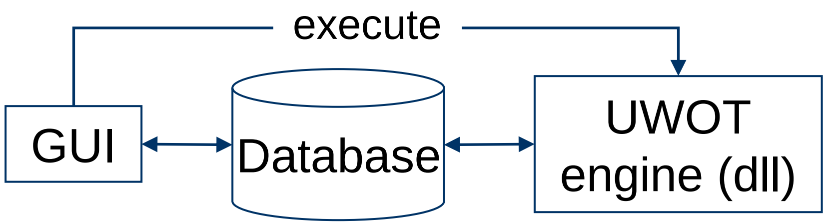
- Integrated with MATLAB



- Integrated with hydrological models (OpenMI)



- Stand alone application



Beyond the state-of-art (research areas)

Urban water system metabolism. UWOT will be used in combination with system dynamic models to analyze the urban water system's metabolism and performance.

Addressing water scarcity. UWOT will be linked with a water resources management model to provide a more accurate estimation of the impacts on the environment of stresses caused by an urban area (and explore *water demand reducing scenarios*).

Sustainable (green) urban growth. UWOT will be integrated with a land-use model based on cellular automata to study the interactions between urbanization and the urban water infrastructure.

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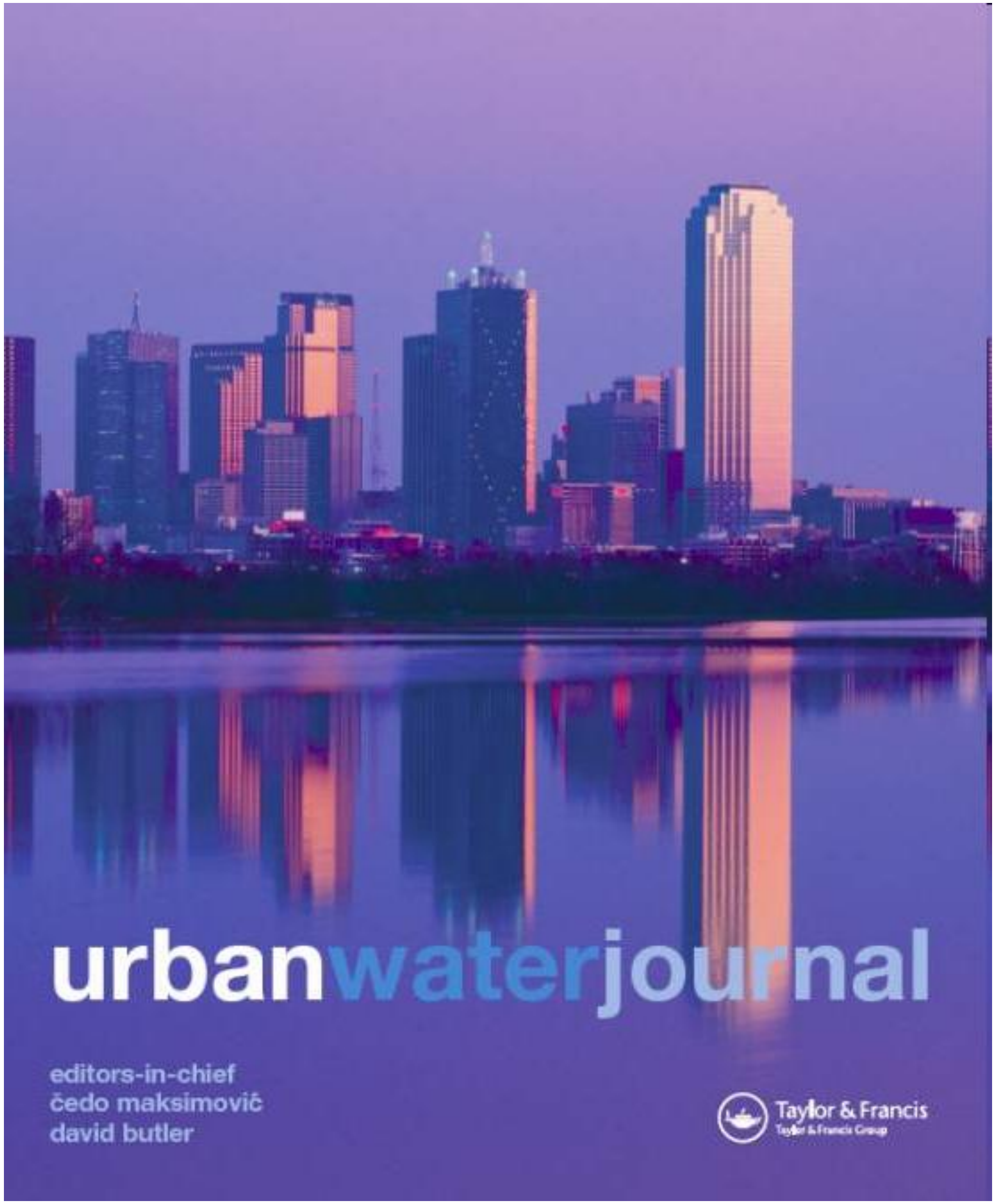
Urban Water Journal



http://www.urbanwater.net/