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The water dimension of urban and land planning: review of the relevant water system components and issues, state of the art and promising research directions towards a more water aware planning process

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SWITCH

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SWITCH Deliverable Briefing Note

SWITCH Document: The water dimension of urban and land planning : review of the relevant water system components and issues, state of the art and promising research directions towards a more water aware planning process
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Audience This deliverable is targeted to persons interested in integrated water management theory, as it offers a theoretical basis for future applications. Therefore, researchers and strategic planners would compose the core of the target audience.
Purpose Define a water management system model to be used as a reference for further steps of development of a framework for holistic, integrated water management.
Background Integrated water resources management (IWRM) is a methodology which requires improvement in its application framework. As a first step in that direction, the extent of what is to be really integrated needs to be identified. This deliverable proposes to develop a holistic approach, which means that water-related objects are considered in their broadest sense, including the social, economic and ecological aspects (such as energy, housing policies, health or virtual water). This done through the following steps: • An inventory of the components involved in integrated water management in a broad sense (including social, economic and ecological aspects), • An inventory of the interactions between these components, • The realisation of a holistic view upon these components and their interactions through a graphical representation: the water management system model.
Potential Impact The result of the study, the water management system model, is viewed as a theoretical first step towards the realisation of a framework for holistic IWRM. It is viewed as a reference and an aide memoir which offers promising research directions. More specifically, it should serve as a basis for: • The systemic analysis of cities or water-related entities such as watersheds, • The development of an information software, to provide in an user-friendly way real cases' systemic data, • The elaboration of algorithms to explore the complexity of the water system network.
Recommendations Print the model in at least A3 format and keep it as a reference while reading the descriptions of the water-related issues. It should be noticed that the model is a background theoretic document designed for specialists; end-users will be provided with future, more user-friendly developments.

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Acknowledgement

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Abstract

Although integrated water resources management (IWRM) is a methodology widely recognised, the way it has to be applied needs to be studied in more details and documented by robust frameworks. In that sense, this paper proposes a water management system model, as a first step towards a framework for holistic IWRM. The term "holistic" means that water-related objects are considered in their broadest sense, including the social, economic and ecological fields. These water-related objects are inventoried and their interactions are identified through literature reviews. Objects and interactions are then graphically represented in the water management system model. This model is viewed as a possible reference, an aide memoir, for future developments such as the realisation of systemic views of complex water-related situations.

I. Introduction

Water-related issues seem to gain increasing focus : the water for life decade was launched in 2005, millennium development goals -also with an horizon on year 2015- let water an important role to play, many large international conferences deal with water-related issues -the 4th world water forum was held in march 2006 in Mexico-, and many reports and guidelines are published by international organizations such as the United Nations' different departments or the World Bank, as well as by teams of researchers. The latest documents not only mention the well-known water-related issues (water for agricultural, industrial and domestic needs, water for energy, water for leisures, sanitation, water conservation, governance, etc.), they also emphasize the increasing consensus about the importance of integrated management.

The integrated water resources management (IWRM) methodology is widely recognised by the water community [1] as a mean to efficiently address water-related issues through a global approach. In several cases, this approach led to encouraging results, such as in New South Wales [2] or in Australia [3]. However, IWRM methodology has no universal definition. One often proposed definition is the Global Water Partnership's (GWP) which states [4]: “IWRM is a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.” The way this coordinated development has to be applied gave rise to a large number of different interpretations [5]. It has also been further argued that the gap between theory and practice remains extensive and that the real benefits of IWRM are still to be demonstrated [6].

Thus, integrated water resources management approach still needs contributions towards the definition of its framework. It is believed that a holistic approach, which would interpret the GWP's “water, land and related resources” in its broadest way, including any social, economic and ecological water-related issue (such as health, education, equity, energy, virtual water, etc.) may provide such a framework. Although each of these issues, taken separately, are well documented (see for instance Niemczynowicz [7], Gleick [8], Zehnder et al. [9], Falkenmark et al. [10]), it appears difficult to apprehend the system as a whole, with all its interrelations. This paper advocates the importance of such a systemic view, as a basis towards a holistic framework for IWRM.

The hereafter describe systemic view is presented as follows : after a short initial section explaining the used methodology (chap. II), it inventories the directly or indirectly related water issues, and infers the related components (chap. III), in order to sketch them into the general system picture (annex I). The last section (chap. IV) summarizes the results and draws the conclusions.

II. Methodology

1. *Inventorying issues*

In order to inventory exhaustively the water-related system, the selected methodology consists in a top-bottom, issues-components approach, starting by the inventory of the water-related issues. A broad literature review provides a reliable exhaustive listing of these issues.

> *Issues here are to be understood in a general way. They embody different stakeholders' various needs, such as freshwater demand and flood protection, as well as ecosystem requirements. They also include governance and management issues, such as water pricing or stakeholder participation rules. Finally, they also*

inventory issues beyond the strict field of water, but with a relation to it, such as health and tenure rights problems, or the state of electric infrastructure.

2. Inferring the components

While issues are no concrete objects, they however correspond to real components which are their physical response. In the literature, the components related to a given issue are mostly mentioned. Components and issues anyway very often directly relate to each other. For instance, the "safe water" issue directly relates to the water resource and to some kind of water supply system infrastructure. Therefore, combining literature information and basic analysis provide the inventory of components related to the issues defined in the previous step.

Components are concrete objects. They are here classified in two categories: physical environment elements (such as surface water, sanitation networks, or dams) and cultural environment (like framework for building capacities, water rights and knowledge database).

3. Sketching the system model

Once components are inventoried, the last step consists in organizing them in a clear and logical way, into the system model. As a very important addition, the relationships -structural or functional- must be shown between components during this process. The methodology to achieve this is a mental exercise of abstraction. The results of such achievements can always be controverted, as there is no unique solution. Different organizations, classifications and generalizations can indeed be imagined, along with different levels of details.

The solution pursued here is a versatile system model, which could be used as a basis for further development, including the relations to be taken into account between elements. It is meant to enable the addition of further levels of details and possible new components and new relations. It is also meant to provide a general picture to better apprehend the global functioning and the interrelations of the water-related system.

III. Issues, components and system

1. Background

Since the first UN conference on water, held in Mar del Plata in 1977, water issues have been evolving, gaining more political focus, and are better scientifically documented. Briefly, these processes can be illustrated by a few important selected milestones :

- 1981, First Water Decade : Launched a first decade of actions, focusing on safe water and sanitation for everybody by 1990. Although reaching these objectives obviously failed, the decade however enlightened issues and obstacles.
- 1987, Bruntland Report : Stated the well-known definition for sustainable development: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." [11].
- 1992, UN Conference on Environment and Development, Rio de Janeiro : Established the Agenda 21, a guide for sustainable development into the 21st century. This agenda mentions the importance of an integrated water management approach [12].

- 1992, International Conference on Water and the Environment, Dublin : Issued four guiding principles regarding water, recognizing (i) its importance as a finite and vulnerable resource, essential to sustain life, development and the environment, (ii) that its management should be based on participatory approaches, (iii) the importance of women's role (iv) it as an economic good in all its competing uses [13].
- 1997, Kyoto Conference on Climate Change : Issued the Kyoto Protocol, aiming the reduction greenhouse gases.
- 2000, Millennium Development Goals : Stated eight major goals for the year 2015 horizon, including poverty reduction, health improvements and sustainable development targets.
- 2002, World Summit on Sustainable Development, Johannesburg : Added a target to the Millennium Development Goals for halving the number of people without safe access to drinking water. Also included a commitment for the development of integrated water management by 2005 [14].
- 2005, Water for Life Decade : Launched a decade of actions to promote efforts in the field of water, targeting the horizon 2015.
- 2005, 13th Commission on Sustainable Development : Called for an integrated management of water, sanitation and human settlements, incorporating "...land-use, housing, water supply and sanitation, waste management, energy, employment and income-generation, education and health care services, transportation and other infrastructure...", which would improve their synergy [15].
- 2006, 4th World Water Forum, Mexico : Published a range of up-to-date guidelines regarding water issues and reaffirmed previous commitments, starting its ministerial declaration with: "Reaffirm the critical importance of water, especially freshwater, for all aspects on sustainable development, including poverty and hunger eradication, water-related disaster reduction, health, agricultural and rural development, hydropower, food security, gender equality, as well as the achievement of environmental sustainability and protection." [16].

Thus, at the beginning of year 2007, many water-related success and failure stories are available, on the base of which new guidelines were promoted. As milestones above clearly show, integrated water management is now a recognized approach.

Along the way, the many water-related issues have been better understood. These issues are described in a host of details in many reports (mentioned in issues' sections), including sometimes evidence of their impacts or dependencies on other issues.

2. *Resulting system model*

Although the water management system model sketch is the final product of the present study, it was decided to unveil it from the beginning, as it will be used as a reference for the following detailed descriptions regarding the issue, components and interrelations.

As mentioned earlier, sketching a system model is a mental exercise in which the elements involved have to be organized and linked. There are many different norms for the representation, and there are many possible results, depending on conceptual choices. The system model achieved by the end of this study aims to be a general representation, therefore offering a global view, which can be integrated into one picture. Thus, it doesn't go to the lower levels of details. Nevertheless, it is seen as a versatile tool which could also serve as a basis to support increased

details. It is also seen as a reference base for the possible development of decision support systems or tools alike.

As for the representation norm, the language used as a base is SysML (which stands for systems modelling language). This is a language used especially for systems representation and description. It was developed on the base of UML (unified modelling language), which is rather oriented towards software development purposes.

Annex 1 shows the developed system model(as subsequent descriptions will systematically refer to this document, and as its large format doesn't fit to screen viewing, it might prove useful to print it out in A3 format and have it handy before proceeding). In this drawing :

- Rectangular blocks are components (concrete objects)
- Arrows terminated with a diamonds indicate a composition relation (a relation in which n objects of a kind are sub-components of only one hierarchically upper component)
- Arrows terminated by a triangle indicate a functional relation, whose nature is documented by one or a few keywords, and a reference to text descriptions (for instance A12 refers to point 12 of issue A). References in normal text are more documented than those in italic. If the relation is bidirectional, keywords for both directions are separated by line symbols (----------).
- The large background rectangle outlines the water-specific domain

In the model, components' blocks are organized in two groups: cultural environment (on the left) and physical environment. All components are part of one of these two groups.

The next section describes in more details the system, from the point of view of the issues, their related components, and the way they interact with other elements within or without the specific field of water.

3. Detailing the water system: issues, components and relations

The system model is described in this section from seven general main issue's perspectives, or entry points :

- Safe water and sanitation
- Water for food production activities
- Water for industry, energy and transport
- Water for recreational, amenity and spiritual purposes
- Aquatic ecosystems : benefits and pressures
- Water-related events and hazards
- Managing and sharing water

This division is arbitrary, as it appeared a logical possible partition. But other perspectives could have been chosen, such as: “Water supply for domestic, industrial and agricultural purposes”. This is why it is all about “perspectives” or “entry points”, as actually, the system contains a host of detailed issues, inventoried below as interrelations between components (e.g. effects of water supply on people's poverty, or ecosystem policies to protect aquatic systems). Some of these detailed issues apply to all or several perspectives (for instance, planning activities of the

decision-making team), whereas other are very specific (for instance, salinization due to waterlogging).

Anyway, this detailed list of issues, below, is an attempt to be as exhaustive as possible. General issues' descriptions are thus followed by detailed interrelations issues, and by the main related components of the physical environment inventoried. Indeed, the cultural environment acts as an always present general background, even if some of its components play a more important role for specific issues (as described in the respective interrelations). Only “main” components are listed, while (as the system model picture shows), they are all linked to each other, directly or indirectly.

A) Safe water and sanitation

Issue description:

Access to safe water: Access to freshwater is required for people, for their households and the public buildings. It is necessary for consumption and hygiene purposes, in relevant quantities and qualities.

A widely spread definition, provided by the UN-Habitat's State of the World's Cities on the base of the WHO/UNICEF Joint Monitoring Programme for Water and Sanitation for “improved water supply” is as follow: “The water should be affordable and at sufficient quantity that is available without excessive effort and time”. This further defines that 20 litres per person per day be available within one kilometre of the residence, from a source “protected from external contamination, including piped household connection, public standpipes, boreholes, hand-dug wells, springs and rainwater collection” [17][18].

Access to safe basic sanitation: Access to safe basic sanitation is necessary for people, as a fundamental hygienic, privacy and convenience need.

The definition given by the UN-Habitat for a household having access to “improved sanitation” is as follow: “it has a human excreta disposal system, either in the form of a private toilet or a public toilet shared by a maximum of two households. In urban areas, access to improved sanitation is defined by direct connection to a public, piped sewer; direct connection to a septic system; or access to pourflush latrines or ventilated improved pit latrines, allowing for acceptable local technologies.” [18].

Although United Nations statistics report that 95 % of the world's urban population benefits such improved water access, this includes many low or middle income levels countries' data, which claim very good or perfect (100 %) performances, although significant part of their population live in slums, and that water-related diseases are important. As for sanitation, statistics estimate that 2.6 million people lack access to improved sanitation, which is far behind access to water [18].

One of the 7th MDG's (ensure environmental sustainability) target (10th target) is to “halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation”. According to the Millennium Development Goals Report 2006, in 2004, about 80 percent of the world's population has access to drinking water from improved sources, up from 71 percent back in 1990 [19]. Again, this is an aggregated value which should be considered with caution. Another UN report, the Human Development Report 2006 mentions for instance that “Today, some 1.1 billion people in developing countries have inadequate access to water” [20]. As for sanitation, The Millennium Development Goals Report 2006 is pessimistic about the

probabilities of success, as they state that now about half the population (up from 35 percent in 1990) of the developing world is lacking basic sanitation [19].

A point which is emphasized by the UN-Habitat report on the state of the world's cities is the disparities that may exist between urban and rural world (respectively 95 and 72 % of access rate to safe water), inside a given city (especially in low and middle income countries with slums), in the consumption rates of water between rich and poor nations (from 60-150 to 500-800 litres per capita per day) and in the investments done in water and sanitation (for 1$ invested in the former, 20 cents go to the latter) [18].

Interrelations involved :

A1. Human health : The Task Force on Water and Sanitation reports that "Safe drinking water and basic sanitation help prevent water-related diseases, including diarrhoeal diseases, schistosomiasis, filariasis, trachoma, and helminthes. 1.6 million deaths per year are attributed to unsafe water, poor sanitation, and lack of hygiene." [21]. Even if sanitation is often not the first priority (safe water comes generally first) for people lacking these services, it is demonstrated that its effect on health are more important, though [18].

Regarding more specifically the 4th Goal of the MDG (Reduce Child Mortality), again, inadequate access to water and sanitation is one factor that accounts for the vast majority of the 1.8 million child deaths each year [20].

A2. Poverty : Most of the indicators of poverty are based partially on the quality of access to safe water and basic sanitation [21]. The link between these issues is indeed important. Inadequate access to safe water and sanitation causes health problems (see point above), and health problems involve in turn productivity losses, and medication costs. Productivity losses are also due to the time spent collecting water, or finding a suitable place and time to defecate, or queuing for collective toilets.

This is numbered to 2 % of GDP of developing countries, rising up to 5 % in Sub-Saharan Africa [20]. In terms of costs-benefits, a study of the World Health Organization found that all water and sanitation investments would prove beneficial; in developing countries, the return on 1$ was estimated to 5-28$ by achieving the 7th MDG's related target (halve the proportion of people without sustainable access to safe drinking water and basic sanitation) [22]

More generally, it can be stated that economic development is heavily dependent on the infrastructure and services conditions, including water supply, waste management, transport, communications and energy supply [23].

A3. Gender inequalities : When improved access to safe water and sanitation is not achieved, women and girls are touched more heavily. It is generally the women and girls who bear the brunt of collecting water from distant sources, often spending more than 4 hours a day for this. Furthermore, women are those responsible of taking care of ill children; illnesses often due to bad water and sanitation conditions [20]. Concerning sanitation, women -for anatomic, modesty and susceptibility to sexual harassments reasons- are those who usually use the toilets, while men and children relieve themselves in the open. This means sometimes much time spent queuing. If women have to go to the open, then, they may wait until it is dark.[18].

A4. Education : As mentioned above, whenever water is lacking, girls are often obliged to spend most of their time collecting it, which keeps them out of school. This inequality is further reinforced when schools are not equipped with water and sanitation facilities. More generally, water-related diseases cost 443 million school days each year [20].

A5. Tenure access : Although this is not direct, it is recognized that "*S*lum and squatter upgrading programmes are the principal means by which water and sanitation provision is improved for lower-income groups in most cities in low and middle income nations" [24]. Indeed, in slums with no land-use legitimacy, with no street names and official addresses, people feel too insecure to invest in the improvement of their homes. Therefore, it may prove useless to equip such location with latest water supply and sanitation systems, because people may not wish to invest to establish the connexion. Furthermore, billing may also prove very difficult with clients without legal address, which will prevent companies to invest.

A6. Funding and housing support : If conditions of water supply and sanitation effect on the economy and have indeed a crucial role to play in the fight against poverty, oppositely, funding resources are also obviously an important factor for the state, development and maintenance of water-related infrastructure.

More specific financial instruments may also prove crucial to improve the situation in slums. An approach is for instance the channelling of subsidies directly to low-income communities, which can then plan and manage the improvements. Micro-credits to support tenure access and housing improvements can also play an important role, as suggested in the "tenure access" point.

A7. Decentralization : Regarding authorities, the report of UN-Habitat called "Sustainable Urbanisation" underlined the fact that lacking local planning, management and urban governance was a bottleneck for sustainable urban development [23].

In 2006, the UN-Habitat's "State of the Worlds' Cities" mentions the success of most decentralization (or bottom-up) processes, adding though that in many countries, best results are attained with strong support from the centre. Going even further than local empowerment and community, countries such as Brazil, introduced "participatory budgeting", allowing community-led city councils to decide on part of budget allocation. In Belo Horizonte, half of the budget was allocated this way. In Porto Alegre, this went along -since 1989- with an improvement of access to municipal sewer network, from 46 to 84 percent. Decentralization also seems to bring a positive impact on slum growth control. On the other hand, it also appears that in some countries, top-down (centralized) planning and implementation played a key role for slum upgrading projects, as it provided clear purpose, effective coordination and the necessary capacities [18].

These elements illustrate briefly the difficulty, and also the importance, of properly distributing means and decisions at the different authorities' levels.

Regarding individuals with respect to this problematic, the chapter related to governance issues of the 2nd World Water Development Report also states that: "People's participation in and access to relevant water information are essential preconditions for successful decentralization" (Water and Settlements, chap.2 in the 2nd World Water Assessment Programme, 2006). Even not considering decentralization, the same recommendations were already given by the agenda 21, which pledged for each individual access to environmental information and the opportunity to take part in the decision making process [12].

A8. Standards : If water quality, or sanitation standards are too low, they may leave people at health risk. But if they are too high, they may be difficult to enforce, won't stimulate improvements and may exclude people with less means to apply them [24].

A9. People as a resource : If specialists and capacity building are recognized approaches, it has been also demonstrated that people as well can sometimes be accounted as a resource, with effect of lowering costs of achievements. A quite well-known example of such a successful approach -whose model was then applied in other locations- is the Orangi Pilot Project, which supports community-managed improvements, including the

construction of a sewer system for the largest informal settlement of Karachi (Pakistan). This community-based process allowed to reduce by five the cost of sewer provision, compared to what the municipality charged, as inhabitants took the responsibility of installing and maintaining the pipes, sewers and drains in their neighbourhood. Municipality had on its side to provide larger facilities, such as trunk collectors and wastewater treatment [25][24].

More specifically, employment rate is a factor that can be taken into account, for instance to favour interventions providing more jobs.

A10. Water withdrawal : Of course, the infrastructure retrieves freshwater (or saline water, in case of desalination process) from one or more of the water system's elements, on which it may impact more or less heavily: directly from rainwater, from groundwater, from surface water or marine water. Conversely, infrastructure is heavily dependent upon the characteristics -quantity and quality- of the water system's elements.

A11. Storage : Supplying water may imply usage of reservoirs (from small scale elements to large dams) to store water. Large dams present examples of projects with possible positive and negative impacts. They may provide several positive effects for people and economy (including water provision, recreational uses and flood protection), but may also have severe impacts on ecosystems and people (displacements, increase of water-borne diseases, land losses by submersion) (see also respective topics below).

A12. Domestic and public buildings : They are the physical locations, such as households and schools, which require a safe access to water and sanitation facilities.

A13. Water rights : In their General Comment No.15 of November 2002, the United Nations' Committee on Economic Social and Cultural Rights declared: “Water is a limited natural resource and a public good fundamental for life and health. The human right to water is indispensable for leading a life in human dignity. It is a prerequisite for the realization of other human rights.” [26]. This declaration, along with possible national legislations, aims at enforcing the eradication of discrimination in basic provision of water, hence enhancing equity for people.

A14. Water management and (land-use) planning : see “Managing and sharing water“ issue and also “Aquatic ecosystems : benefits and pressures“ (users' impacts on each other).

A15. Wastewater, reuse and energy : See “Water for industry, energy and transport“ issue's related points.

A16. Influence on the ecosystem : see “Aquatic ecosystems : benefits and pressures“ issue.

Main physical components involved :

- Domestic water supply and sanitation infrastructure (infrastructures)
- Domestic and public building, fountain, garden, park & sport field, swimming pool and spa (consumers)
- Water (resource)
- Water system, including sub-elements: Aquatic fauna and flora, watershed, and water compartments: wetland, lake, river and stream, precipitation, snow and ice, groundwater, coastal water and marine water (aquatic ecosystems)
- People (health, equity, gender, poverty, manpower)
- Funds (resource)

- Storage and regulation infrastructure (reservoirs)
- Energy (for operation)
- Water supply and removal infrastructures (reuses)

B) Water for food production activities

Issue description :

People need food. In agriculture, food production requires water, and thus irrigation may enhance productivity. Aquacultures and capture fisheries also produce food, and also require water. Both depend upon quantity and quality of water, but in different ways.

The challenge faced by the agriculture in general can be summarized as follow : "producing more food of better quality while using less water per unit of output; providing rural people with resources and opportunities to live a healthy and productive life; applying clean technologies that ensure environmental sustainability; and contributing in a productive way to the local and national economy" [27].

Regarding water consumption [27], globally, agriculture relies on rainfall provision (so-called green water) for 90 percent, as irrigation (blue water) covers the remaining 10 percent. However, this 10 percent represents 70 percent of the water used for human consumption. Expressed in terms of individual consumption amounts, following uses require :

- Drinking water intake : 2-3 litres/person/day
- Hygiene : 30-300 litres/person/day
- Agriculture : 2000-5000 litres/person/day (green and blue water)

But agriculture products are sometimes used consequently for production of livestock. Obviously, the final quantity of water required for the production of 1 kilo of meat is then much higher than for 1 kilo of wheat. This principle is called "virtual water". It means the total water consumption for an industrial, agricultural, etc. good production. Thus, virtual water for 1 kilo of the following products are [27]:

- Wheat : 1-2 m3
- Cheese : 5 m3
- Beef : 16 m3

Irrigated land represents 18 percent of total croplands, which are themselves 12 percent of world's total land area (27 percent are used for pasture). In terms of land used per capita, this means 0.25 ha. This value was equal to 0.45 ha back in 1960. Indeed, intensification of agriculture between 1960 and 2000 allowed to feed more than the double of population while croplands' area was just increasing by a few percent. Obviously, land productivity is not equally distributed, and there are already countries (like Egypt and Jordan) where water is scarce and where it is not possible to produce enough food for domestic demand [27].

In opposition to water scarcity, waterlogging (excess water) may also be an issue for food production. Excess water in crop root zones generate oxygen lacks that lead to diminution of production, and eventually (for long exposures) to plants death. In such cases, the implementation of an artificial drainage system may eliminate the excess water and therefore improve crop yields. Drainage infrastructure may also help managing salt concentrations in cases of salinization due to waterlogging [28].

In the future, food demand is going to increase (55 percent increase estimated by 2030) [27]. As extending croplands is difficult, further intensification will be necessary to provide food of good quality in sufficient quantities for everyone. As irrigation already claims 70 percent of the human consumption of water, the way water will be used in agriculture will play a crucial role.

Whereas agriculture doesn't only produce food, food is also produced by aquaculture and capture fishing. While the latter didn't show much increase since 1990s, the former did, especially in China [27]. Whereas capture fish is attaining its full production potential, aquaculture provides a way to further increase fish production. In opposition to agriculture, aquaculture is not a significant water consumer, as the water returns to the system [29].

Interrelations involved :

B1. Hunger and poverty : At present, about 13 percent of the world's population lack food. 15000 Children under the age of five die each day because of malnutrition [27]. In urban areas, hunger is a consequence of poverty, as poor people lack the means to buy food. This is also true in rural areas, but in this case, hunger is also caused by climatic reasons, and in particular droughts, which cause local deficits of productions [18]. Conversely, hunger, as a health issue, also contributes to poverty and education deficits (inability to attend school, jobs, and medication costs, see also related point in "Safe water and sanitation" issue).

Thus, in rural areas, aquaculture and irrigation nonetheless provide a direct way to increase productivity, and consequently fight against hunger and poverty, but may also indirectly support rural livelihood -by the provision of secure access to food (and also to water in the case of irrigation)- through health improvement, employment increase and possibly through emigration reduction to cities (or even immigration).

Aquaculture and irrigation may also have negative effects, that should be addressed in order to minimize them: impacts on the environment (see related point in "Aquatic ecosystems : benefits and pressures" issue), increase of water-borne infections, more inequalities (see below) and increase in land prices [27][18].

B2. Decentralization and participatory approach framework, tenure and water rights, gender and inequalities : For the specific aspect of irrigation, "decentralization and the devolution of authority to the local level may enhance political participation and accountability. Whether that reduces inequality depends on whether disparities in access to land, water and power are addressed" [20]. Indeed, handing to communities the power to manage their irrigation system may still leave place for disparities. It appears that old power relations still prevail, that friendship and possibly bribery may lead to inequalities. As for women, they sometimes don't have access to land tenure and their membership to committees are therefore denied. Furthermore, in many communities, water rights depend on contribution to maintenance of the system, but cultural norms may prevent women from working in this activity [20].

In aquaculture, the issue is very parallel. The prerequisites for development are the access to land and water. In some regions, this may exclude people without such accesses, especially women and the poorest [29].

B3. Trading virtual water : As stated earlier, irrigation is a big water consumer. In regions where water is scarce, therefore, other strategies can be envisioned for food provision. In that view, the concept of virtual water -explained in the introduction to this issue- is useful. Indeed, it was stated that the production of one kilo of beef requires 8 to 16 times more water than wheat production. On that base, a state (or within a state, a region with regard to other regions) could export products with high virtual water contents, whereas for water scarcity conditions, water could be used for products of low-level of virtual

water content, and import for instance meat. However, trade analysis show that other factors drive international food circulation, except for some countries facing water scarcity (Egypt, Tunisia, etc.) which tend to increase their dependencies upon staple food [27].

B4. Consumptions patterns : Meat requires more water than wheat for its production. Then, the importance of consumptions habits is straightforward for water requirements. For example, the shift from bovine meat to poultry -which is now more eaten than the former in the world- has stemmed a change in the water demand, compared to the projections, for water required in irrigation [27].

B5. Biotechnology framework : The impact of this technology is still uncertain. It may enhance food productivity and address issues such as resistance to difficult conditions (drought or salinization), although this is still under research. In opposition to traditional biotechnological techniques, genetically modified organisms (GMOs) are subject to controversy [27].

B6. Agriculture and aquaculture areas : Agriculture areas are locations where irrigation and drainage may enhance production. Aquaculture also requires water supply.

B7. Storage : see “Safe water and sanitation“ issue's related point.

B8. Influence on the ecosystem : see “Aquatic ecosystems : benefits and pressures“ issue.

B9. Water management and (land-use) planning : see “Managing and sharing water“ issue and also “Aquatic ecosystems : benefits and pressures“ (users' impacts on each other).

B10. Wastewater reuse, standards and energy : See “Water for industry, energy and transport“ issue's related points.

Main physical components involved:

- Water (resource)
- Water system, including sub-elements: Aquatic fauna and flora, watershed, and water compartments: wetland, lake, river and stream, precipitation, snow and ice, groundwater, coastal water and marine water (aquatic ecosystems)
- Aquaculture and Irrigation infrastructure , drainage infrastructure (infrastructures)
- Agriculture and aquaculture areas (users)
- Energy (for operation)
- Pier, harbour & fisheries, fishing zone (fish & sea food production)
- Water supply and removal infrastructures (reuses)
- People (hunger and health, equity, gender, poverty, manpower)
- Funds (production, resource)
- Storage and regulation infrastructure (reservoirs)
- Food & goods (resource, virtual water)

C) Water for industry, energy and transport

Issue description :

People need water in industrial activities, which provide them with jobs opportunities and produce goods and services. Energy production is a special case, of particular importance. Transportation, actually do not use the water as an element of production, but rather make use of waterways. Dredging, even more indirectly, makes use of sediments carried in water, and thus has an impact on water systems.

Industry uses water in very different ways : constituent part of of the product (like beverages), for cleaning, heating, cooling, to generate steam, to transport dissolved substances and particles, as a raw material, as a solvent. Obviously, water quality requirements are quite different in these different processes. For instance, in cooling, good quality is not required, whereas pharmaceutical industry often requires very high quality. Another important feature of industry as a water user, is that the water that is actually consumed is generally much less than what is withdrawn. For instance, when water is used as a cooling agent, almost no water may be consumed, although large quantities may be withdrawn. It is returned to the system, but it is warmer than before [30].

Energy is also a product requiring water. It requires water for its production, either for cooling, in nuclear and coal power plants for instance, or more directly for turbine motion in hydropower. As an energy source, hydropower was accounted in 2002 for 19 percent of all electric power generated in the world. There are different types of hydropower, including reservoirs (dams are multi-purpose and are often also used in parallel for water supply purposes; only 25 percent of the large dams are involved in hydropower production) and run-of-river. The former provide the flexibility to process energy during peak periods. The latest generally involves small or no reservoir, and is seen as having better social and environmental impacts, as dams [31].

Access to electricity lags far behind the access to safe water. In 2002, they were 1.6 billion without electricity, and World Energy Outlook's previsions for 2030 state a small reduction, down to 1.4 billion. In the same period, people cooking and heating with traditional biomass in an unsustainable way will rise from 2.4 billions to 2.6 billions [32].

Another industrial activity which has a special connexion with water is the water transport. In that case, water is not used directly, but waterways, with proper topographic and geometric characteristics to enable ships' circulation. In Europe, 35000 kilometres of waterways connect hundreds of cities and industrial regions. In 2003, 125 billion tons-kilometres of freight were transported on them. Many cities developed also due to their position as water transport hubs : Paris, London, Shanghai, San Francisco and Rotterdam for instance. Where potential exist, developing inland water transport may prove a very cost-effective, as well as a more environmental friendly possibility (energy consumption is half what is needed for the rail, and one-sixth of what is need for the road, in terms of tons-kilometres) [33].

Interrelations involved :

C1. Water and energy, Watergy™: If water is required in the process of producing electricity, conversely, large amounts of electricity are necessary for water, for operating pumps, in supply and wastewater removal systems. The alliance to save energy, estimates this to around 7 percent as part of the world's energy consumption [34]. Water and energy are thus strongly linked, and improvement measures shall consider both inputs linked, and not separately. This is what the alliance proposes to call the "Watergy™" principle. Indeed, in the case of a dishwasher for instance, the device requires more energy than hand washing, but it may use less water, depending on its efficiency. Finally, the general Watergy™ efficiency of the dishwasher may prove better than hand washing. Conversely, there are cases in which improving irrigation techniques

to save water may require a lot more energy, and finally, the Watergy^{TM} efficiency may be less than before improvements [31].

Saving water may therefore sometimes begin with indirect measures, such as improving pumps efficiency (pumps are big energy consumers). This may save energy, and, consequently, save water in hydropower plants, or in cooling systems of other kinds of power plants.

Regarding the population, as energy consumers, habits of saving energy may also mean saving water.

C2. Economy and poverty : Although electricity access improvement is not part of the Millennium Development Goals, its indirect role to improve situations has been underlined. For instance, the world summit on sustainable development stated :

"Take joint actions and improve efforts to work together at all levels to improve access to reliable and affordable energy services for sustainable development sufficient to facilitate the achievement of the Millennium development goals, including the goal of halving the proportion of people in poverty by 2015, and as a means to generate other important services that mitigate poverty, bearing in mind that access to energy facilitates the eradication of poverty." [14].

The way electricity levers on poverty is well expressed by the International Hydropower Association (IHA), by the following mechanisms [35]:

- providing relatively cheap and reliable electricity
- energizing industrial processes and commercial activities providing employment opportunities and revenues
- increasing productivity by extending productive time beyond dusk through lighting
- improving productivity by powering more efficient electrical appliances
- facilitating water pumping for adequate drinking water
- enhancing food security through powering irrigation systems
- assisting national development, thereby improving GDP

Access to electricity is thus a prerequisite to operate many systems, and in particular water-related systems. Conversely, hydropower, especially small hydropower plants (SHP), can provide access to electricity in remote communities, in an environmental friendly way, bringing also other social benefits such as jobs opportunities. The 2nd World Water Report's chapter on industry and energy, on the base of the INSHP's (International Networking on Small Hydropower) website indicates that in China, 30 percent of the hydropower is produced by SHP plants; in rural areas, it allowed to improve access to electricity grids. In 2000, 28 million people had no access. In 2002 this figure had dropped to 10.15 million [36][31].

More generally, industrial activities (including water transport and dredging) provide jobs and goods, and as such, they play a crucial role for the economy, and therefore, in the fight against poverty.

C3. People's influence as consumers : Another way people are involved in this issue is trough the pressure they may exert as clients upon the producers, to require from them more eco-awareness. Companies may thus retrieve benefits from their commitments towards social and environmental issues, as they will be favoured by customers. This

principle stemmed certification such as eco-labels or ISO 14001 for instance, which provides environmental management standards [30].

C4. Virtual water : The virtual water principle, discussed in “Water for food production activities” related point, is also true for industrial production : where water is scarce, such industrial sectors shall be fostered, which require little water, while importing industrial products embedding more virtual water; and vice-versa.

C5. Wastewater reuse, standards : Around cities, as an industrial or domestic output, wastewater can be a stable and valuable source of water. Water reuse might occur directly, or after treatment (reclaimed water).

As stated earlier, quality needs depend upon the use of water. For irrigation purposes, wastewater with high nutrient contents, may be usable directly. However, depending on the quality of the wastewater, this can pose risks to human health, for instance by consuming food with high contents in heavy metals. For instance, in Israel, 84 percent of the sewage is reused in agriculture irrigation, after treatment. As for industries, they may find opportunities of reusing their wastewater, either directly or after treatment, in processes requiring water of lesser quality (e.g. for heating / cooling uses). Industrial effluents also sometimes contain valuable resources, which can be recovered and traded. Less directly, synergies may be found between different industries, which could adequately use each other's wastewater. Domestic applications are also numerous : they include fire fighting, toilets flushing, car washing, garden watering, etc. Another possible use of reclaimed water is to aquifer recharge, to avoid saline intrusions, or simply to balance depletions. There are also even cases of wastewater treated to very high standards, and then reused for supplying potable water, as in Namibia's capital, Windhoek [30].

If industrial wastewater and by-products may contain valuable products that can be recovered, there are also many discussions about recycling domestic urine, in order to recover their valuable contents, such as nitrogen nutrients.

The city of St.-Petersburg, Florida, US, is the first city in the world that reached the ideal target of zero effluent discharge, thus releasing no wastewater into its surroundings. To achieve this, the city laid a dual-reticulation network (to convey freshwater and reclaimed water). Reclaimed water is used especially for irrigation and industrial cooling applications, which account for half the municipalities' needs [30].

As mentioned in the point about “relations between energy and water”, Watergy™ efficiency of such reuse systems shall be thoroughly examined. Indeed, treatments of wastewater may require considerable quantities of energy, which could possibly lead to decreases in total Watergy™ efficiency, even if water consumption is lessened and water productivity increased.

Standards and water reuse policies play here a crucial role, for fostering or discouraging reuse. Standards have to prevent risks for human health, but requiring full treatment may prove to expensive to achieve and would then prevent wastewater reuse, thus losing this possibly valuable alternative.

C6. Hydropower plants : As stated earlier, hydropower plants provide hydropower through installations of different sizes from small-scale installations on the river without reservoir, up to large dams.

C7. Storage : see “Safe water and sanitation“ issue's related point.

C8. Influence on the ecosystem : see “Aquatic ecosystems : benefits and pressures“ issue.

C9. Water management and (land-use) planning : see “Managing and sharing water“ issue and also “Aquatic ecosystems : benefits and pressures“ (users' impacts on each other).

Main physical components involved:

- Water (resource and "product" (treatment, transport, etc.))
- Energy (resource and product)
- Water system, including sub-elements: Aquatic fauna and flora, watershed, and water compartments: wetland, lake, river and stream, precipitation, snow and ice, groundwater, coastal water and marine water (aquatic ecosystems)
- Industry water supply and sanitation infrastructure, locks and transportation-related works (infrastructures)
- Water supply and removal infrastructures (reuses)
- Industry, hydropower plant, navigable zone, dredging / mining platform (users)
- People (jobs, well-being, poverty, manpower)
- Funds (production, resource)
- Storage and regulation infrastructure (reservoirs)
- Food & goods (virtual water)

D) Water for recreational, amenity and spiritual purposes

Issue description :

People require water for their recreational activities. Although often overlooked, as it might not be considered a first priority, this issue is important for the social life and also for economic purposes, through tourism activities. Water may also play a role for amenity purposes and in spiritual contexts.

According to the Vision on Water and Nature [37], a report of the World Conservation Union, adapting deGroot's work [38], generally, ecosystems may provide "information functions", defined as "providing opportunities for reflection, spiritual enrichment and cognitive development". Such information functions may be further classified as follow :

- Aesthetic information (sceneries)
- Recreation and (eco-)tourism
- Cultural and artistic inspiration
- Spiritual and historic information
- Scientific educational information

Aquatic environments are ecosystems, and may therefore provide such functions. Uses include popular activities [39] :

- Water sports : bathing, swimming, sport fishing
- Navigation : sport boating and yachting
- Winter sports : skiing, skating

- Sight seeing (hiking, camping, etc.)

Beyond ecosystems, water also plays similar roles, -or more indirectly, is required for watering-, trough infrastructures including : swimming pools and spas, fountains ("since ancient times fountains have been seen as desirable components of city architecture, creating a feeling of quality of life and well-being" [40]), gardens, parks, religious buildings (Mosques are built around a spring, Hindu temples have tanks for ablutions, Christian churches use water in baptising, and as holy water [40]), sports fields (including golf courses).

Interrelations involved :

D1. Land-use planning : Maintaining recreational, amenity and spiritual water-related zones, usually not regarded a first priority, is thus highly dependent upon its strategic management through land-use planning framework. In rural areas, such zones need to be protected in order to keep their intrinsic value. In urban areas, they can be created, through the construction of parks, fountains, piers, etc.

In an article about the water 'in' and 'around' the building, G. Peretti et al. underline the general disappearance of the water from the image of the city, "losing its meaning as an aesthetic and a symbolic element". They mention for instance the case of a building in Venice which allows tides to flow in and out.

D2. People' benefits : Recreational, amenity and spiritual water-related zones (fishing, boating, bathing, etc.) of course generate well-being. In urban areas, fountains, spas, swimming pools, garden, parks, sport fields, piers and religious-building also serve well-being. This includes also educational aspects, through architectural elements (fountains, spas), or the implementation of information panels (didactic paths).

Other elements, whose primary purpose is usually not recreation may also provide well-being. Dams often serve multi-purpose uses, including provision of well-being (recreation, scenery, visits of the equipments). This is also true for reservoirs, at a smaller scale (See also "Safe water and sanitation" issue's related point). Dykes, locks, hydropower plants, retention basins may also prove interesting educational equipments. Harbour may prove to be attractive walking locations. Etc.

D3. Tourism : Tourism to enjoy the well-being provided by recreational, amenity and spiritual areas is a sector prone to providing funds. People can come from far away to enjoy natural locations, such as waterfalls, national parks, beaches. In cities, water may also play a role in the tourism attraction, like the channels of Venice or Amsterdam, the Trevi fountain in Rome, or Spas in Budapest fort instance.

D4. Standards : In order to protect human health, standards are important, for instance to allow or restrict bathing in given locations.

D5. Influence on the ecosystem : see "Aquatic ecosystems : benefits and pressures" issue.

D6. Water management and (land-use) planning see "Managing and sharing water" issue and also "Aquatic ecosystems : benefits and pressures" (users' impacts on each other).

Main physical components involved :

- Water (element)

- Water system, including sub-elements : Aquatic fauna and flora, watershed, and water compartments: wetland, lake, river and stream, precipitation, snow and ice, groundwater, coastal water and marine water (aquatic ecosystems and recreational environments)
- Water-related objects (potential providers of well-being), especially : recreational zone, fishing zone, navigable zone, protected aquatic area, fountains, garden, park, sport field, swimming pool, spa, pier and dams.
- People (well-being)
- Funds (tourism, resource)

E) Aquatic ecosystems : benefits and pressures

Issue description :

Aquatic ecosystems are required by animal and vegetarian species as habitats. They provide goods and services, needed for socio-economic activities, and they may play a role in risk protection. Conversely, these activities put aquatic ecosystems under pressure, sometimes endangering or even destroying them, along with their animal and vegetarian populations, and thus also along with their goods and services.

As stated by the UNEP, “Aquatic ecosystems refer not only to coastal waters, rivers and lakes, but also to a complex and interconnected system of permanent and temporary habitats, with a high degree of seasonal variation. Temporary habitats play a key role in the overall value of water ecosystems.” They further specify that “Generally speaking, the more biologically diverse an ecosystem is, the greater the range of services that can be derived from it.” [41].

Indeed, as stated in previous issues descriptions, water, in its different occurrences, is used for very different goods and services, including domestic, agricultural and industrial supply, recreational uses, energy production, transport and protection against risks.

But these activities generate pressures. It is difficult to analyse their impacts separately, as effects are often intertwined. Furthermore, it is often difficult to provide general trends, as no universal indicators are agreed upon, and also while data is sometimes lacking, and is measured too differently. However, values provided by the Living Planet Index (developed by the UNEP's World Conservation Monitoring Centre (WCMC) and the World Wide Fund for Nature (WWF) show that freshwater vertebrate species populations have decreased by 50 percent, and marine vertebrate species populations by 35 percent, between 1970 and 2000. Other indicators, assessed by the World Conservation Union (IUCN) show similar trends, for amphibious and migrating bird species for instance. On the other hand, if many of the world's coastal and freshwater ecosystems are continuing to deteriorate, reverse trends have also been observed in some areas [41].

The aquatic system can be divided into different components, presenting different characteristics, offering benefits and submitted to pressures :

- Precipitations : About 40 percent of precipitations come from ocean-derived vapour, the other 60 percent being evaporated from lands. Precipitations can occur under the form of rain and snow, but also sleet, hail, frost or dew. They play a key role in renewing other aquatic components (surface water, groundwater and wetlands) and to supply natural systems with freshwater. In some regions, snowfall may represent an important part or even the major part of precipitation. Precipitations quantity range from 100 to 3400 mm / year, from arid to tropical countries. [42].

The water-related benefits for agriculture are direct (green water). Rainwater can also represent a source of freshwater for consumption and other activities, if harvested directly. Finally, if precipitations' quantities are important, their patterns are also crucial, if they get scarce or too intense, they may cause droughts or floods (See “Water-related events and hazards”).

Main pressures undergone by precipitations are climate change and atmospheric pollutions generating acid rains (see related points below).

- Snow and ice : About three quarters of the freshwater are under the form of ice and snow. Most of it (97 percent) is stored in polar ice sheets, the remaining part -glaciers and permanent snow and ice- being present on all continents, except in Australia.

  Snow and ice contribution to water resources is critical for many nations. As it is highly dependent upon temperatures, melting occurs during warm periods, during which stream flows could be otherwise low [42]. Snow environments may also prove relevant for tourism and some recreational purposes.

  The major threat for the water resources aspect of snow and ice environments is the climate change (see related point below).

- Surface, coastal and marine water : They encompass seas, lakes, rivers, streams and wetlands with a wide variety in types of environments, more or less water and salt saturated : estuaries, deltas and floodplains, swamps, lagoons, bogs, coral reefs, mangroves, etc. Lakes are the major reservoir of fresh surface water (they store forty times more water than rivers and streams). Wetlands area is four times greater than that for lakes, albeit water content is ten times less than for other surface waters. Continental surface water environments are recharged by direct precipitation inputs, or through flows providing from rainfall, melting snow or groundwater. They represent 0.3 percent of the earth's total freshwater resource [42].

  Surface waters, especially in their interfaced variations (estuaries, flood plains, lagoons, mangroves, coral reefs, etc.) are environments that may support a very large fauna and flora biodiversity [41].

  The water-related socio-economic benefits are many and varied : freshwater supply, fish provision, hydropower supply, flood buffering, transport, water cleaning, recreational uses, religious and spiritual purposes [41].

  The pressures acting on these environments, their fauna and flora can be divided into the following categories : drainage, increased sediments loads, pollutants emission, flow fragmentation and regulation, overuse, invasive species and water-related constructions [42][41] (see related points below).

- Groundwater : This refers to the water located beneath the ground surface. It therefore stands for soil water, contained in soil pores. Whenever this water forms a layer which can be extracted (usually through bore well pumping), it is called an aquifer. Groundwater is often strongly linked with surface water, within discharge/recharge processes. Rainfalls also provide groundwater with renewed resources.

  Groundwater is mainly used for water supply. It is usually a way to provide a relatively stable, low-cost and good-quality water, especially where other sources are not sufficient, or too variable. When groundwater is hot, it is also a natural richness which is often promoted through thermal facilities [42].

  Pressures on groundwater are especially due to over-abstraction and pollution, including salt concentrations, which may also pose problems, through salinization process. (see related points below).

Interrelations involved :

E1. The following points describe how human infrastructures may negatively impact on the aquatic ecosystem, trough operation (accidents, see “Water-related events and hazards“ issue) :

- Drainage : Drainage of wetlands and coastal zones may lead not only to structural changes involving loss of habitat and species, but also to indirect effects for the surrounding human population trough : droughts and floods (wetlands may function as buffer zones, see “Water-related events and hazards”) and sediment flow change (see below) and saline intrusions along coastlines [41]. It may also play a role in water-quality issues stemming from agriculture practices (see also “Pollution” point below), depending on how drained water is managed.

- Pollution : Pollutants reach surface and groundwater when released directly into them (domestic and industrial effluents, aquaculture operations), leached from the soil (agricultural practices, acid rains effects on soil), or deposited from the atmosphere (acid rain, direct depositions).

  - Acid rain : Some industries, including coal power plants, release sulphur and nitrogen compounds into the atmosphere. These compounds may then dissolve into droplets, which finally precipitate in acid rains [41].

    Acid precipitations acidifies surface waters, which has a negative impact on aquatic organisms. In soil, this may leach heavy metals such as aluminium, which then reach water bodies or groundwater [42].

  - Salinization : Salinization is the process of salt accumulation in soils or water. Irrigation, by bringing water to crops, tend to accelerate the accumulation of salt, after evapotransipration of the water. Similarly, waterlogging may also induce salinization. This not only may adversely affect plant growth, but may also further salinize surface and groundwaters, which may pose problems for water supply facilities [27].

  - Increased sediments loads : Sediments occur in water bodies naturally or as a result of human interventions. Main identified sources include poor agricultural practices with subsequent soil losses and deforestation, road building and construction, which generally create conditions of increased surface water runoff and sediments availability [42][41]. Also, skiing can enhance erosion and therefore increase sediments loads.

    The impacts are many. On the aquatic ecosystem, it mainly poses problems because of the increased suspended solid concentration, the diminution of light penetration, the increase of water temperature (due to increased absorbed solar energy) and the settling of the sediments. Indeed, these processes adversely affect plants, invertebrates and insects, which in turn, as food for fishes, affect fish populations. They also affect directly fishes, reduce reproduction capacities and bury and suffocate eggs[42].

    Further impacts include [42]:

    - Reduction of transport capacity through deposition of sediments and consecutive depths diminutions

    - Consequences on water supply and hydropower equipment (pump and turbines wear, new constraints)

- Deposition in reservoirs (including dams) and capacity reduction

- Thermal effects : Thermal changes are mainly due to industries, and especially power plants, using water in cooling systems. Also streams modifications can cause changes, if the water stays more in reservoirs for instance, giving it time to warm up. Temperature changes have effects on oxygen levels and organic matter degradation rates, and it may cause species populations shifts [42].

- Organic matter : Organic matters occur in water mainly by domestic and industrial wastewater release. Their degradation require oxygen, and consequently, may lower the dissolved oxygen concentration.

  Oxygen depletion may lead in turn to suffocation of aquatic life. Of course, this also may impact on uses downstream which require good quality water: aquacultures, recreational activities, fishing zones, and water supply infrastructures [42].

- Nutrients : Nutrients (i.e. nitrogen and phosphorous components) provide mainly from intensive agricultural sites where soluble fertilizers are used, from domestic and industrial wastewater, and also from aquaculture operations.

  Nutrients stimulate algal growth (eutrophication), which then decompose, using oxygen, and causing its depletion, with the same impacts as for organic matter (see above). Furthermore, nitrates in drinking water are cause of human illness [42][41].

- Pathogens and microbial contaminants : These organisms are released in water by domestic sewage release, and by livestocks. They represent a special threat for human health, causing diarrhoeas and intestinal parasitism [42].

- Heavy metals : These elements reach water mainly from industrial sources. They may also come from soil leaching, possibly due to acid rains. They accumulate in organisms' tissues, with toxic effects on both aquatic organisms and humans [42].

- Toxic organic compounds and micro-organic pollutants : This denomination include compounds such as pesticides, PCBs, endocrine disrupter, antibiotics, etc., which have often acute toxic effects on aquatic organisms and humans. Their sources are many, including : industry, agriculture, personal care products, solid waste leaching [42].

- Flow fragmentation and regulation : This point covers hydraulic works such as dams, reservoirs and locks. Their obvious direct impact is on the flow regime (including also sediments circulation). Whereas natural variability, including seasonal variations and floods (see also “Water-related events and hazards”) sustain complex biological communities, such hydraulic works may completely alter flow regimes. Reduction in sediments moving downstream may lead to the elimination of beaches and backwaters, as well as of the riparian vegetation, and to the degradation of deltas. Those habitats losses lead in turn to species populations extinctions and changes. Migrating species may furthermore be disturbed by these obstacles. Finally, still waters may warm up, which is also a possible pollution factor (see above) [43][41].

- Overuses : Water over-abstraction is a well-known issue, which leads to evident changes to the surface water aquatic ecosystems. In groundwater, indirect impacts furthermore include : reduced contribution to springs and base-flows, saline or poor-quality water intrusions, stresses on groundwater-dependent systems (e.g. Wetlands), and land subsidence [42].

  Overexploitation of other aquatic ecosystem resources may also lead to threats on species. Regarding fishes, overexploitation has led to stock depletion in many cases [27].

- Invasive species : This phenomena is considered as a very important cause of biodiversity loss in freshwater systems, trough competition and predation processes. Introduction of alien species can be intentional, as well as accidental, for instance as a result of the escape of aquacultures [41].

- Water-related constructions : The effects of large hydraulic works (dams, reservoirs and locks) have already been stated (see above), with their possible large-scale effects. More locally, the implementation of other water-related facilities obviously also have an impact. Such facilities include : harbours and flood / wave protection infrastructures (like dykes and channels).

- Other pressures : locally, recreational activities and transport may also cause disturbances, on the water and to the shores.

E2. Positive impacts : Although the threats inventoried above represent a long list, anthropogenic objects or measures may also have positive impacts. For instance, sanitation infrastructures mitigate the pollutant loads. Land-use changes may contribute to protection or even to restoration of ecosystems.

E3. Inter-users impacts : As described above, different users may benefit from a same aquatic ecosystem and resources, and have impacts (positive or negative) on its quality and quantity. This way, they may also have impacts on the other users (sediments loads causing wear of equipments, pathogens or toxics preventing bathing, over-abstraction upstream, etc.), eventually leading to situations of competition or conflicts (see also “Managing and sharing water“).

E4. Aquatic system safeguarding policies : This is a key point. The way aquatic ecosystems will actually be managed in practice depend upon the corresponding international, national, and local policies, and the way they are enforced. For instance, the Ramsar Convention on Wetlands, signed in Ramsar, Iran in 1971, is dedicated to the protection of wetlands. It provides a framework for national actions within international cooperation [41].

E5. Impacts of water-related events on the aquatic ecosystem, climate change: see “Water-related events and hazards“ issue.

E6. Water management, monitoring and (land-use) planning see “Managing and sharing water“ issue.

Main physical components involved:

- Water (component and resource)

- Water system, including sub-elements: Aquatic fauna and flora, watershed, and water compartments: wetland, lake, river and stream, precipitation, snow and ice, groundwater, coastal water and marine water (aquatic ecosystems)

- Water-related objects (beneficiaries, negative or positive (including protected areas, and possibly sanitation infrastructure and water-related land-use change area) impacts.

F) Water-related events and hazards

Issue description :

When water is too less or too much, it may endanger human lives and infrastructures. Conversely, beside their possible disastrous effects, floods events may also bring valuable resources to the ecosystem.

The Johannesburg Plan of Implementation (JPOI) states that : “an integrated, multi-hazard, inclusive approach to address vulnerability, risk assessment and disaster management, including prevention, mitigation, preparedness, response and recovery, is an essential element of a safer world in the twenty -first century.” [14].

During the last three decades, the number of natural hazards, affected populations and the associated costs has increased, the former having more than tripled since the 1970s. However, the corresponding death toll has halved during the same period [44]. Four types of natural hazards are responsible of 94 percent of deaths: earthquakes, tropical cyclones, floods and droughts [45].

There are several natural water hazards :

- Floods : Their causes include intense or long rainfalls, snow-melting and stream jams. These causes may sometimes be due to primary phenomena, like tropical cyclones heavy rainfalls, earthquakes causing stream blockage and so on.
- Droughts : They are caused by water scarcity, possibly caused by deficits of precipitations, of surface or groundwater resources. Agricultural droughts more specifically define conditions of water scarcity for cultures. [44].
- Waves/surges : People living close to bodies of water such as oceans are exposed to sea waves (including tsunamis), which can inundate coastal environments. Waves can be caused for instance by earthquakes, volcanic explosion or landslides.
- Mudflows, avalanches and banks erosion : Mudflows are flows of a fluid mass of various solid materials (sediments, rocks, etc.) and water. Mudflows and avalanches, with their masses and velocities can both, at a more local level than the previous hazards, claim lives and generate important damages.
- Banks erosion : Also locally, erosion might be a threat for infrastructures and people located close to coasts and river banks.

The following table shows the impacts of floods, droughts and waves in the period 2000-2007, in terms of number of recorded events, of human lives toll, of people affected (injured, homeless and requiring immediate assistance) and of costs.

Hazard / Impact	**Number**	**Deaths**	**Total affected**	**Damages (1000xUS$)**
Floods	1'184	36'440	668'205'954	97'552'394
Droughts	142	1'407	692'965'614	21'656'958
Wave / surge	17	227'238	2'486'330	7'712'800

Source: "EM-DAT: The OFDA/CRED International Disaster Database - www.em-dat.net - Université Catholique de Louvain - Brussels - Belgium"

Table 1: Impacts of floods, droughts and waves between 2000 and 2007

Hazards can induce many indirect effects, and can trigger further other hazards, especially technological hazards (see related point below).Conversely, various other hazards can indirectly trigger floods, droughts and waves. Other hazards may also endanger water security : earthquakes, volcanic eruptions, wars, wind storms, technological hazards, landslides, etc. can damage water supply infrastructures or deteriorate water quality.

On the other hand, floodplains often show deep, fertile alluvial soils, which are ideal for high crop yields. Floods are also important to provide temporal variations which are enhancing conditions for high biodiversity (see also ecosystem' s point below).

Interrelations involved :

F1. Ecosystem : Concerning floods, the Associated Programme on Flood Management (APFM), a joint initiative of the World Meteorological Organization (WMO) and the Global Water Partnership (GWP) underline its positive role for the aquatic ecosystems: ."In order to support natural ecological processes, riverine habitats require three environmental conditions to be fulfilled simultaneously: water of adequate quality; availability of appropriate quantity and spatial and temporal variability of water; and availability of diverse physical habitats." Thus, floods may produce spatial and temporal variability, modifying river morphology, and floodplains, sustaining wetlands, renewing floodplain ponds, etc. [46].

More generally, concerning the hazards, the World Union Conservation (IUCN) however emphasizes that "disasters can affect biodiversity through the spread of invasive species, mass species mortality and loss of habitat. Poorly planned post-disaster response and reconstruction work often do more damage to biodiversity than the disaster itself." [47].

Conversely, ecosystems play an important role in protection against natural water hazards. For instance, forests can buffer stream flows and protect from avalanches and mudflows, mangroves and coral reefs lessen waves, wetlands and lakes can store water, and therefore decrease peak flows [47][46] and provide water for drought periods. Vegetation may also offer protection against banks erosion.

F2. Technological hazards : Industrial accidents can pose a major threat to ecosystems and human health and goods. There are many examples of contaminated aquatic ecosystems during such as the following, described on the APELL's (Awareness and Preparedness for Emergencies at Local Level) website [48]:

- In 1986, Basel, Switzerland, during a fire in a chemical storehouse, large quantities of pollutants were released into the Rhine, and into the groundwater. After the accident, the biota in the Rhine was heavily damaged, for several hundred kilometres.
- In 1999, along the France's Breton coastline, the *Erika* vessel foundered, spilling heavy oils and killing 300'000 birds.
- In 2000, Baia Mare, Romania, a tailings dam at a gold mine ruptured and released cyanides into the Somes river, a tributary of the Szamos, Tisza and Danube rivers. Cyanides reached 700 times their normal concentration, massively killing fishes and other species.

Natural hazards may also be the triggers for technological hazards (natech: Natural Hazard Triggering Technological Disasters). For instance, in 2002, during floods in the Czech Republic chlorine was released from a plant, with a consequent declaration of emergency state in the surroundings, warning the local population to stay inside and keeping doors and windows closed [49].

F3. Protection infrastructure : Physical structural measures for protection against floods and waves include waves breaks, dykes, embankments, channels, canalisations, infiltration zones, dams and retention and basins. Fighting drought requires reservoir capacities.

In rich countries, such infrastructures are generally well developed. Although they might have caused damages to ecosystems (see also related issue), their role for human progress has been fundamental, supporting economic prosperity and social progress. In less developed countries, infrastructures deficit often lead to greater losses, as the Human Development Report analyses [20] : "Indonesia loses an estimated 25,000 lives a year to drought-related problems. Australia, with a similar droughtrisk exposure, loses none. Investments in Japan have mitigated the impact of floods so that flood damage costs seldom rise above 0.5% of GNI and losses of life are rare. But when floods struck Mozambique in 2000, they left 700 people dead and half a million homeless. Crops were destroyed, and infrastructure was damaged. Total losses amounted to an estimated 20% of GNI, with economic growth falling from 8% in 1999 to 2% in 2000."

Dams, although generally not primarily designed for this purpose, may however also act as infrastructure against floods. The World Commission on Dams explains [43]: "Large dams are used to control floods by storing all or a portion of the flood waters in the reservoir and then releasing the water slowly over time. Typically, the principal use of such dams is to store a portion of the flood in order to delay or manage when the peak occurs.". See also "Safe water and sanitation" issue's related point about the multiple purposes of dams.

In cities, intense rainfalls may also cause problems. For so-called storm water management, specific infrastructure may be required to avoid important surface runoffs, local inundations, and consequent damages and disturbances.

F4. Health : Disasters may cause immediate deaths, but they may also generate conditions for triggering epidemic diseases, causing sometimes even more human lives losses. For instance, floods associated with high temperatures may cause water-borne diseases such as malaria. In other cases, damages to health infrastructures -hospitals- may prevent quick and effective treatments [45].

Whenever water supply and sanitation infrastructures are damaged, this may also lead to very dangerous conditions (see "Safe water and sanitation" issue's related point). Damages to other important infrastructures, including roads and electricity, may also disrupt responsiveness to the event.

Conversely, a population already suffering from diseases will be less resistant, and reduce its capacity to respond effectively to disasters [45].

F5. Poverty : As stated earlier, there are differences between rich and poor countries, in which protection infrastructure deficits generally go along with greater damages from natural hazards. Furthermore, within a same event, the poor are generally the less protected, due to weaker infrastructures. During the flood in 2000 in Mozambique, poor households, lying on lower areas bore the brunt of the damages; in New Orleans, 2005, during the Katrina hurricane event, poor black neighbourhood were affected the most [20].

F6. Managing risks and disasters may involves many different policies into a framework for prevention, preparedness, emergency intervention and post-disaster actions. These policies include:

- Land-use planning : Mapping the hazards, knowing their potential extents and intensity is crucial. On the base of such maps, constructions in dangerous zones can be avoided.

  Protecting the ecosystems that in turn protect infrastructures and populations (see above) is also a critical objective of land-use planning.

- Building codes : In occasional inundation-prone zones, restrictions on the type of buildings and their design may allow to minimize possible losses. More specifically, industrial equipments should fall under restricted conditions, in order to avoid subsequent technological hazards.
- Capacity building : Training in management and emergency response is necessary at all levels (see "Managing and sharing water" issue's related point).
- Disaster early warning and response management : Reducing risks to zero is an utopia. Therefore, preparing actions for disaster cases is necessary, to act efficiently whenever is necessary.

  First of all, early detection of the events should be set, by monitoring stations and possible forecasting methods.

  Then, the informations should be transmitted to relevant organizational levels, from international, to local levels.

  Finally, relevant actions have to be undertaken at all levels to ensure best interventions before, during and after the disaster. Regarding emergency water management, this may include :

  - Dams and reservoirs may release water before foreseen flooding events in order to provide more storage capacity for buffering peak flows.
  - Regarding droughts, if water scarcity period is foreseen, restricting distribution for certain activities (recreation and agriculture for instance) may prove necessary.
  - If water supply or sanitation infrastructure are damaged during the event, their restoration, or alternative emergency provision for affected people should be achieved within a short period to avoid consequent problems, including water-borne diseases.

F7. Investments and paybacks : As stated earlier, protection infrastructures allow to reduce damages. Indeed, it is usually cheaper to invest in protections than to pay for fixing the damages afterwards [47]. In a discussion paper prepared for the 4th World Water Forum [50], the authors discuss the hypothesis that some minimal investments are required to pass a "tipping point" beyond which relative water security is reached. Until this points, returns to investments would be fairly modest. Passing the point, sufficient water security would make investors more confident and therefore provide much more returns to investments. This S-curve would finally end with a decrease in the paybacks due to the fact very high security is reached. In developing countries, reaching the tipping point would thus be crucial for further developments.

F8. Climate change : Although this is still a controversial topic, with multiple evolution scenarios, the UNDP's (United Nations Development Programme) Human Development Report underlines that recurrent themes show that dry regions will probably be drier, and wet regions wetter, along with more unpredictability in water flows, with more extreme events. Thus, regarding natural hazards, droughts and floods might be more violent in the future. Other impacts involve inland glaciers further shrinking, and sea level raising, due to polar ice melting (and related threats to low-level coastal areas) [20].

F9. Monitoring : As stated above, monitoring stations may provide early warning, and therefore play a crucial role in hazards management. More generally, they provide useful data for management (see "Managing and sharing water" issue's related point).

F10. Water management and (land-use) planning : see "Managing and sharing water" issue and also "Aquatic ecosystems : benefits and pressures" (users' impacts on each other).

Main physical components involved:

- Water (hazard)
- Water system, including sub-elements: Aquatic fauna and flora, watershed, and water compartments: wetland, lake, river and stream, precipitation, snow and ice, groundwater, coastal water and marine water (aquatic ecosystems, protection)
- Water-related objects (as potential triggers for technological hazards, at risk), Storage and regulation infrastructures, flood and waves protection infrastructures (protection), monitoring station (early warning, measures)
- People (at risk)
- Funds (resource, investment)

G) Managing and sharing water

Issue description :

As previous sections outline it, water resources are needed for very different uses, including ecosystem safeguarding. These uses may enter into competition, with regard to quantity or quality aspects. Therefore, proper management and sharing are required.

As stated in the four Dublin's principles in 1992, water is a “finite and vulnerable resource” which “has an economic value in all its competing uses and should be recognized as an economic good” [13]. Managing a given finite amount of water, by protecting its quality and its ecosystems, avoiding overuse and wastages, increasing the benefits everyone can retrieve from it in competing uses, possibly solving conflicts, considering uncertain supply trends and generally increasing demand, in a sustainable way, is generally not a simple one-dimensional problem!

To address this challenge, the present widely recognised response is the implementation of integrated water resources management (IWRM). The Plan of Implementation of the World Summit for Sustainable Development in Johannesburg called for: “develop integrated water resources management and water efficiency plans by 2005” [14].

There are no universal definition of IWRM. The Global Water Partnership (GWP) proposes: “IWRM is a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.” It further recognises three basic important elements for an effective IWRM [4]:

- The enabling environment: the general framework of national policies, legislation and regulations and information for water resources management stakeholders
- The institutional roles and functions of the various administrative levels and stakeholders
- The management instruments, including operational instruments for effective regulation, monitoring and enforcement that enable the decision-makers to make informed choices between alternative actions. These choices need to be based on agreed policies, available resources, environmental impacts and the social and economic consequences.

Integrated water resources management, being developing since the beginning of the eighties, is a bottom-up strategy replacing traditional “water master planning” (top-down) [51]. It provides a

suitable framework for a holistic approach of all water-related issues, integrating the following dimensions (see below for details) :

- People's involvement
- Stakeholders' interests
- Sectoral institutions
- Administrative levels
- Spatial extent
- Time and sustainability
- Legislative framework
- Data and knowledge

Practically, once the IWRM platform is operational, issues can be debated, stakeholders can propose solutions, and scenarios can be assessed, and, eventually, decisions can be taken. As a base for discussions, informations are needed, such as water resources assessment (WRA), demand statistics, legislative and policies framework, state of the infrastructure, etc. Furthermore, tools, such as models, may provide a way to assess propositions and scenarios' effects.

During this decision-making process, possibly assisted by decision support system (DSS), conflicts have to be solved, and trade-offs found. Objective informations and tools, as well as non-arbitrary supervision (also defending general purposes such as sustainability) are therefore necessary for equitable, efficient and sustainable development solutions to be reached.

Interrelations involved :

G1. People's involvement (participatory approach, sensitization, communication) : Informed people can act in a responsible way towards the environment. They can put institutions and industries under pressure to change them. They can be effective stakeholders in decision-making processes if they are allowed to. This is possible through participatory approaches.

The importance of these points is well explained in the executive summary of the Water Resources Institute publication based on the TAI's results (The Access Initiative, a global civil society coalition promoting public access to information, participation, and justice in decision-making that affects the environment) :

"Access to environmental information enables citizens to make informed personal choices and encourages improved environmental performance by industry and government. For example, citizens need to know whether water is safe to drink, and public knowledge of contamination creates pressure for pollution control."

"Informed and meaningful public participation is a mechanism to integrate citizens' concerns and knowledge into public policy decisions that affect the environment. Decisions that incorporate public input generally result in outcomes that are more effective and environmentally sustainable than those that do not." [52]

Participatory approaches thus provide a mean to improve efficiency of decisions, but also equity, between poorer and richer, women and men, and between ethnic groups, as they may all actively participate.

G2. Stakeholders' interests : As stated in the issue "Aquatic ecosystems : benefits and pressures", the many users of water may generate impacts on each other and on the ecosystem in terms of quantity (scarcity, over-abstraction) and quality (pollutants,

sediments). Competing uses may lead to ecosystem degradation and to conflicts between users.

In IWRM, all competing uses and user's claims may be integrated and analysed in a holistic way to provide solutions satisfying each one at best. Ecosystems might be defended partly or as a whole by some stakeholders like sport fisher groups or ecological associations. In any cases, their protection should be ensured by the legislative framework.

G3. Sectoral institutions (horizontal administrative integration) : Traditionally, water management is fragmented within different institutions, each one responsible of possibly conflicting specific tasks [4], such as: water supply, wastewater management, nature safeguarding (including fauna and aquatic ecosystems), agriculture management (including irrigation). Taking measures to solve a particular sectoral problem independently may lead to unexpected outcomes, or even negative effects for other sectors. IWRM may provide sectors representatives with a common platform to better communicate and cooperate. This includes indifferently private institutions, which may be involved partly or completely in investments and water management (e.g. as water provider or for wastewater treatment).

G4. Administrative levels (vertical administrative integration) : The integration of international, national, regional, etc. regulations and policies may be achieved within IWRM, ensuring that local measures are in-line with more general directives.

G5. Spatial extent : Natural water boundaries do not necessarily correspond to administrative ones. Actually, "over 260 of the international or transboundary basins, with over 50 percent of Earth's surface and 40 percent of the global population, are shared by one or more countries worldwide." [33].

Lack of considerations of other communities' (regions, countries, etc.) needs for the same shared resources may create serious problems and even conflicts. This is however not the norm, as cooperation within transboundary agreements prevail [53]. For instance, the Nile basin involves ten countries, and nine of them are part of an international partnership, the Nile Basin Initiative (NBI) whose purpose is the conciliated management of the river [4].

Watershed and/or aquifers, as natural water boundaries, may indeed be logical delimitations for IWRM exercises. However, some considerations may require even larger spatial extents, as for instance, virtual water consideration (water embodied in products) -taking into account food and goods inputs and outputs. Also, cities and rural hinterlands relations and inter-cities relations may be important, as unequal developments, or rural droughts for instance may cause unexpected effects such as migrations (indirect conflicts).

G6. Time and sustainability : There are different interpretations of what sustainability really implies. The Brundtland report stated in 1987: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [11]. The 2005 World Summit Outcomes further specifies to "promote the integration of three components of sustainable development – economic development, social development and environmental protection – as interdependent and mutually reinforcing pillars".

Ensuring sustainability, avoiding conflicts between present and future users, therefore requires to take into account the socio-economic aspects, along with ecosystem safeguarding, at present and in the future. This includes considering socio-economic trends, water demand evolution, hydrological changes (climate changes, see related point in "Water-related events and hazards" issue), and water resources availability changes.

G7. Legislative framework : As stated above, legislation framework is a fundamental factor for enabling IWRM. In turn, IWRM requires an exhaustive knowledge of existing legislations, at different levels (international, national, regional, agreements, standards, etc.) in order to act in concordance with it within its management and planning decisions. It can also provide a relevant platform to integrate the many and varied laws regarding water, as references to water resources "are often dispersed in a multitude of sectorally oriented laws and may be contradictory or inconsistent on some aspects of water resource usage." [4].

Legislation hence provide stakeholders and managers with a framework, but also with enforcement and fostering tools (see following points).

G8. Legislative framework, standards and controls : They may provide a clear and strict framework for various fields such as wastewater treatment, used quantities control, specific technological solutions control, etc. These solutions are sometimes criticised as being being "inflexible, costly to implement, prone to imperfect implementation and evasion and for failing to allow users the freedom to employ a range of techniques to conserve water or reduce waste disposal" [4].

G9. Legislative framework, economic instruments : Although governments generally rely on standards, economic instruments may present several advantages, such as changing users' behaviour or helping financing investments [4]. They include notably water pricing, taxes and subsidies, and investments policies. These policies may have different direct and indirect effects. They may directly affect technologies and equipments and people's behaviour. And of course, they directly influence the funding resources. These effects may stem a host of further indirect effects including changes in : water consumption rates, water quality, paybacks and funds, security, well-being, poverty, etc. (see related topics in previous issues descriptions, above).

For instance, if water is expensive, it will probably affect the set of industrial equipments -and people's behaviour- in order to minimize water consumption, but in the same time, it may prevent safe access to poor people; if water is cheap, it may foster wastages. If subsidies are available for renewable energies, it may support hydropower construction. If recreational equipments are supported by subsidies, it will provide well-being to users. If taxes are set for wastes, it may decrease their quantities, and potentially reduce subsequent pollutions. If protection infrastructures are financed, they may foster further private investments and provide significant paybacks. Supporting economic sectors that require less water for production may lead to water savings, but not supporting irrigation may lead to under-development in rural areas. Etc.

G10. Legislative framework, self-regulation : Self-regulation can prove to be a cheaper alternative to sometimes expensive standards and direct controls. This is achieved by measures such as requiring labelling of products or disclosure of results. Submitting publicly such informations provide water users with incentives to do their best and exposes them to governmental and public opinion pressures.

G11. Data and knowledge : In order to make informed relevant water planning and management decisions, data is required. This involves first of all a good knowledge of the water resources state, as stated by the Global Water Partnership: "In many countries available information about the water resources situation is scarce, fragmented, outdated or otherwise unsuitable for management purposes. Without adequate access to scientific information concerning the hydrological cycle and the associated ecosystems it is not possible to evaluate the resource or to balance its availability and quality against demands. Hence, the development of a water resources knowledge base is a precondition for effective water management." [4].

The GWP also stresses the importance of demand-related data [4]. The database should as well contain trends, for perspectives analysis. With this regard, monitoring stations play an important role to provide reliable long-term data, about hydrological and ecosystems conditions and evolutions.

Furthermore, more general data may also prove helpful, such as detailed situation maps, miscellaneous statistics, other infrastructures situations, administrative boundaries, etc.

Beyond local situation data, global knowledge repositories may provide water specialists with worldwide experiences about technologies and policies, including performances, advantages and drawbacks, best practices, etc. For instance, the CSD WAND (Water Action Network Database of the Commission on Sustainable Development) [54] proposes a web platform to browse through worldwide projects related to water and sanitation.

G12. Data and knowledge, capacity building : Data and knowledge provision is one thing, but if empowered people don't have the necessary skills to manage them, management and planning outcomes may not be satisfying. Hence, people with adequate background are required for water-related responsibilities such as : proper daily operation of infrastructures, sustainable aquatic ecosystems management, hazards prevention and emergency interventions, sustainable planning, and adequate IWRM platform operation. The GWP further defines capacity building : “At the basic conceptual level, building capacity involves empowering and equipping people and organizations with appropriate tools and sustainable resources to solve their problems, rather than attempting to fix such problems directly. When capacity building is successful, the result is more effective individuals and institutions that are better able to provide products and services on a sustainable basis.” [4].

Thus, capacity building may have effects on any aspects of water management, through the enhancement of specialist's capacities.

G13. Integrated planning and management : As a conclusion, for management and planning activities (including land-use planning) the whole list of dimensions above should be integrated, including : the global legislative framework as well as sustainability (socio-economic and environmental aspects, for instance through environmental impact assessments (EIA)) and trends. Therefore, planning and management activities may successfully be led within IWRM platforms.

Main physical components involved:

- All previously mentioned elements (integrated view)
- Specialists, decision making team, private / public institution (managers)
- urban / rural area, national / regional area (management scales)

4. *Synthesis: drawing the system model*

As the quite numerous descriptions above show, there are many issues and sub-issues related to water, and these issues are very much interconnected.

These descriptions also emphasize that water-related elements have effects going sometimes beyond the strict field of water, acting for instance on development and poverty, on international geopolitics, on institutional organization and energy. Conversely, elements beyond the strict field of water may play significant roles for water management, such as tenure rights, building codes, importation policies (virtual water) and energy.

In the present study, it was estimated that apprehending this global system, with a holistic understanding of its numerous issues and their interdependencies was just too much to integrate for a normal brain. Therefore, the question was raised for the subsequent possibility of providing solutions (scenarios of interventions), without having this holistic understanding.

As a first step to tackle this problem, it was decided to represent the system with a model, showing the components and their interdependencies.

Indeed, this model may directly help by :

- Providing the required holistic view and understanding, transcending the strict field of water
- Understanding the direct and indirect effects when modifying a given component
- Finding levers, even indirect ones, to act on given components; this also includes the possibility to act on non water-related issues with components specifically related to water and vice versa.

This model representation of the water management system is an original contribution of this study, as no evidence was found for an antecedent such result. It is viewed as a basis for further developments in the field of integrated water resources management, transcending the strict field of water, and as such, it is not only targeting water specialists, but also planners in general, for a more water aware planning process. Such developments may relate to the fields of : situation analysis (for the holistic framework), planning scenarios elaboration (to point out the action levers and interactions), scenarios' performances assessment (to encompass the multiple repercussions), planning optimization (automatic screening of levers and effects), and the decision making process (inclusion of broader stakeholders, beyond the strict field of water). Hence, as they include these different fields, particularly interesting perspectives may especially arise in decision support system applications.

IV. Conclusion and outlooks

In this study, in a first time the issues related to water are reviewed, their related components are inferred and divided into physical and cultural environments -and then further classified-, and their interrelations are emphasized.

Seven general issues are chosen as perspectives or “entry points” to describe as exhaustively as possible the many aspects of water, the related components and their interrelations: Safe water and sanitation, Water for food production activities, Water for industry, energy and transport, Water for recreational, amenity and spiritual purposes, Aquatic ecosystems : benefits and pressures, Water-related events and hazards, Managing and sharing water.

This analysis enables to sketch, in the second time, the components and their interrelations into a general water management model. This model emphasizes that water specific issues depend sometimes upon more general considerations (as in the example of slum upgrading through tenure access rights improvement, which in turn may bring more security to households, and finally encourage people to upgrade their accesses to safe water and sanitation). Conversely, the model also emphasizes that water-related components may have considerable effects on more general issues (as in the example of saving water to save energy, or when providing water to improve gender and education issues).

Whereas water-related issues are well-known, being generally described in many different papers and in a host of details, the analysis into components and interrelations for the realization of a

holistic graphical model is an original contribution of this study, as no evidence was found of previous such work.

Apprehending water-related issues globally was found a very difficult exercise, as implications are very numerous and interrelations so complicate. The final result of this study -the water management system model- provides this holistic understanding within one large integrated view, offering the possibility to better understand the levers and repercussions when acting on given components.

On that basis, further research and developments, especially in the field of information sharing and decision support systems seem promising. In particular, the water management system model could be used as an aide memoir to achieve case studies' water-related system analysis and representations. For that, the generic components of the model should be translated into actual, real components and groups of components. A software could be developed to manage this system-related information: it could help navigate form very synthetic views showing groups of components, to detailed views showing sub-groups and the actual components; it could also be used as an information system, through user-friendly provision of component and interaction's data. An even further step could consist in the elaboration of algorithms to explore the components-interactions network, comparing actual case studies' data with benchmarks, and trying to find adequate leverage points in complex water-related issues, in a semi-automatic way. These interesting research directions will be investigated in upcoming activities, in continuation to the present study.

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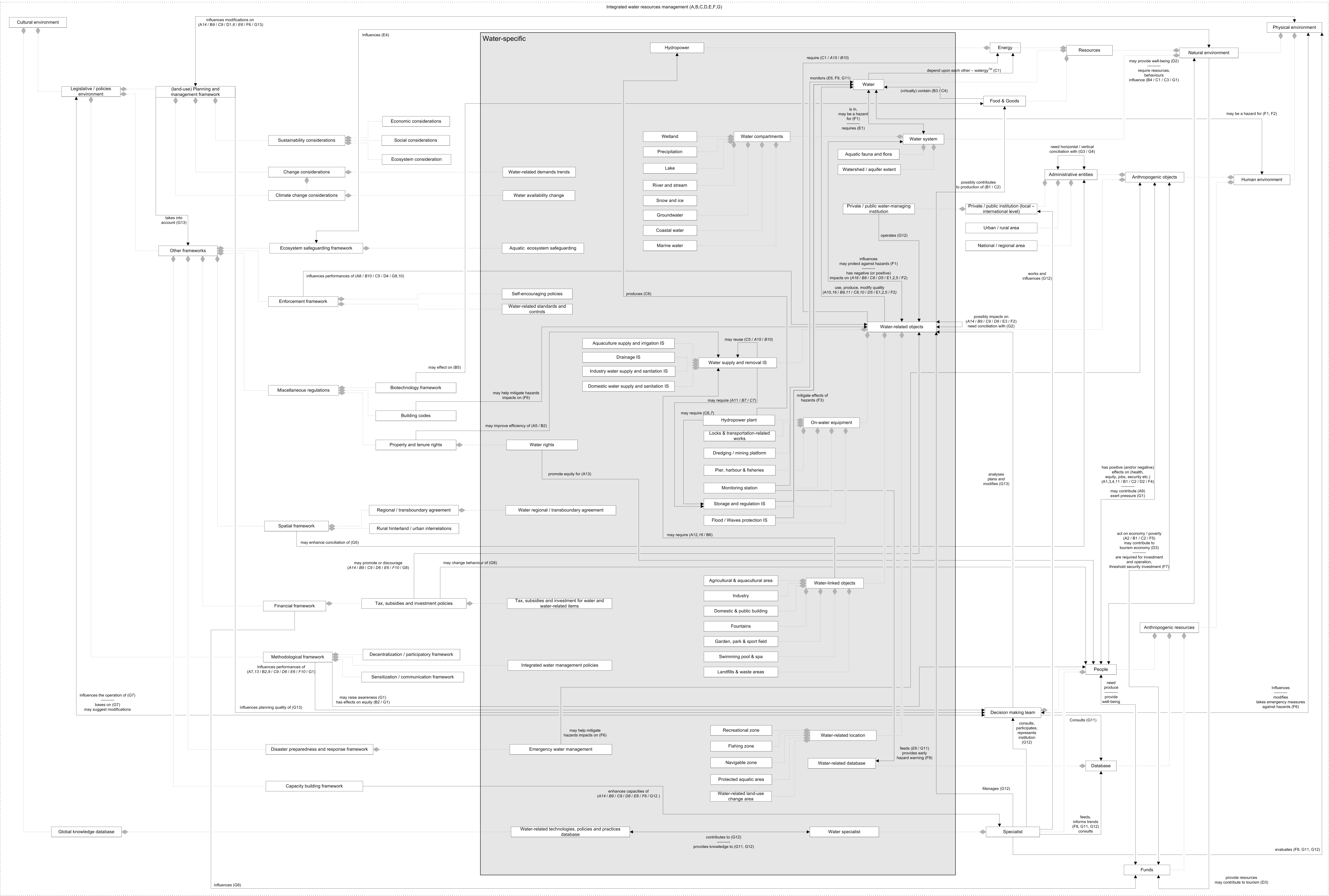
Annex 1. Water management system model



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