Process data and integrated urban water modelling : conclusions from a CityNet junior scientists workshop

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Abstract
The paper presents a brief summary of and the main conclusions drawn from the 19th European Junior Scientists Workshop organised in March 2004 under the umbrella of the European cluster CityNet on the theme "Process data and integrated modelling workshop". 24 junior scientists from 11 countries not only gave presentations on their work, but also thought and analyzed the links between their own work, the projects in which their work is included, and how these projects themselves are inter-related and elements of a wider and integrated approach of urban water systems. Additionally, during specific working group sessions, the participants analysed and identified the interests and difficulties of the integration of data, knowledge and models for UWS. The issue "integrated urban water systems" will remain a very critical one in the next years and decades, and many scientific and operational efforts will be necessary in order to solve the remaining difficulties linked to the lack of and to the uncertainties in knowledge, data and models. This workshop may be considered as a contribution to disseminate this issue and its pertinence, and to encourage the next generation of researchers to work with wider scopes, multidisciplinary and integrated approaches, tools and concepts accounting for all aspects of the urban environment.

Keywords : integrated urban water management, CityNet

INTRODUCTION

The structural and functional performance of urban water systems and services (i.e. hydraulics, transfer and treatment of pollutants, failures, service reliability) and of their subsystems can be described by field data and/or simulation models. Field data are considered here as measured physical, chemical and biological quantities such as water level, flow rate, oxygen and pollutants concentrations, etc. which are used to describe and understand the state and the functioning of integrated urban water systems (IUWS) - data such as costs, operating time, etc. are not included. But field data are also a prerequisite for any model development, and their acquisition in urban water systems is extremely cumbersome and costly. Simulation models and decision support tools are built on hypotheses, and calibrated/confirmed with process/field data. Usually they only describe some processes of interest in a sub-system. In order to evaluate the performance of entire urban water systems, models need to be interfaced such that they can be applied in an integrated way.

As most of the six CityNet cluster individual projects, which deal with different parts of the urban water system (Schilling *et al.*, 2002; Bertrand-Krajewski *et al.* 2003), include gathering and analysis of field data, with modelling applications, it was decided to dedicate a CityNet work package to a workshop on the collection and interpretation of field data, their application for model development, and the integration of models. The workshop has been organized in two parts : i) a European Junior Scientists Workshop on "Process data and integrated urban water modelling", in order to present and discuss the potential and limitations of integrated monitoring of urban water processes and integrated simulation, and also to initiate "grass root"-networking with junior scientists; ii) a senior workshop to formalize and draw conclusions based on the junior workshop minutes and on seniors' expertise. This paper presents successively : i) the organisation and the content of the junior workshop, ii) the organisation of the senior workshop, and iii) the main conclusions from both events.

ORGANISATION AND CONTENT OF THE JUNIOR WORKSHOP

The CityNet junior workshop has been organised as the 19th European Junior Scientist Workshop (19th EJSW) on "Process data and integrated urban water modelling". It has been held in Meaux-la-Montagne, France, in the Beaujolais area, approx. 60 km north of Lyon, on 11-14 March 2004. It was organised by INSA de Lyon. Accompanied by 3 seniors (the authors), 24 junior scientists (i.e. mainly PhD students and post-docs) from both the six CityNet projects and other external projects and institutions, all of them coming from 11 countries in Europe and Australia (Figure 1), spent 4 days of intensive work. As traditionally in junior scientists workshops (Schilling, 1999), individual presentations were given by each participant on his/her research work; all juniors also worked as chairperson, rapporteur and "advocatus diaboli" during all sessions.

Figure 1: participants in the 19th EJSW (photo JLBK)

The main topics presented during the workshop included : integrated analysis and modelling of urban water systems, hydrological modelling, groundwater pollutant transfer and modelling, sustainability of urban water systems, infrastructure assessment and rehabilitation, performance indicators for technical and natural urban water systems, monitoring and data acquisition and validation, model calibration. In total, 23 individual presentations have been given, as listed in Table 1. All presented papers have been disseminated as workshop proceedings to all CityNet partners and are publicly available on the CityNet website (at http://citynet.unife.it/, in the folder "Conferences").

In order to promote interaction, sharing of experience and productive collective work, additional plenary and working group sessions have also been organised, during which the junior scientists were invited to identify interests and difficulties in modelling of IUWS, according to their own knowledge and to the information provided by the 23 individual presentations. The paper on integrated models from Rauch *et al*. (2002) has been used to provide a minimum common background and starting thoughts for all juniors. Five working group and plenary sessions have been organised :

1 definition, elements and boundaries of IUWS
2 IUWS processes, variables and interactions
3 IUWS model identification, monitoring and measurements

4 practical problems and applications
5 thematic minutes of the four above sessions.

These working group sessions have been very intensive and very challenging for all juniors, who had to discover, to reflect and to elaborate some material on complex scientific and operational questions involving multidisciplinary approaches and backgrounds. Such a multidisciplinarity may be difficult to be handled by junior scientists (mainly PhD students) who usually focus on very specialised and limited aspects of IUWS. The three seniors were present as facilitators (by providing basic information and knowledge, by answering and/or suggesting questions, etc.), but not to impose their own views and ideas. The minutes of the working group sessions have been presented during a final plenary session and later on by four delegated juniors at the CityNet senior workshop devoted to the same general theme (see next paragraph). This was an additional challenge for these four juniors to give presentations and to report in front of seniors.

n°	Speaker	Title of presentation
1	L. Benedetti and F. Blumensaat	System Analysis of urban wastewater systems – two systematic approaches to analyse a complex system
2	S. de Toffol	Needs for integrated modelling from the point of view of the European Water Framework Directive implementation
3	M. Biegel	Improved resolution in Urban Water Modelling for Large River Basins
4	J. Langeveld	Integrated modelling and data needs: quantification based on the interactions within the wastewater system
5	B. Ráduly	Empirical modelling of wastewater treatment processes- An approach to model reduction and integration
6	C. Westerlund	Modelling of Snowmelt Quality Parameters
7	F. Rodriguez	Development of a distributed hydrological model based on urban databanks
8	L. Wolf	Integrating Leaky Sewers into numerical groundwater models
9	J. Klinger	Using the UVQ Model for sustainability assessment of urban water system
10	R. Ugarelli	Reliability of a water supply system in quantity and quality terms
11	H. Haidar	Multi-criteria model for annual rehabilitation planning of water supply networks: sensitivity analysis and impacts of the quantity of data
12	J. Caletkova	Methodology of Ecological Discharges Assessment of Small Streams in Urban Environment
13	F. Ruysschaert	Monitoring tools and program for modelling subsurface flows through the bed of a stream receiving urban storm-water runoffs
14	S. Winkler	An integrated water quality monitoring network
15	M. Francey	Monitoring of Stormwater Runoff in Melbourne
16	G. Ramon	Data Acquisition in a Combined Sewer System
17	C. Flamink	Design and optimisation of monitoring networks in urban drainage
18	M. Mourad	Calibration and validation of multiple regression models for stormwater quality prediction: data partitioning, effect of data sets size and characteristics
19	F. Hamioud	Statistical modelling for validation of data issued from the sewer network
20	R. Baur	Statistical analysis of inspection data for the asset management in sewer networks
21	L.S. Hafskjold	Improved assessment of sewer pipe condition
22	M. Rutsch	Field Data to Estimate Infiltration into Sewer Systems
23	V. Prigiobbe	Assessing exfiltration from sewers with dynamic analysis of tracer experiments

Table 1 : list of junior scientists presentations

ORGANISATION OF THE SENIOR WORKSHOP

Ten senior scientists from the 6 CityNet individual projects and four delegated junior scientists from the 19th EJSW participated in the CityNet senior workshop organised on 15 March 2004 morning in Ghent, Belgium. Each junior gave a presentation based on the minutes prepared in Meaux-la-Montagne. The topics were then further discussed by all participants.

MAIN CONCLUSIONS FROM BOTH WORKSHOPS

The main elements and conclusions discussed during the senior workshop are presented hereafter in four paragraphs corresponding to the four key topics identified during the junior workshop, with large reuse of the material given in the slides prepared by the junior working groups :

1 public health and ecology/environment
2 questions regarding the integration of UWS
3 scenario thinking for IUWS
4 difficulties, critical points and conflicts.

Public health and ecology/environment

Public health and ecology/environment have been considered as the two main issues to be accounted for when dealing with urban water systems. Public health, which is a key objective for human beings, is an extremely wide issue covering almost all elements of UWS. As an example, standards for maximum acceptable concentrations of pathogens have to be defined for drinking water (water supply sub-system), bathing / recreational waters (surface aquatic sub-system), groundwater (water resources sub-system), water reuse (internal and external water reuse sub-systems) and sludge (wastewater treatment plant sub-system). Priority pollutants have also been defined because of their negative impacts of human health, which may be found in all sub-systems, like heavy metals, endocrine disruptors, xenobiotics, etc. The main problems linked to public health in UWS are leakages of polluted water (exfiltration of sewer systems, combined sewer overflows, discharges of untreated effluents) leading to contamination of ground and surface water bodies, accumulation of pollutants in water resources and in the food chain, etc. Regarding public health, measurements and models are used to define standards, to control actions, and to define improvements of the system. In terms of modelling, an ideal integrated model would have to use pathogens and priority pollutants as inputs to estimate some indicators of public health as outputs.

Ecology/environment issues are important for both surface and ground waters. Regarding surface water modelling, there are many inputs from many sub-systems : wastewater treatment plant (WWTP) effluents, combined and separate sewers overflows (CSOs and SSOs) and discharges, industrial discharges, surface runoff, rainwater, channelling, groundwater, etc. The processes that should be measured and included in models are hydraulics, mixing, dilution, accumulation, biochemical reactions, and growth of biocenosis. These processes have effects on morphology of surface waters, hydraulic stress, ecological quality, biodiversity, and all water quality and ecological indicators. Regarding ground water modelling, the main inputs are extraction for water supply, industry and irrigation, exfiltration from sewers, leakage from drinking water networks, local infiltration of waste and stormwater, and agriculture sources of nutrients and pesticides. The main processes to be accounted for are : flow, absorption, adsorption, accumulation, and biochemical reactions. Most important effects are fluctuation of aquifer level and transfer of pollutants.

Some questions regarding integration of UWS

When one considers the integration of all components of UWS, it is obvious that there are numerous interactions. For some of them, the scientific knowledge has reached a level where they can be analysed, measured, described and modelled. For other interactions, only general qualitative descriptions are available, like basic "if...then" rules. As a consequence, it is very difficult today to have a fully integrated modelling approach including homogeneous levels of description and of complexity. For example, wastewater treatment plants and drinking water systems are more easily simulated than sewer systems, rivers and aquifers, in both terms of flows and water quality. And if ecological aspects and quality are accounted for, as e.g. the good ecological status requested by the European Water Framework Directive, our levels of knowledge in terms of cause-effect relationships are still relatively weak. Usually, a pragmatic approach consists to identify the most important processes and interactions to be accounted for, but it is very difficult to check the hypotheses because of the lack of experimental data, of their uncertainties, and of unavoidable problems in models like over-parameterisation, calibration, equifinality, structural errors, etc.

In Figure 2, only two main sub-systems (water supply system and sewer system) are considered in association with the two main issues mentioned above, i.e. public health and ecology/environment. Pathways of water and pollutants and associated risks are briefly analysed hereafter.

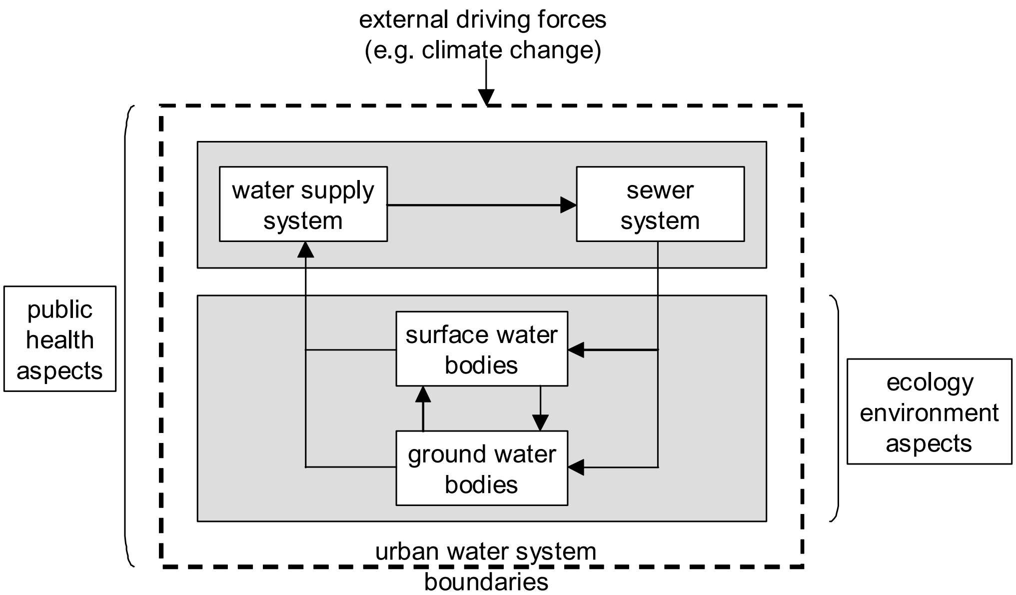

Figure 2 : some aspects of IUWS (adapted from Benedetti *et al.*)

On one hand, the water supply system depends on the quantity and quality of water resources : surface water resources themselves depend on wastewater discharges (from WWTP, CSOs, SSOs...), on interactions with ground water bodies, on upstream surface water quality even outside the urban water system boundaries which are never fully closed, and on rain and surface runoff; while ground water resources depend on sewer exfiltration, on recharge from surface waters, on lateral inflows, etc. Between its source and its use by inhabitants, as the pipe infrastructure is ageing and progressively degraded, drinking water may leak from both public and private pipes, and some pollution may occur. Once used, drinking water becomes wastewater transported in sewers before appropriate treatment. Along sewers, exfiltration may occur and there are some risks that untreated or insufficiently treated wastewater is discharged directly into aquatic environment. Finally, the key questions to be answered are : how is it possible to guarantee the system reliability, for both quantity and quality problems ? are public health and ecology/environment always compatible and do they have the same significance ?

On the other hand, the urban area, the sewer system and surface waters may be affected by other interactions associated to CSOs and flooding. E.g. flooding during storm events may lead to surface water contamination that may sometimes interrupt the drinking water production and which may also directly affect public hygiene. Flooding disturbs the functioning of WWTPs and increases the negative effects of CSOs. Urban floods also have high social costs. CSOs may affect the surface water quality. How to define an efficient global control ? How to balance between hydraulic (flows, volumes, velocities) and pollutant (concentrations, loads) control strategies ? How to evaluate them with measurements and how to define appropriate simulation tools ?

The worst and most important interactions, which shall be accounted for in any integrated approach, should include : the CSOs as they may affect the public health objectives, the infiltration and exfiltration of sewer system as they are related to water supply and to public health on one hand and to the surface water flooding on the other hand. The interactions between sewers and groundwater and the evaluation of sewer infiltration and exfiltration rates appear as some of the most important research needs in order to progress towards a more integrated approach.

Scenario thinking for IUWS

By considering an IUWS, four main points of view may be adopted, depending on the component which is considered for a given set of objectives : i) drinking water, ii) flooding, iii) public health, and iv) ecology/environment. For each aspect, four key issues should be addressed : i) conflicts due to not compatible design and operation objectives between two or more of the four above components ii) controllability of the components, iii) scenarios for an integrated analysis, and iv) research issues.

Some of the most important difficulties are due to lack of knowledge at two levels : i) lack of knowledge about state and functioning of the components, ii) lack of knowledge on the interactions between components. Additionally, it should also be emphasized that even the relevance (and even the existence) of all interactions is not yet well evaluated. This is why an approach based on scenario analysis could be helpful in such an uncertain context.

For drinking water, a first objective could be the reduction of water consumption in order to diminish the pressure on water resources. However, this could lead to longer retention times in water supply networks, with potential negative impacts on public health. Less water consumption will also lead to less water discharged in sewers, with potential effects e.g. on solid transport capacity and deposition in sewers. A second objective could be the reduction of water supply leakages. This would also contribute to less pressure on water resources and would participate in a general movement towards better operation and management and towards more sustainable integrated water management.

For flooding, an increase of the hydraulic capacity of sewer systems would contribute to decrease the flooding frequency. But the negative consequence would be a increase of CSO frequency and volumes, with negative impacts on the receiving waters. Additionally, it appears here clearly that urban water systems should be conceived, planned, built and operated in close connexion with city planners, urbanists, architects, etc. The UWS can not be simply a technical system to be introduced in an urban environment that would have been decided independently of it. Any progress will emerge from better joint conception of all urban elements. On another hand, the reduction or the limitation of local flooding may have detrimental effects on the ecology/environment side : impacts on river morphology (lining of river banks and beds, fast transfer of flows, etc.), reduction of habitats for the fauna and the flora, reduction of biodiversity, etc.

For sewer systems, innovative storm water management (BMPs, alternative techniques, source control) may be introduced, in order to mimic more closely the previous natural water cycle. This could contribute to the increase of the groundwater level and of the potential water resources. Nevertheless, in some urban environments with many underground facilities (parking lots, cooling facilities, subways, tunnels, etc.), this increase of the water table could have negative impacts (soil movements and associated geotechnical risks for buildings, increased pumping costs, etc.). The accelerated transfer of some pollutants into the soil and the groundwater would also require deeper analysis and investigations to ensure the protection of groundwater resources. It is also well known that storm events may have dramatic impacts on sewers and WWTPs, and these interactions should be accounted for.

Public technical systems can not be operated by neglecting public perception and education. Social aspects, including social and individual habits and behaviours, cultural and religious thinking, etc. can not be ignored and should be part of IUWS. Education and public information campaigns (like e.g. “think before you flush”) should be more developed.

Finally, some important research issues should focus on :

- identification of the type, amount and quality of all data that would be necessary to operate an integrated urban water system, and to increase the transparency and communication between the various components and sub-systems which, up to now, have usually been conceived, built and operated independently one from each other by ignoring interactions ;

- analysis of the impact of emerging technologies on UWS and their effects. As an example, local decentralised membrane filtration to produce drinking water from local water resources or even from local reuse of wastewater may completely modify the water consumption, the technical operation and control, the responsibilities in case of failure or accident, the social behaviour, the costs structure and investment rules, etc.
- analysis of the relation between local water related customs and UWS requirements. A recent trend is the promotion of decentralization against the centralization of UWS observed since approximately 160 years. A detailed analysis should be carried out on advantages and drawbacks, including not only technical and financial aspects, before the paradigm is changed. Additionally, the transition phase between present and future systems is not sufficiently investigated. It would also be important to have more flexibility and adaptability to local contexts instead of applying the same approach everywhere.

Difficulties, critical points and conflicts

From all above elements, the most critical points and questions regarding IUWS appear to be the following ones :

- difficulties to define clear and universal system boundaries ;
- persistent lack of knowledge on interactions and on the identification of the most important ones that shall be accounted for in the analysis of any system ;
- conception and decisions to be made in a rapidly changing environment : changes in urbanisation, in social needs and requirements, in legislation, in climate, in politics and policy, etc. ;
- unequal level of complexity of knowledge and models for the different sub-systems ;
- difficulties to really implement integrated analysis and approach : even if it appears as a promising approach, real applications are still insufficient due to all above limitations and difficulties ;
- conflicts between local and short term (sub-)optimisation and long term thinking and sustainable approaches. These difficulties are not only scientific and technical difficulties, but are also related to governance, decision making processes and social and democratic control. Technicians and engineers should learn how the behave in a new social context where they are not the single partners in decision making processes. This is partly illustrated in Figure 3 which summarises the level of control engineers may have on UWS.
- consequently, users and community expectations should also be integrated in design and operation of IUWS.

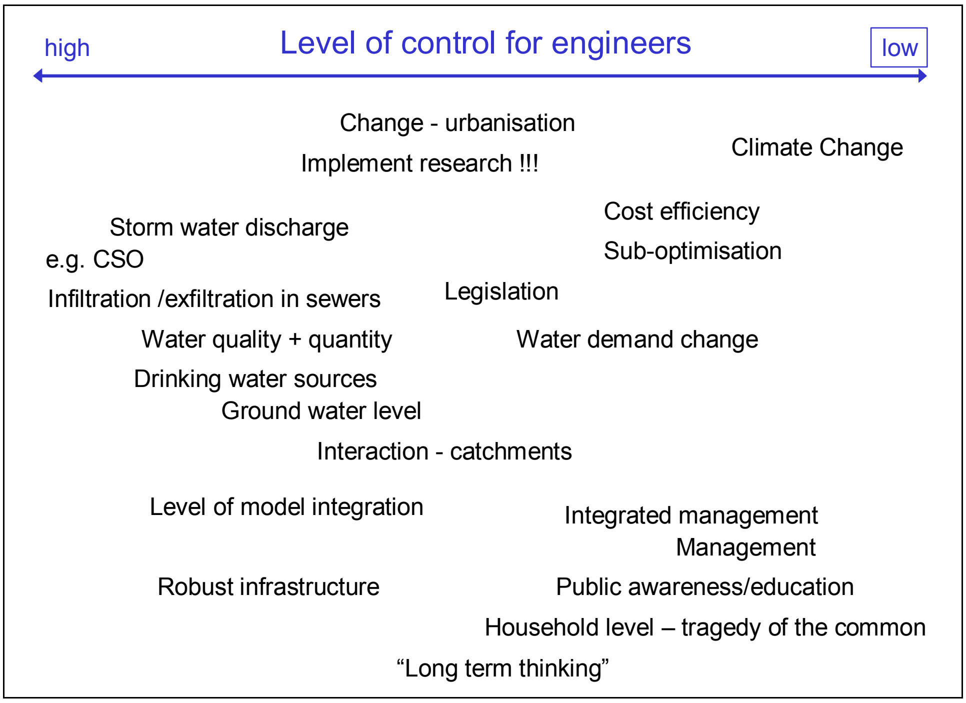

Figure 3 : levels of control engineers may have on UWS (from L.S. Hafskjold *et al.*)

FINAL REMARKS

The 19th European Junior Scientist Workshop on "Process data and integrated urban water modelling", organised in the frame of the CityNet cluster, has been an opportunity for 24 junior scientists from 11 countries not only to give presentations on their work, but also to think and to analyse the links between their own work as PhD students or post-docs, the projects in which their work is included, and how these projects themselves are inter-related and elements of a wider and integrated approach of urban water systems. Additionally, and this was a very unique added value compared to traditional junior scientists workshops, the participants have been invited to participate in plenary and working group sessions to identify the interests and difficulties of the integration of data, knowledge and models for UWS. They have been fully and enthusiastically involved in these tasks, and four delegates have reported their main conclusions to the following senior workshop on the same topics. The main written conclusions have been summarised in the above paragraphs.

Of course, during such an event organized for and with junior scientists, the objectives are more oriented towards mutual information and education, sharing of experience, data, models and concepts, and group working rather than towards the production of new scientific results and concepts. An important objective for the CityNet partners was to contribute to facilitate mutual exchange and information at PhD and post-docs level, and to the dissemination of the issue "integrated urban water systems" for junior scientists who are usually focussed on their own limited and very specialized topics. From this point of view, there is no doubt that the workshop was a success, and the continuing exchanges and contacts between the participants prove this.

The topic "integrated urban water systems" will remain a very critical one in next years and decades, and many scientific and operational efforts will be necessary in order to solve the remaining difficulties linked to the lack of and to the uncertainties in knowledge, data and models. This workshop may be considered as a contribution to disseminate this approach and its pertinence, and to encourage the next generation of researchers to work with wider scopes, multidisciplinary and integrated approaches, tools and concepts accounting for all aspects of the urban environment.

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Further information
The current and future activities of CityNet are continuously published on the CityNet website :
http://www2.unife.it/care-w/citynet1.html, on which links to all individual projects are given.

References

Bertrand-Krajewski J.-L., Eiswirth M., Krebs P., Saegrov S., Schilling W., Thévenot D. (2003). CityNet : a European cluster on integrated urban water management. *Proceedings of the IMUG 2003 Conference*, Tilburg, The Netherlands, 23-25 April 2003, 8 p.

Rauch W., Bertrand-Krajewski J.-L., Krebs P., Mark O., Schilling W., Schütze M., Vanrolleghem P. (2002). Deterministic modelling of integrated urban drainage systems. *Water Science and Technology*, 45(3), 81-94. ISSN 0273-1223.

Schilling W. (1999). The European Junior Scientist Workshops - a flying start for doctoral students. *Water Science and Technology*, 41(2), 93-98.

Schilling W., Bertrand-Krajewski J.-L., Eiswirth M., Krebs P., Saegrov S., Thévenot D. (2002). Integrated Urban Water Management Approaches : CityNet. *International Conference "AQUAECO : Science in support of European water policies - Sustainability of aquatic ecosystems"*, Stresa, Italy, 26-28 November 2002, 4 p.