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A hybrid artificial intelligence modelling framework for the simulation of the complete, socio-technical, urban water system

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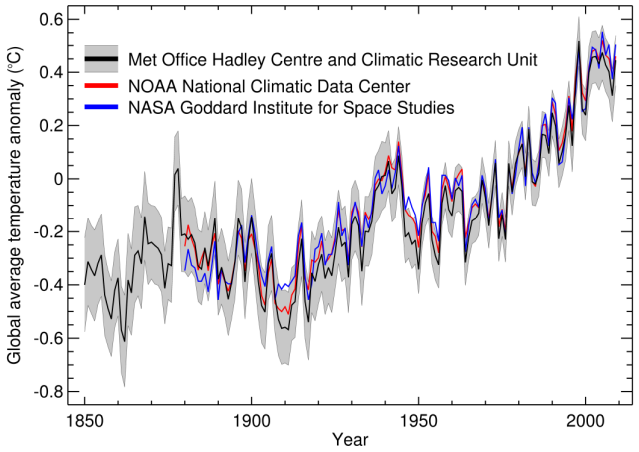
The socio-technical Urban Water System

Complex System



Hydroclimatic variability

Anthropogenic / social change

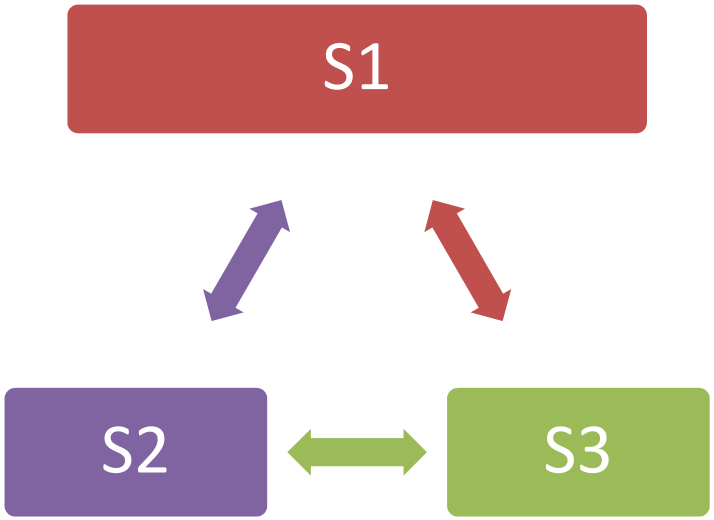
The socio-technical Urban Water System

- Conventional approaches: technical sub-system
- But what about the users?
- Socio-economic drivers
- Missing link and interactions between technical and social subsystems
- Complete socio-technical water system

Interdisciplinary approach

The need for decision-making tools "thinking platforms"

- Dynamic complexity and feedbacks
- Critical communication paths
- Information flow between sub-systems

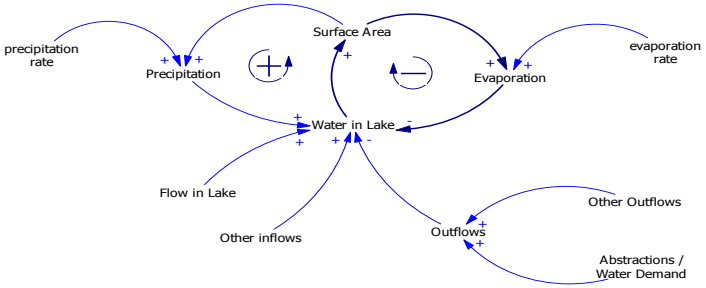


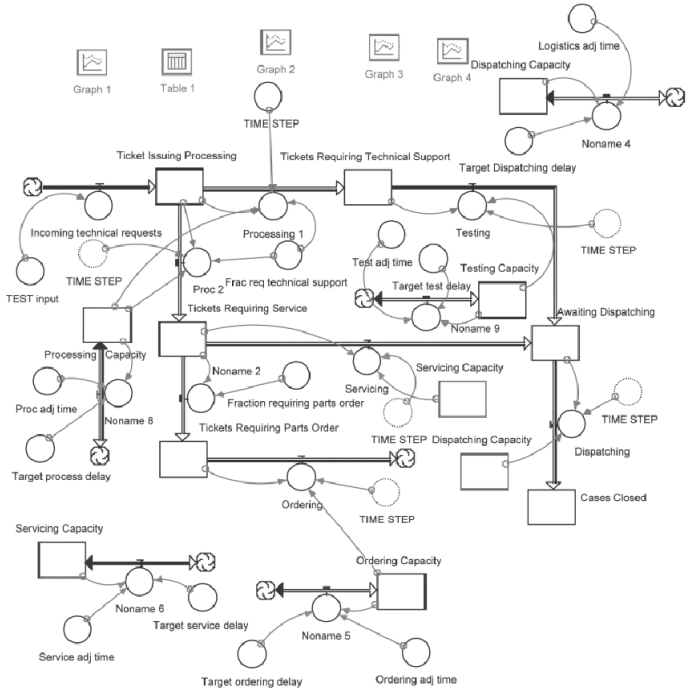
The need for decision-making tools "thinking platforms"

- Designing **demand management** strategies (under climatic and behavioural uncertainty)
- Designing **supply management** strategies (under climatic uncertainty)
- Exploring **interactions** between:
  - technical and social subsystems
  - centralised infrastructure and decentralised interventions,
  - customers and their behaviour,
  - impact of policy, pricing, water markets…

System Dynamics (SD)

- Complex dynamic systems
- Interdisciplinary problems
- Visualisation - Facilitating Communication
- Decision Support Tools



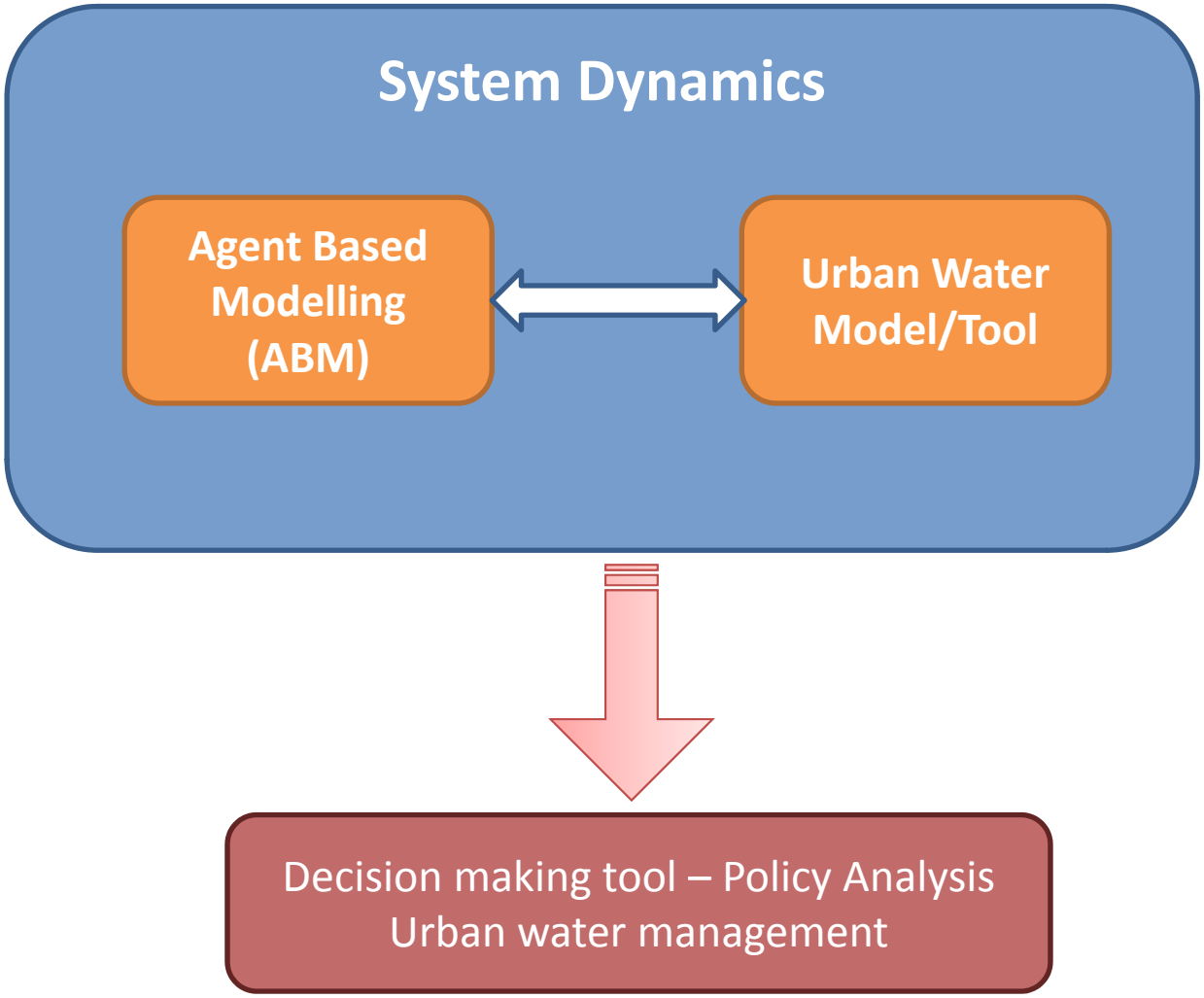


- Flexible interdisciplinary modelling platform
- Link with more specialised models

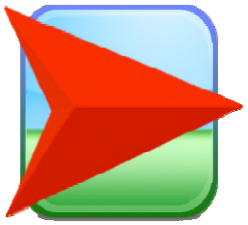
System Dynamics (SD) & Agent Based Modelling (ABM)

SD	ABM
Top-down modelling	Bottom-up modelling
Known system behaviour	No fixed structure
Fixed system structure	Emergent behaviour from agents
Series of feedback loops	Heterogeneity
	Social simulation

Integrated modelling tool



The modelling environment

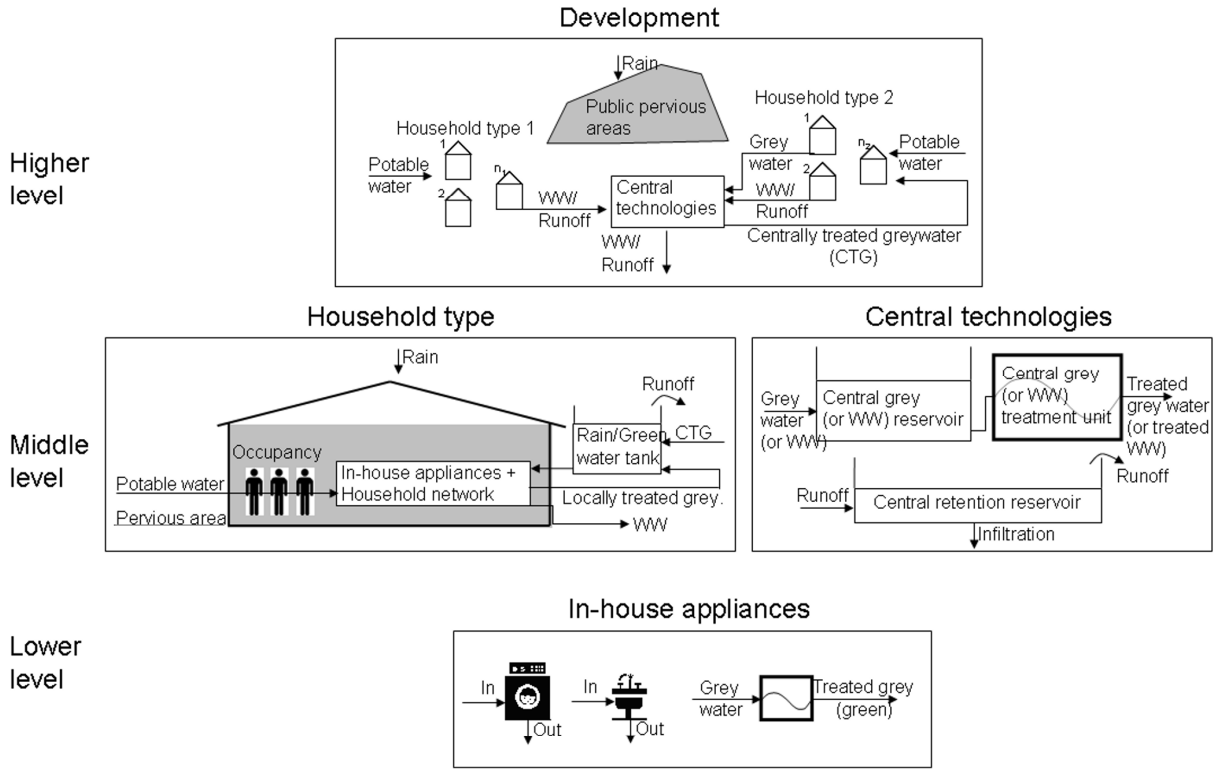


NetLogo

- Agent based simulation platform
- System Dynamics
- Free - but not open source
- Runs on Windows, Mac OS X, Linux
- Own programming language
- Good documentation and tutorial
- Good user forum (Netlogo-users)
- Very high level language

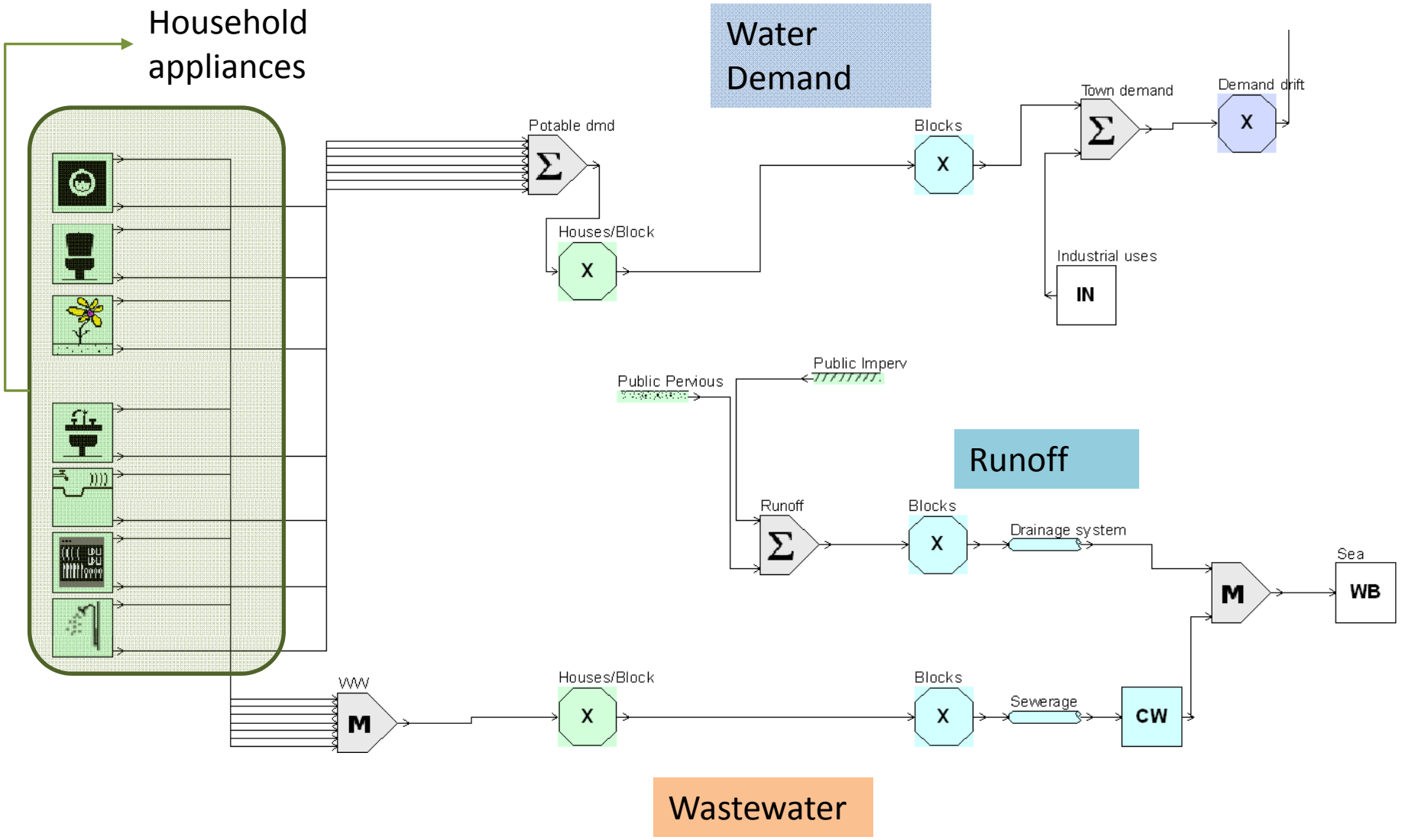
The Urban Water Optioneering Tool (UWOT)

- UWOT simulates the urban water cycle by modelling individual water uses and technologies and aggregates their combined effects at development scale
- UWOT puts human behaviour in the centre of the modelling.

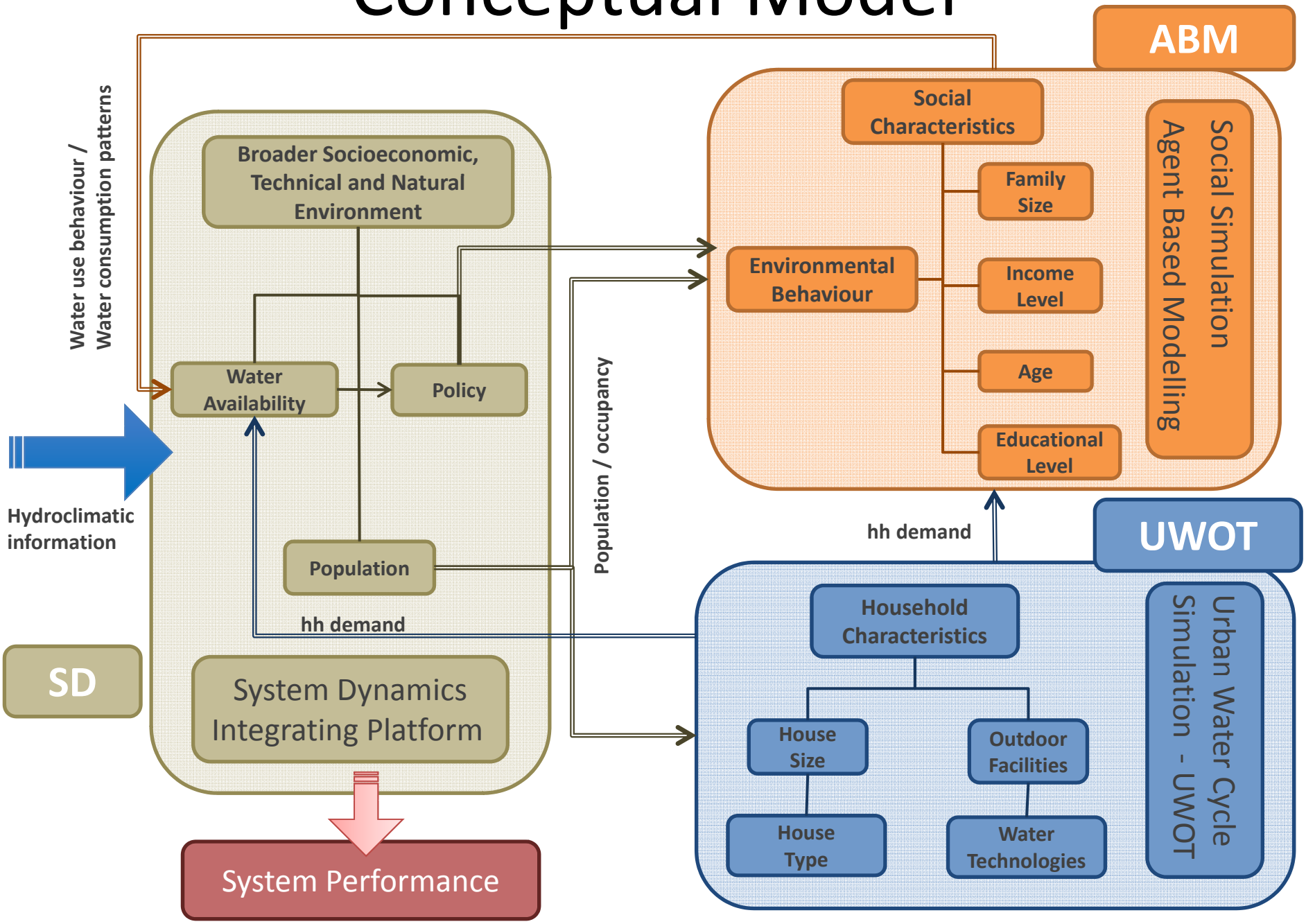


- UWOT is not focusing on flows but on demand signals.

UWOT - Internal water supply system

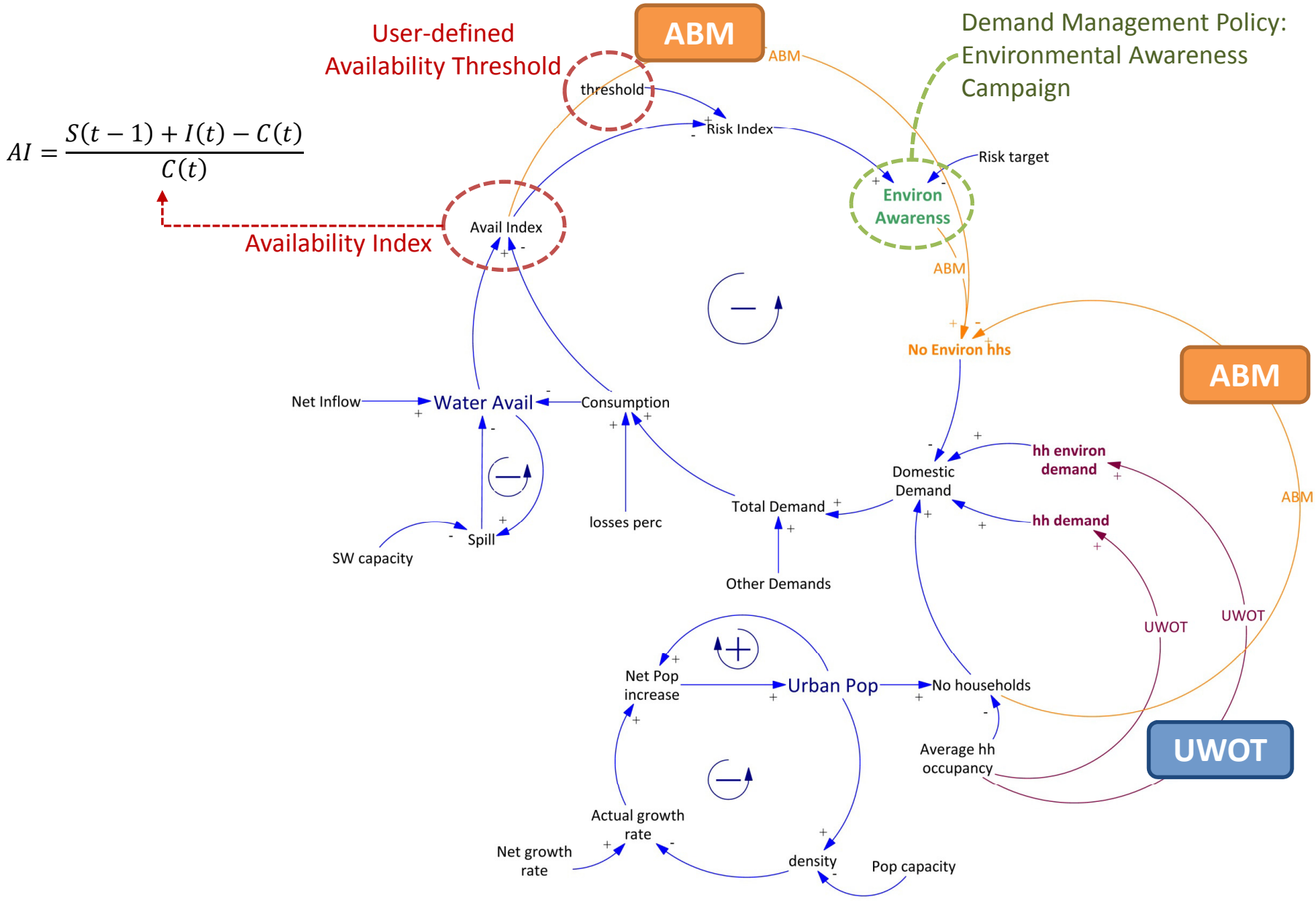


Conceptual Model

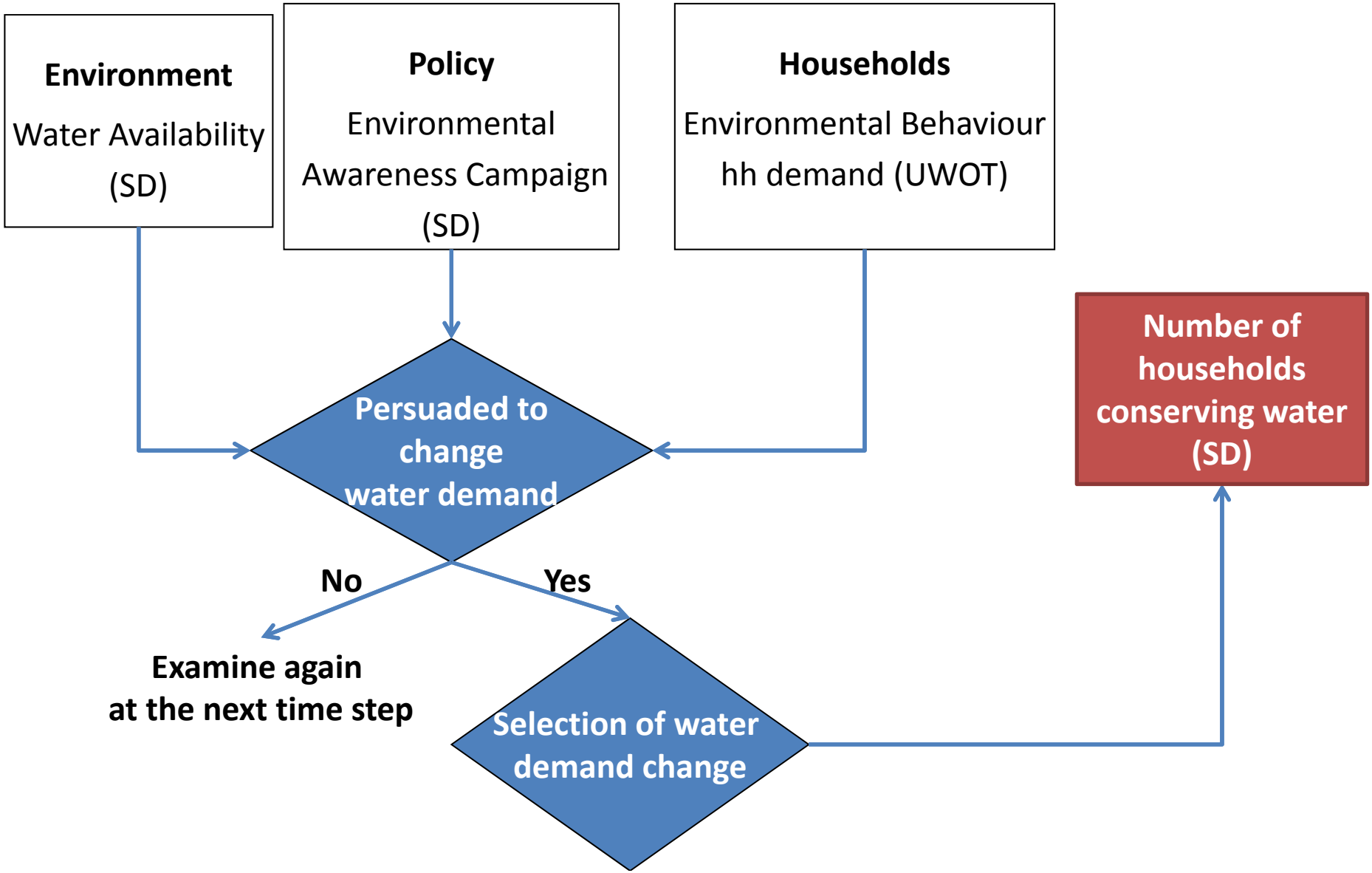


Hybrid model Causal Loop Diagram (CLD)

$$AI = \frac{S(t-1) + I(t) - C(t)}{C(t)}$$



Household's decision process



The Athens Water Supply System

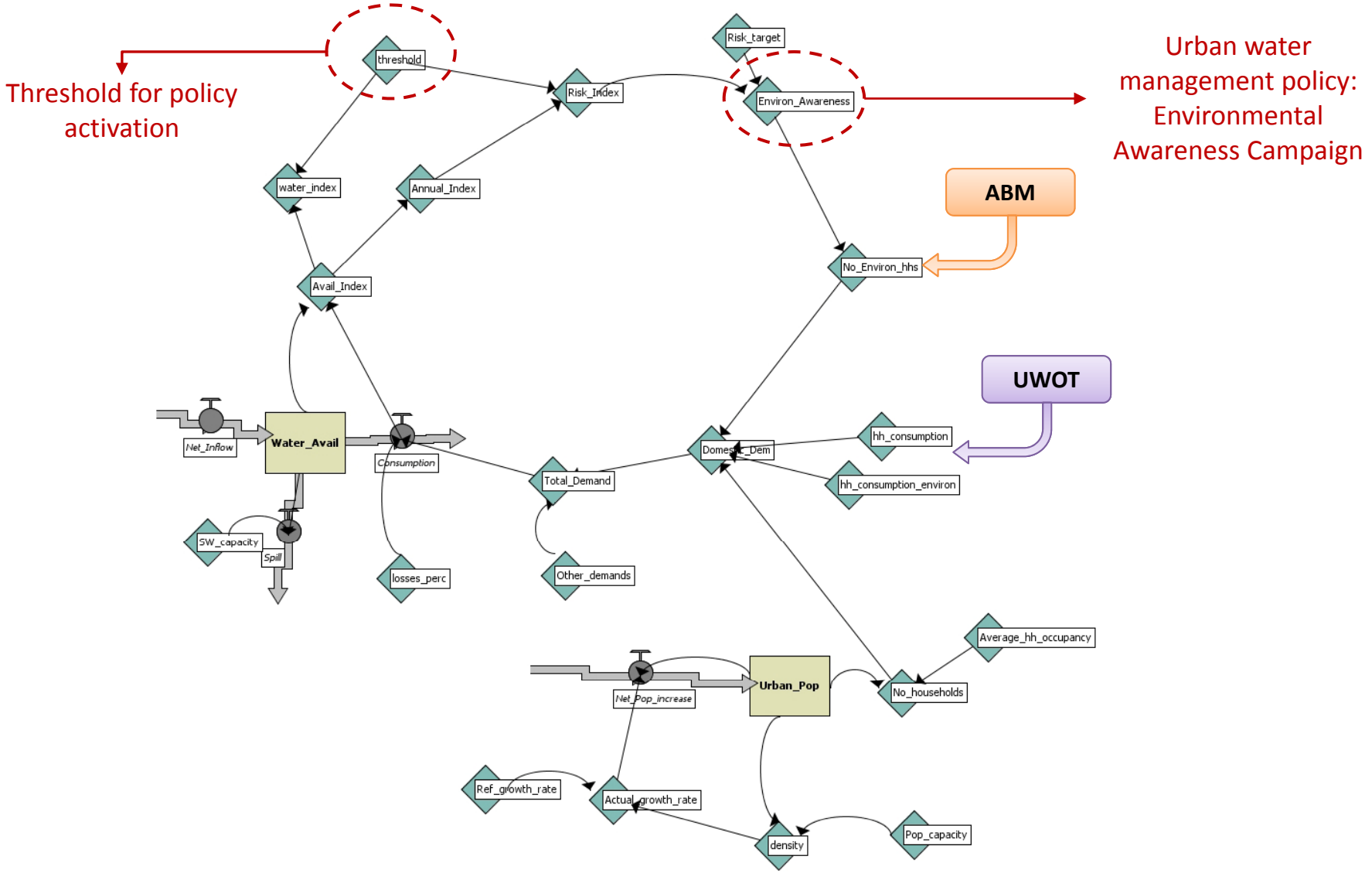
Model assumptions

- Main driver: Domestic water demand
- Initial conditions, Losses
- Monthly time step
- Constant population at current levels
- Varying climatic conditions
- 100-year synthetic timeseries – inflows to the 4 reservoirs

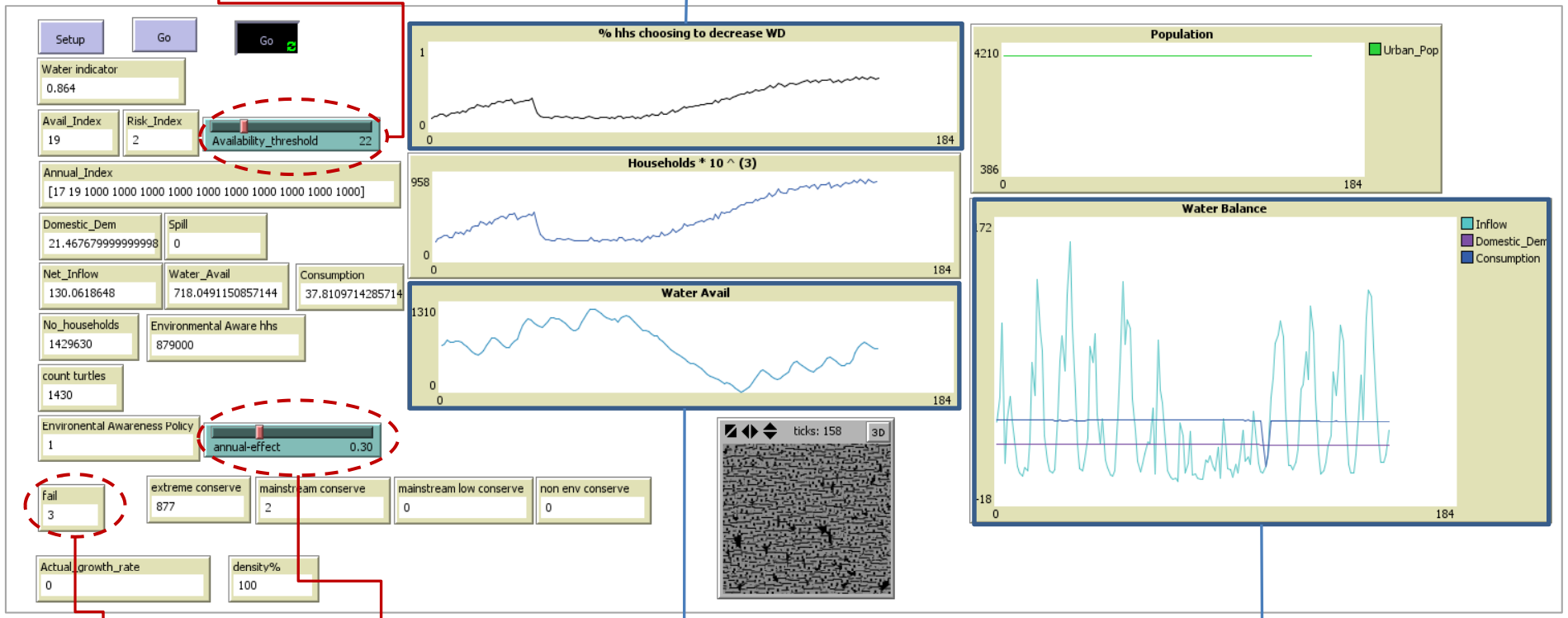
Model assumptions

- **Baseline scenario**: current situation, no demand management policy
  - Conservation choice: mainly agents' social characteristics
- **Policy scenario**: Environmental awareness campaign
  - Availability index below set threshold
  - Targets all households – environmental behaviour
  - 10% possible reduction
  - Different availability thresholds & levels of assumed policy effect

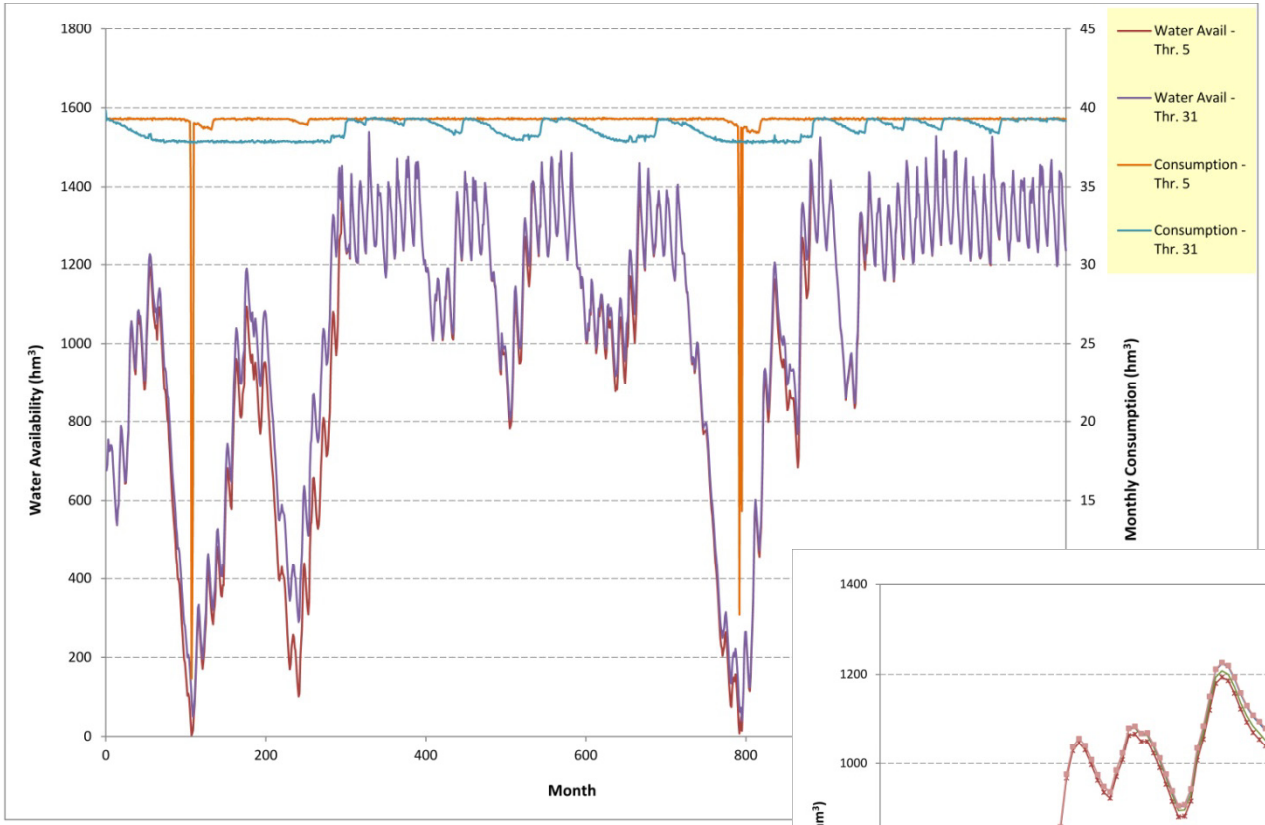
System Dynamics model (Netlogo environment)



Hybrid model interface in Netlogo

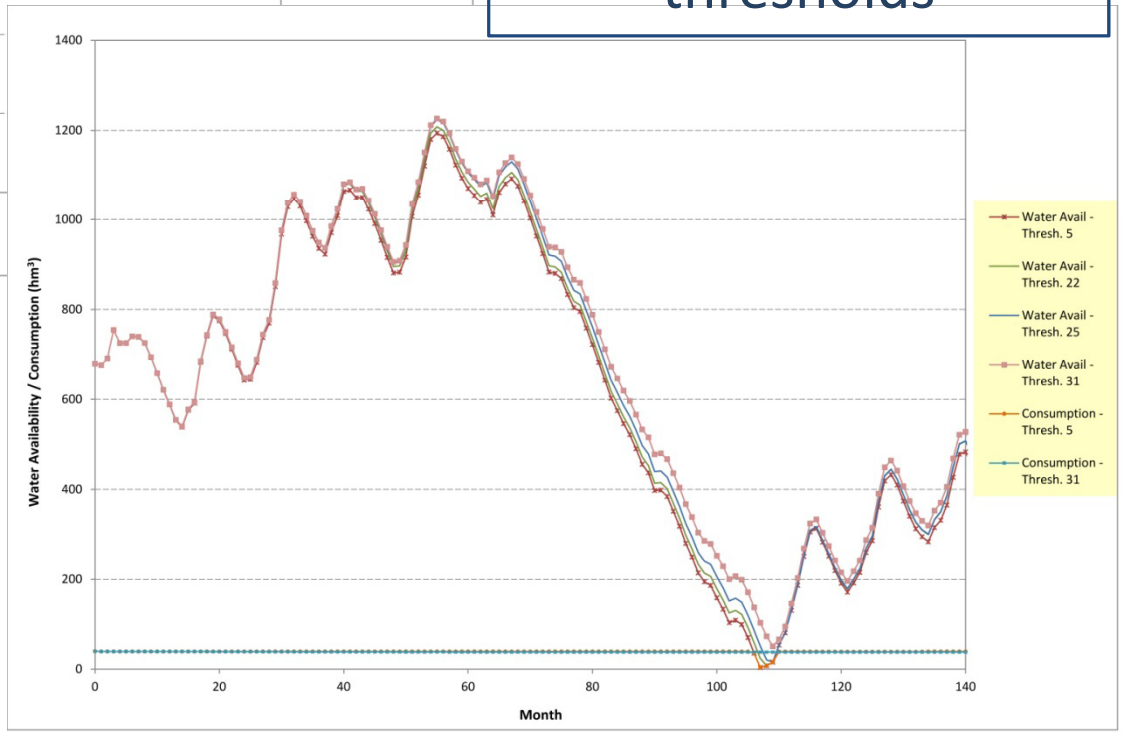


Model results



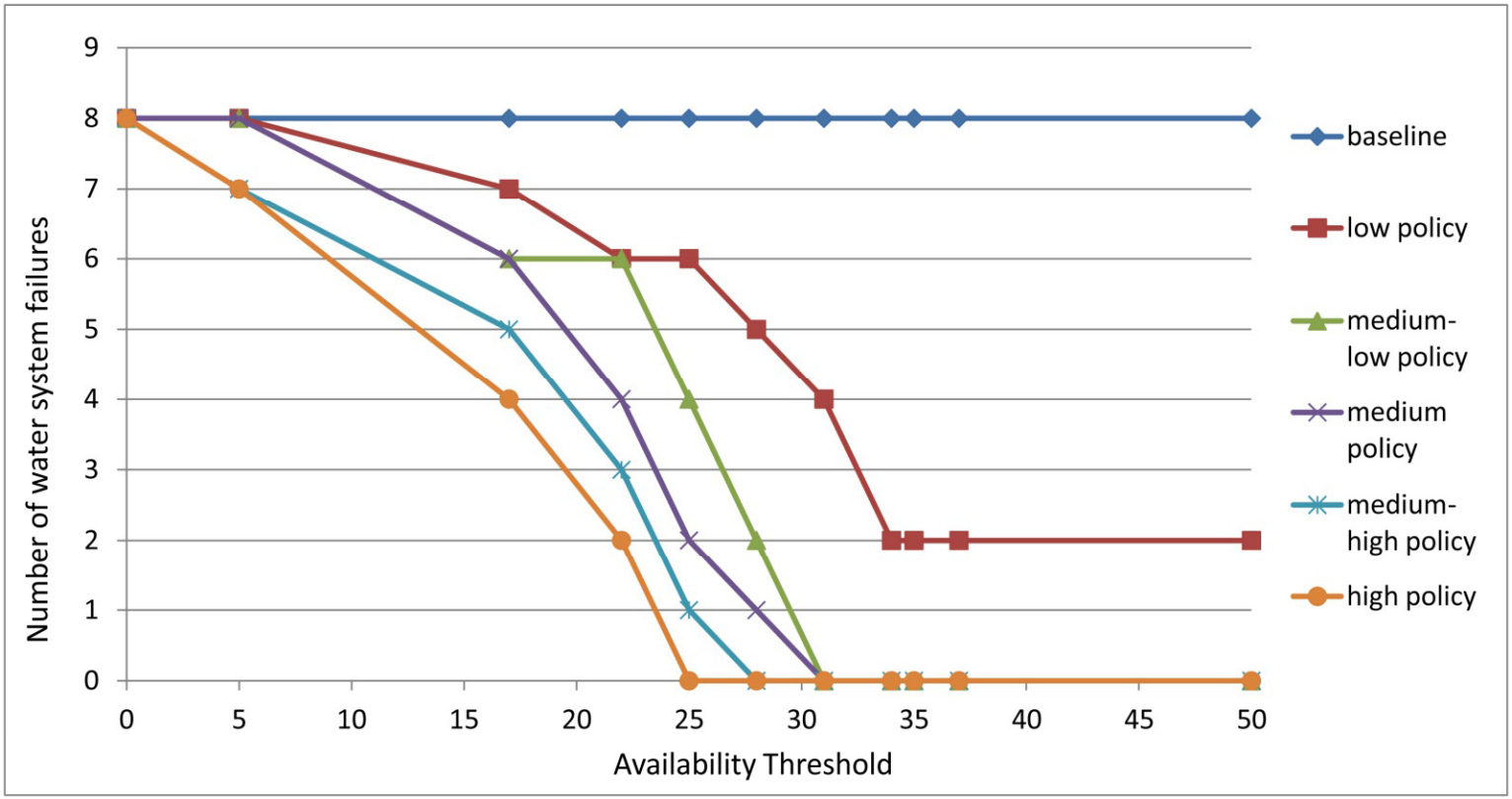
Water Availability & Consumption

Medium-low effect policy under varying water availability thresholds



Model results

Water system failures vs. water availability threshold under varying policy effects



Conclusions

- Thresholds for water scarcity and drought management
- Acceptable levels of risk
- Identification of critical leverage points in customised campaigns
- Identification of effective intervention strategies/policies for urban water systems
- Decision making under continuously changing environmental and socio-economic conditions

Potential / Next steps

- Decision-making / Policy testing
- Economic and urban development scenarios – feedback relations with UWS
- Link with urban growth models
- Stakeholder participation in decision making
- Different urban water demand policies:
  - Water pricing
  - Penetration of decentralised technologies

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Thank you!

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