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A decision support system for the management of the water resources system of Athens

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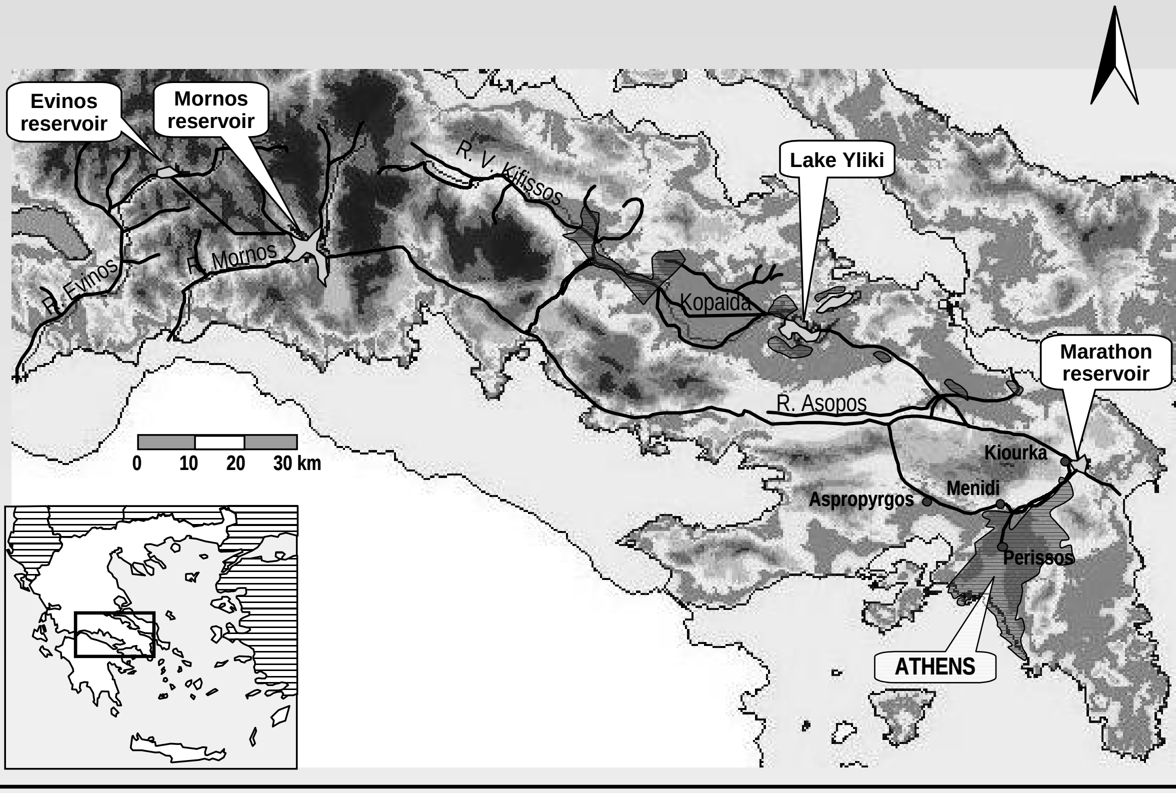
The Athens water supply system



Hydronomeas
A DSS for the Athens Water Supply System

- *Hydronomeas* has been developed by the N. T. University of Athens within the framework of the project “Modernisation of the Supervision and Management of the Water Resource System of Athens”, funded by the Athens Water Supply and Sewage Company (1999-2000).

Critical questions to be answered

- What is the maximum total withdrawal from the hydrosystem, for a given hydrologic regime and a given reliability level?
- What is the minimum failure probability in achieving a given set of operational goals, for a given hydrologic regime?
- What is the minimum cost to achieve a given set of operational goals, for a given hydrologic regime and a given reliability level?
- What are the consequences of modifications in the hydrosystem (e.g., construction of new projects), and the impacts of different management policies or hydroclimatic scenarios?
- How could the system respond to special occasions such as channel damages or an intense increase of water demand for a specific period (e.g., during the 2004 Olympic Games)?

Characteristics of *Hydronomeas*

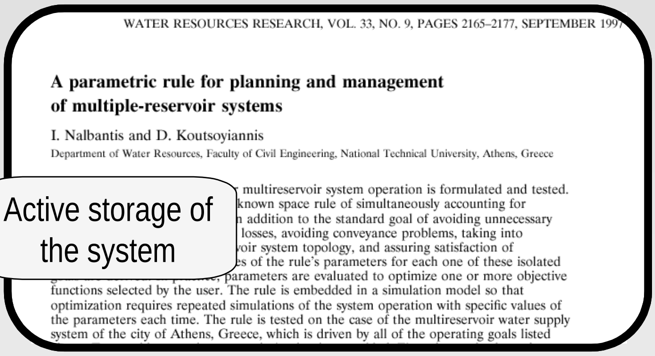
- Suitable for simulating complex multipurpose, multireservoir systems and for detecting the optimal water resources management policy
- It applies the parametrisation-simulation-optimisation methodology, keeping the number of control variables small
- The results are given in probabilistic terms
- The software has been developed in an Object Pascal environment (Delphi) and uses a relational database
- Hydronomeas cooperates with the stochastic simulation system **Castalia** for the generation of synthetic hydrological time series

Parametric operating rules

Main idea: Distribution of the total active storage of the system *V* at each of the *N* reservoirs according to a simple linear rule:

$$S_i^* = K_i - a_i K + b_i V$$

- Target storage for the *i* reservoir: S_i^*
- Control parameters: a_i, b_i
- The capacity of the *i* reservoir: K_i
- Total capacity of the system: K
- Active storage of the system: V



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A parametric rule for planning and management of multiple-reservoir systems

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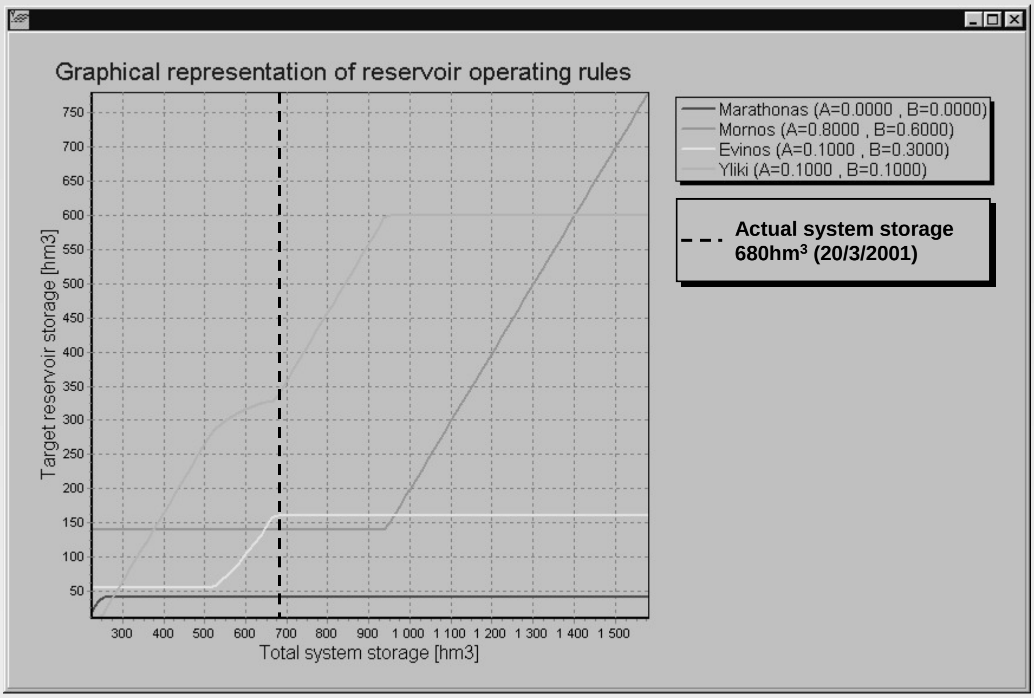
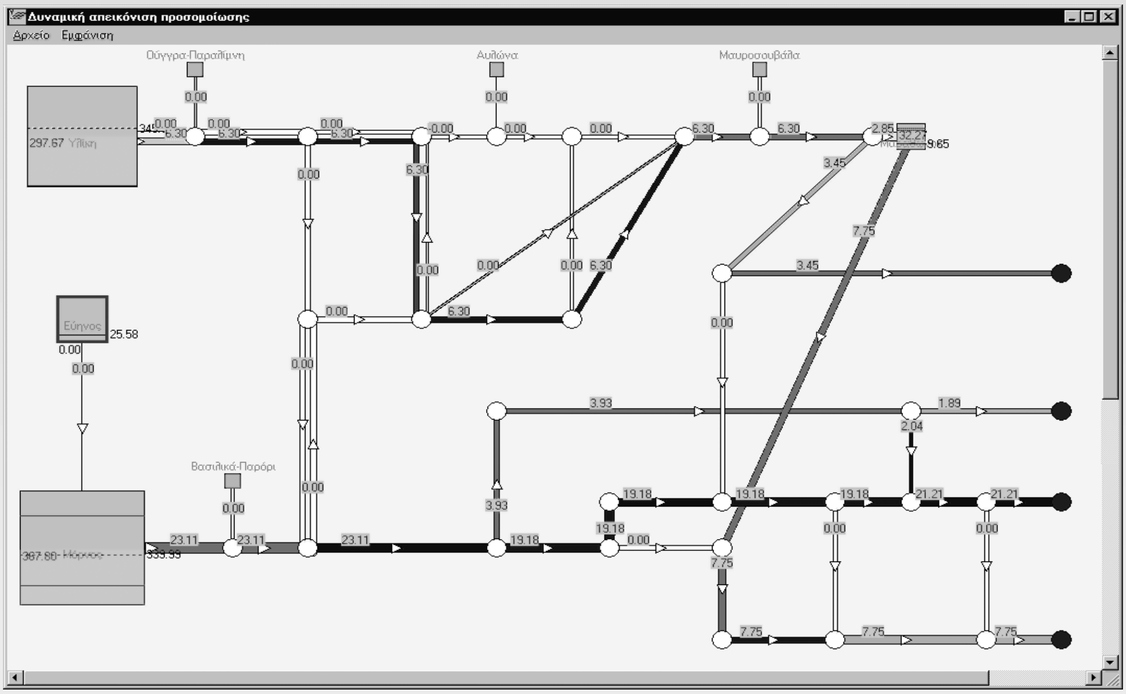
… multireservoir system operation is formulated and tested. … known space rule of simultaneously accounting for … addition to the standard goal of avoiding unnecessary … losses, avoiding conveyance problems, taking into … voir system topology, and assuring satisfaction of … es of the rule's parameters for each one of these isolated … parameters are evaluated to optimize one or more objective functions selected by the user. The rule is embedded in a simulation model so that optimization requires repeated simulations of the system operation with specific values of the parameters each time. The rule is tested on the case of the multireservoir water supply system of the city of Athens, Greece, which is driven by all of the operating goals listed

- Initial rules are corrected according to an adjusting procedure, in order to satisfy reservoir capacity constraints, and thus they become nonlinear
- The total number of control variables of the system remains 2N and becomes independent of the simulation length

Graphical representation of reservoir operating rules



The visualisation of the simulation process

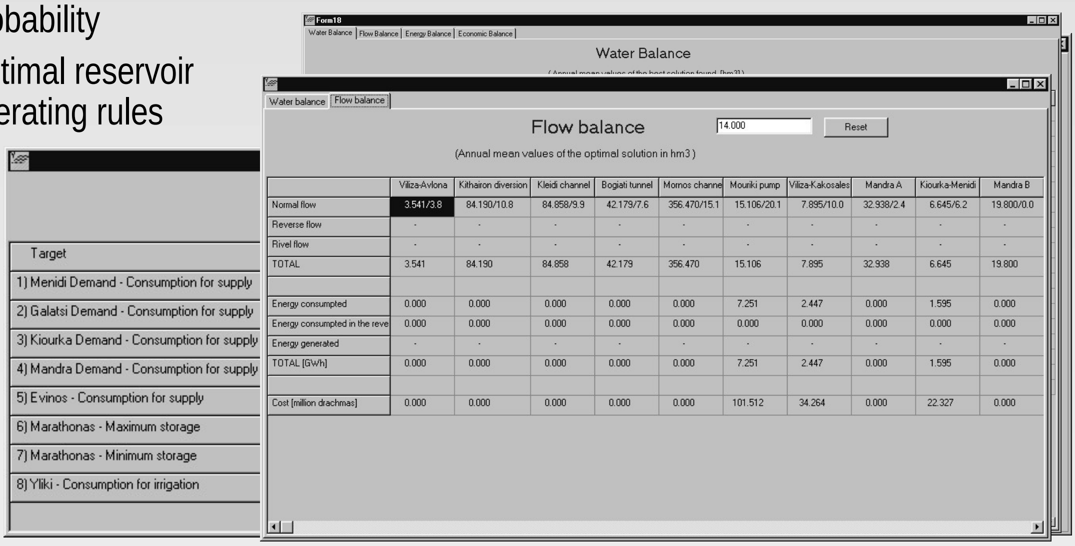


Calculating the optimal operating rule

- An objective function is formulated, expressing the performance measure of the management
- Types of problems to be solved:
  1. minimisation of the total operational cost
  2. minimisation of the failure probability, for a given set of operational goals (targets)
  3. maximisation of the total annual withdrawal, for a given reliability level
- Operational targets:
  1. water consumption
  2. firm power generation
  3. minimum flow preservation
  4. reservoir storage control.
- The objective function is evaluated through the simulation process
- The optimisation problem is strongly nonlinear
- Advanced techniques are used, particularly the multi-start downhill simplex algorithm (Press el al. 1992) and the shuffled complex evolution method (Duan et al. 1992)

Steady state simulation results

- Reservoir water balance including annual mean value of water runoff, rainfall, evaporation, reservoir leakage, aqueducts inflow, outflow, losses, consumption
- Aqueducts flow balance
- Targets failure probability
- Optimal reservoir operating rules



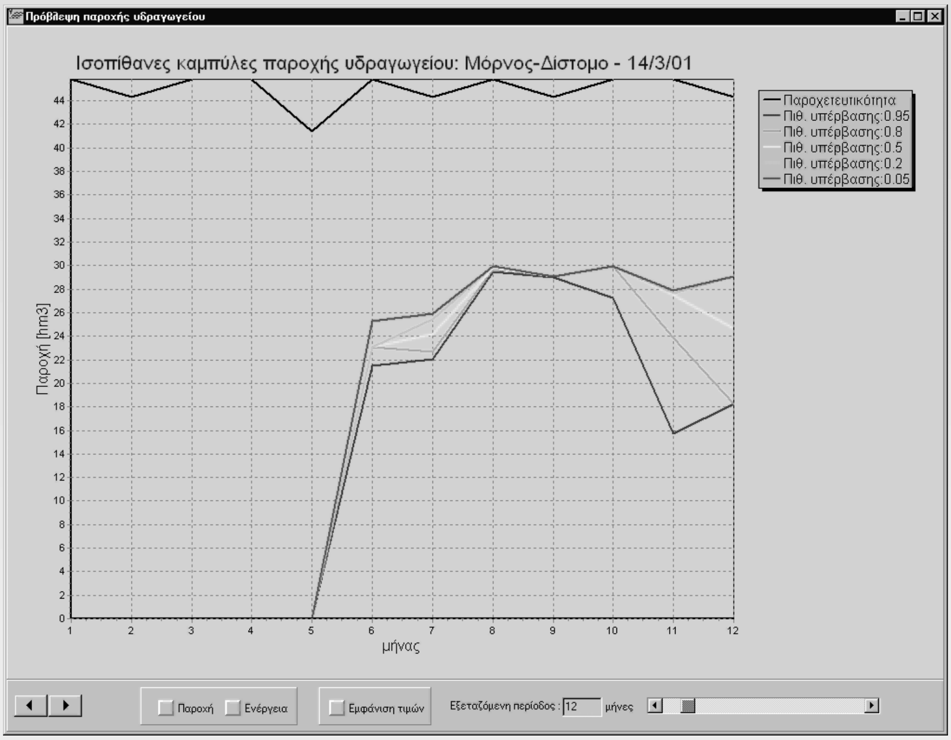
	Viliza-Avlona	Kithairon diversion	Kleidi channel	Bogiati tunnel	Mornos channe	Mouriki pump	Viliza-Kakosales	Mandra A	Kiourka-Menidi	Mandra B
Normal flow	3.541/3.8	84.190/10.8	84.858/9.9	42.179/7.6	356.470/15.1	15.106/20.1	7.895/10.0	32.938/2.4	6.645/6.2	19.800/0.0
Reverse flow	-	-	-	-	-	-	-	-	-	-
Rivel flow	-	-	-	-	-	-	-	-	-	-
TOTAL	3.541	84.190	84.858	42.179	356.470	15.106	7.895	32.938	6.645	19.800
Energy consumpted	0.000	0.000	0.000	0.000	0.000	7.251	2.447	0.000	1.595	0.000
Energy consumpted in the reve	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Energy generated	-	-	-	-	-	-	-	-	-	-
TOTAL [GWh]	0.000	0.000	0.000	0.000	0.000	7.251	2.447	0.000	1.595	0.000
Cost [million drachmas]	0.000	0.000	0.000	0.000	0.000	101.512	34.264	0.000	22.327	0.000

Terminating simulation results (1)

System storage prediction curves

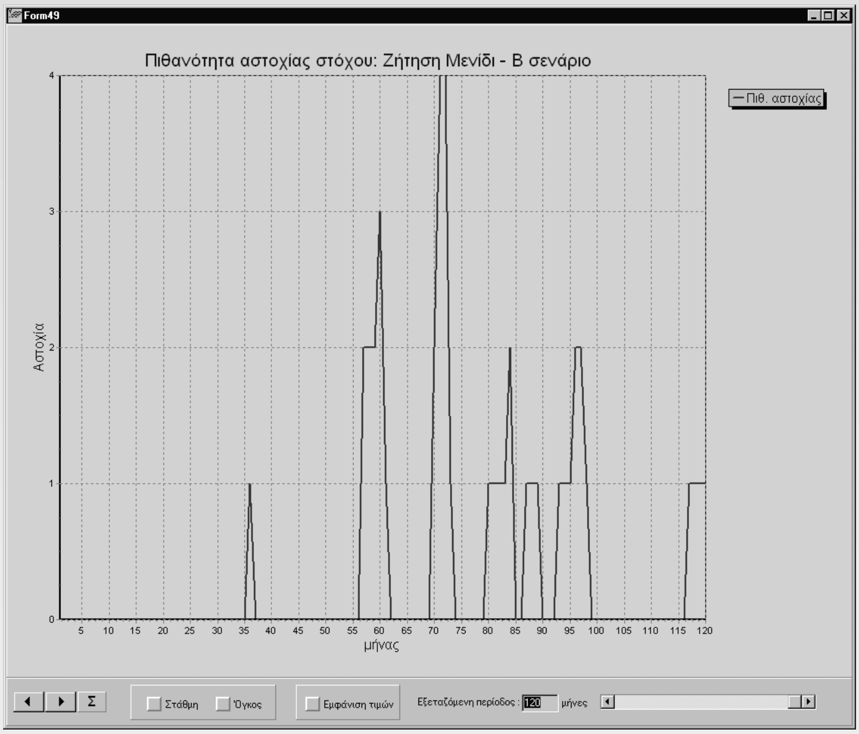
Terminating simulation results (2)

Water flow prediction curves



Terminating simulation results (3)

Target failure prediction curves



Answers to questions

- The mean total annual runoff of the 4 river basins is **860 hm^3**
- The annual safe yield of the system, ignoring all aqueduct capacity constraints, is **480 hm^3** (failure probability of 1%)
- The annual safe yield of the system, taking into account the current aqueduct capacity constraints, reduces to **420 hm^3** (failure probability of 1%)
- Assuming a moderate increase of water demand over the next 10 years, the failure probability (management risk) is **1.3%**
- The energy needed in order to comply with the estimated demand of the actual hydrologic year is **94 GWh** (with a standard deviation of 35 GWh)