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Report on current state of the art and major knowledge gaps to characterize water stress in different sectors.

Aquastress D2.1.2 - Final report

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AQUASTRESS

Mitigation of Water Stress through new Approaches to Integrating Management, Technical, Economic and Institutional Instruments

Integrated Project

D2.1-2

REPORT ON CURRENT STATE OF THE ART AND MAJOR KNOWLEDGE GAPS TO CHARACTERIZE WATER STRESS IN DIFFERENT SECTORS

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State of the art of water stress in the different sectors

1.1 State of the art of water stress in the domestic sector

This section discusses the state of the art and major knowledge gaps in characterising water stress in the domestic sector. One of the major barriers to understanding domestic water demand, and therefore a barrier to mitigating domestic water stress, is the high level of disaggregation of end-uses (Michelson et al, 1999; Renwick and Green, 2000; Turner et al, 2004). This means that intensive data collection, which usually requires the installation of individual meters in households, is necessary in order to understand domestic water consumption patterns. Absolute demand in any one year will not prove useful because it does not account for other factors such as climate variables or restrictions which can significantly change household demand from year to year. This problem, which is unique to the domestic sector due to the large number of individual end-users, underlies many of the knowledge gaps discussed below.

The following section (Section 1.1) first introduces the concept of minimum human requirements using a number of referenced examples. We then compare average water demand in various European countries using data supplied by the European Environment Agency (EEA, 2003) as a comparison to the minimum human requirements.

1.1.1 Domestic Water Use

The simplest indicator of domestic water demand efficiency is daily, monthly or annual volumetric per capita use. A simple measure of water use efficiency can use a comparison between water uses in different regions or a hypothetical comparison between basic human needs and actual water consumption. Basic human needs vary for different regions due to climate, cultural, and economic factors. One approach is to use a volume based on the minimum human water requirements. The WHO/UNICEF (2000) adopt a figure of 7.3 m³/capita/year (20 l/day/capita) accessible from a source within 1 km of a user's dwelling as achieving "reasonable access" to water. Because of economic and cultural reasons, the volume of water consumed in any society varies significantly and the WHO/UNICEF figure is far below the level of domestic water use in most developed countries and makes no allowance for the needs to maintain even a non-agricultural economy. A figure of 18.3 m³/cap/year (50 l/day/capita), as suggested by Gleick (1996) could be taken as a minimal domestic water requirement, but this figure makes no allowance for industrial needs since it is based only upon estimates of the amounts of water required for drinking, sanitation, bathing and food preparation at a minimal acceptable basic level. For this reason, when estimating the cost of supplying an adequate volume of potable water to all people at all times, the figure of 125 m³/capita/year could be adopted, as proposed by Shuval (1992). Domestic needs as well as modest industrial and gardening needs are incorporated in this figure.

The total water use for domestic purposes in Europe is 56,458 Hm³/year which amounts for 18 % of total abstraction. During the period 1993-1999 the urban use per capita slowed down from 285 to 271 litres/per capita/day. Over this period, many changes occurred which influenced the patterns of urban water use. Changes include: increasing urbanisation, changes of population habits, use of more efficient technologies and water saving devices, use of alternative sources of water (desalination, wastewater re-use), increasing metering, and the use of economic instruments (water charges and tariffs). Connection of the population to water supply systems has also increased, especially in Mediterranean countries. Nevertheless there are important variations between regions and countries (EEA, 2003).

Water use per capita in the Nordic countries is higher than in Central Europe and varies between 290 litres/per capita/day in Sweden to 771 litres/per capita/day in Iceland. Some studies suggest that this high use is related to personal washing and dishwasher use. In Central Europe the variations are between 186 litres/per capita/day in Germany to 342 litres/per capita/day in Ireland. These variations reflect differences between the structure of water supply systems and water saving measures applied. The northern Accession Countries use 26 % of their abstraction for urban purposes. Baltic countries have the lowest water use per capita, together with Czech Republic, Poland and Hungary. The

restructuring of the economy and the institutional framework in these three countries accounts for the decline. Bulgaria, Romania and Slovenia with 805, 336 and 339 litres/per capita/day respectively, have the highest urban water use per capita. The high levels of use in Romania and Bulgaria can be explained by the number of breakdowns in water-supply networks, water losses and water wastage. The southern Accession Countries use 13 % of their abstraction for urban purposes. There is a consistent decrease in the late 1990s (from 224 litres/per capita/day in 1995 to 183 litres/per capita/day in 1999) with the exception of Cyprus, where the urban water use increased steadily throughout the whole period considered. The share of urban water in southern Europe is 16 % of its total abstraction, the lowest in Europe with the southern Accession Countries. The relative high use per capita in Mediterranean countries, around 350 litres/per capita/day in 1999, reflects their hot climate (increase in water for showering, garden use, public services), and the trend reflects mainly changes in lifestyle derived from increasing urbanisation (EEA, 2003).

1.1.2 Determination of water use efficiency

The main causes of variation in regional domestic per capita demand are variation in affluence (i.e. higher affluence = more water intensive goods = higher consumption), household occupancy, outdoor use, rural/urban types, and also unaccounted for water (UFW) (i.e. system leakage). The graphs overleaf show how water demand in the UK varies according to household characteristics such as micro-component use (Figures 1) and occupancy (Figure 2) impact on per capita consumption. Household occupancy, and other variables, can significantly affect the aggregate consumption levels in a region. However, the exact cause of the frequency of different levels of demands, shown in Figure 3, requires intensive data collection and analysis. Regression analysis is often used to identify correlations between the variables mentioned above and water demand (e.g. Kanakoudis, 2001, Baumann et al, 1998). Micro-component use can also be used to measure domestic water use efficiency. The data in Table 1 was collected from a number of sources (Ofwat, 2002). Most significantly it shows that outdoor water use and high volume toilets can contribute significantly to high domestic demand.

Table 1: MICRO-COMPONENT USE IN SIX COUNTRIES (OFWAT, 2002)

	England and Wales	Scotland	Finland	Switzerland	USA	Australia
Toilet flushing	33	31	14	33	11	20
Bathroom	20	32	29	32	8	26
Kitchen	17	35	34	19	16	20
Miscellaneous	27	<1	21	14	7	-
External	3	1	2	2	58	34

Figure 1: Per capita water demand vs. household size (Jacobs, 2004)

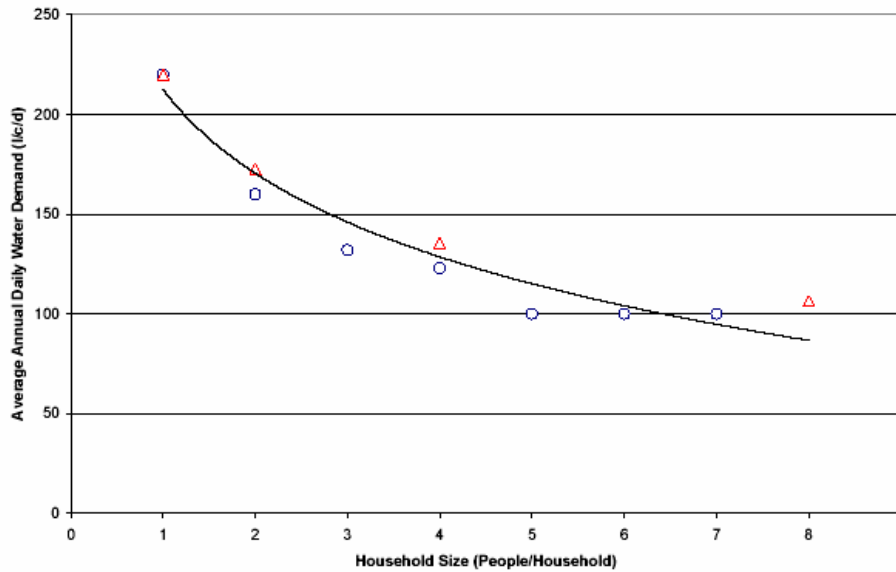
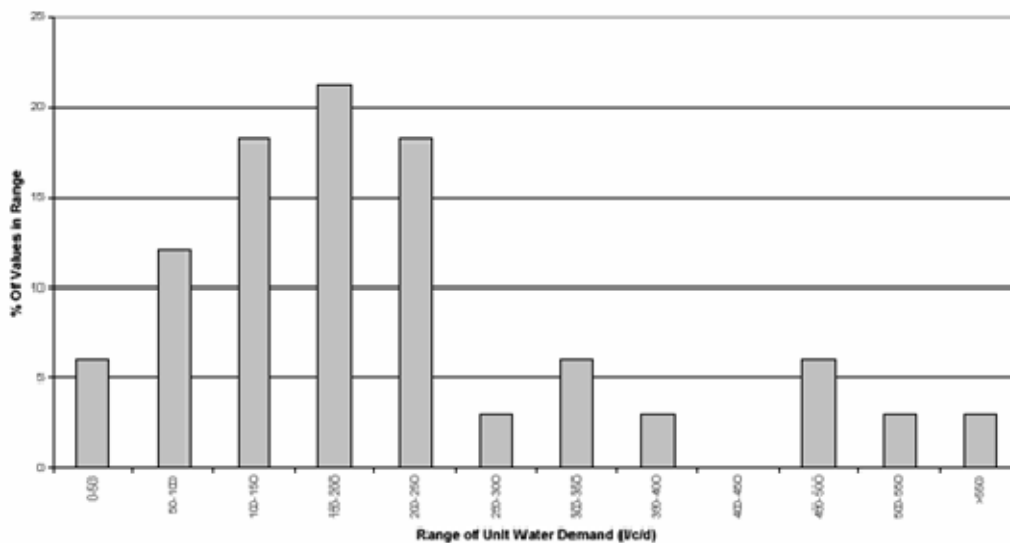


Figure 2: Frequency Histogram of per capita demand (Jacobs, 2004)



1.2 State of the art of water stress in the agricultural sector

Several reasons justify crop irrigation. First of all, the irrigation makes it possible to increase yields and to get an insurance against climatic risks thus guaranteeing higher and less variable incomes for farmers. The irrigation also makes it possible to diversify the production and thus to make the farmers less dependent on the conditions of market than in the event of monoculture. Lastly, for a few decades, the recourse to the irrigation has been often justified by the need for increasing the quality of the products and for limiting variability of it in order to ensure itself of the outlets near the food industries or the intermediaries of the distribution. For many countries, the control of the irrigation is then a considerable stake in terms of agricultural development, national food security and more

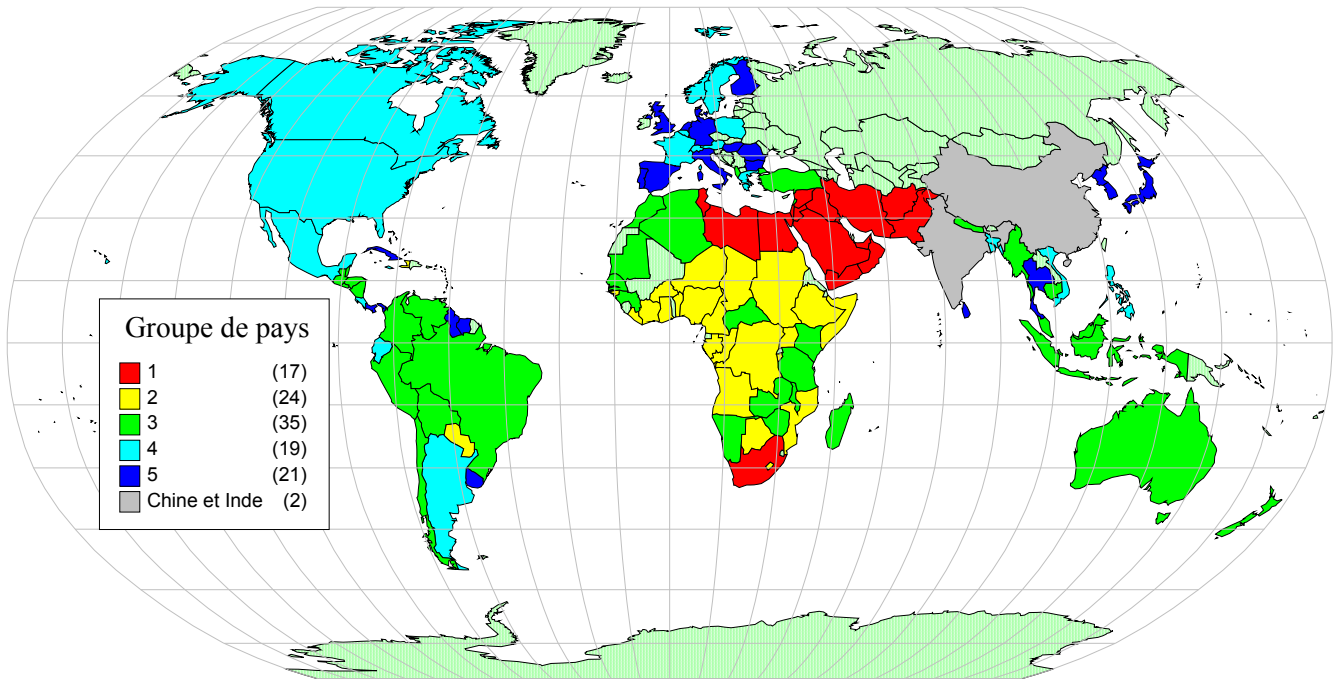
generally in terms of economic development. By the past, irrigation played a major role in the satisfaction of food needs, in the poverty reduction and in the development of life conditions in rural areas. The irrigation extended horizontally in term of surface where the conditions of production are less favourable and vertically by a rise of the production per unit of ground by intensification (Pereira 1995).

In 40 years, the world irrigable area tripled. It accounts for 1/6 of the actual agricultural area and provides 1/3 of the food supply (Waggoner 1994). In 1990, Rangeley estimated that during the last 25 years, 50% of the increase in food production did come from irrigated lands and FAO (1996) forecasts that during the next 50 years, 60% of the new needs will have to be satisfied by irrigated agriculture. However, the growth of the irrigation is constrained by two key factors which are the availability of the resource and the scarcity of the capital to finance the new projects more and more costly. Indeed, Seckler et al. (1999) estimate that a quarter of the world population lives in areas which will have to face extreme scarcity of water during the first 25 years of this century. In the field of hydraulic infrastructures, the cost of new schemes is high and rising. In 30 years, the irrigated area doubled in India and Indonesia, it tripled in Sri Lanka, it increased by 50 % in the Philippines and 40 % in Thailand (Carruthers et al.. 1997). The rising costs, the decline of cereals prices (partly due to the agricultural policies of the OECD countries) and the disengagement of international donors, leads to a low profitability rate of new irrigation systems (Carruthers et al.. 1997).

A prospective analysis of the water requirements for various countries at the horizon of 2025 was carried out by IWMI (Seckler et al.. 1998). This study relates to 118 countries gathering 93 % of the world population and holds account of the evolution of the domestic, industrial and environmental needs. Two scenarios of efficiency of irrigation were tested: reproduction of the efficiency of 1990 and improvement of efficiency. Without holding account of the constraints of mobility of the resource, it appears that to satisfy the food requirements in 2025, according to scenarios', the irrigated surface should grow from 13 to 60 % and the requirements out of water for 23 to 56 %, i.e. an improvement of the efficiency of irrigation would make it possible to satisfy 50 % of the future water requirements (Seckler et al.. 1999). The 118 studied countries were classified in 5 groups (Figure 1) according to an optimistic scenario of improvement of the efficiency of irrigation.

Group 1 regroups countries which will have to reduce the agricultural withdrawals and consequently to import foodstuffs of the 4 other groups (Seckler et al.. 1998; FAO 2002). Groups 2, 3, 4 are groups which will have to increase their consumption, therefore their infrastructures, respectively of more than 200 %, 25 to 100 % and less than 25 %, whereas group 5 can, according to cases, reduce its consumption till 2025. Seckler et al.. (1999) studied India and China separately, fault of not having been able to classify these vast and heterogeneous countries in one of the previous groups. According to these authors, world food safety should depend on the capacity of India to increase its efficiency of irrigation and of China to transfer its water from north to south.

Figure 1: Indicator of relative water scarcity (Source: (Seckler 1999)



But this study neglects two essential constraints: climatic change and the relative scarcity of the capital of each group for at the same time investing in the infrastructures and developing programmes of improvement of the efficiency of irrigation.

However, the increase in the hunger in the world at the horizon of 2060 would lie between 0 and 300 % according to climatic scenarios' tested (Chen et al.. 1994). The climatic change should increase the outputs in the countries with high and average latitudes and reduce them to the weaker latitudes, in particular in the near total of the African continent (Parry et al.. 1999). In spite of the positive effects that a CO₂ rise would have on the outputs, Lal et al.. (1998) estimate that those would be more than compensated by the fall of productivity due to the thermal and hydrous stress. But research on the climatic change also neglects, often, to integrate the effects policies aiming at inflecting the climatic change. However, from an energy point of view, one can reasonably make the assumption that irrigation could be in competition with hydroelectricity, arable lands in competition with afforestation (Rosenberg et al.. 1994) and food production in competition with biological fuel production.

Preceding studies, in particular that of Seckler et al.. (1998), project the slowing down of the yields rise already notice during past years, on cereals in particular, and identify this deceleration as being one of the explanatory factors of the food insecurity at the horizon of 2025. This thesis is however not supported by all the authors. Some (FAO 2002) estimate indeed that 2/3 of the food production rise (in 2030) could come from yields improvement and that the growth of the irrigated area could account in 2030 for only 1/3 of the growth noted during the thirty last years.

“Sustainable water management is the key factor to countries to achieve sufficient food production. However, irrigation is also associated with negative economic, environmental, social and political consequences. For this reason there is a great deal of interest in meeting future food needs through rainfed agriculture as a partial substitute for irrigation”. The potential for rainfed agriculture (figure4) is derived from evapotranspiration (figure 5), rainfall (figure 6) and soil maps. “On a global scale, 46% of the earth’s surface is unsuitable for rainfed agriculture due to climatic constraints. This leaves approximately 7 billion ha with a potential for rainfed crop production, of which, 4.7 billion ha is classified as moderate to highly suitable. Researchers are currently refining this preliminary estimate taking into consideration non-climate related factors (e.g. areas not available for conversion to agriculture)”.

Figure 3 : Potential for rainfed agriculture on a global scale (source: <http://www.iwmi.cgiar.org/WAtlas>)

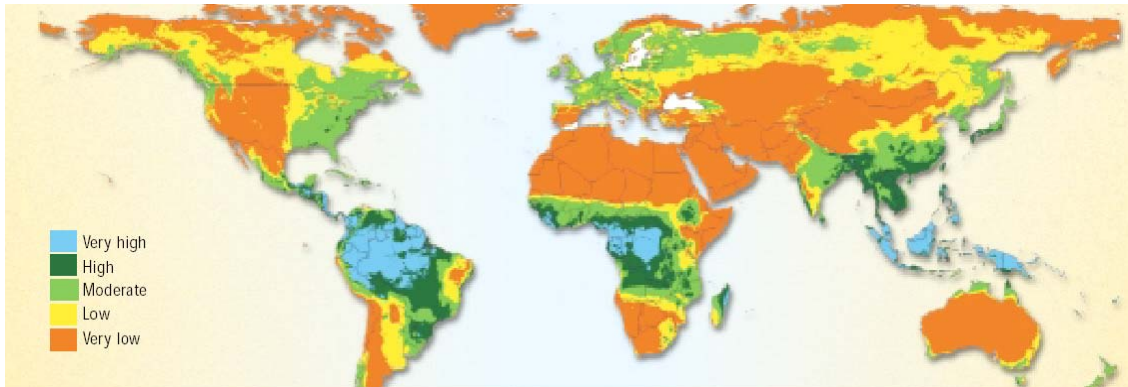


Figure 4 : World evapotranspiration (source: <http://www.iwmi.cgiar.org/WAtlas>)

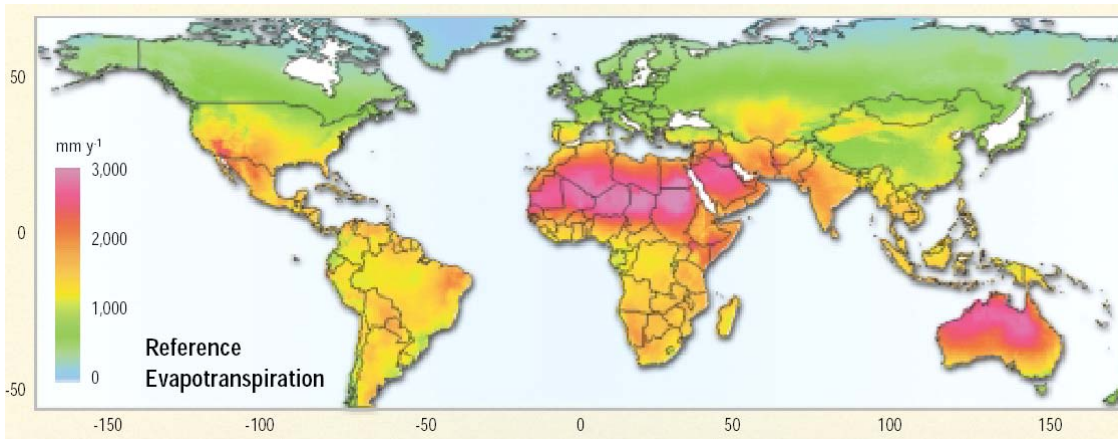
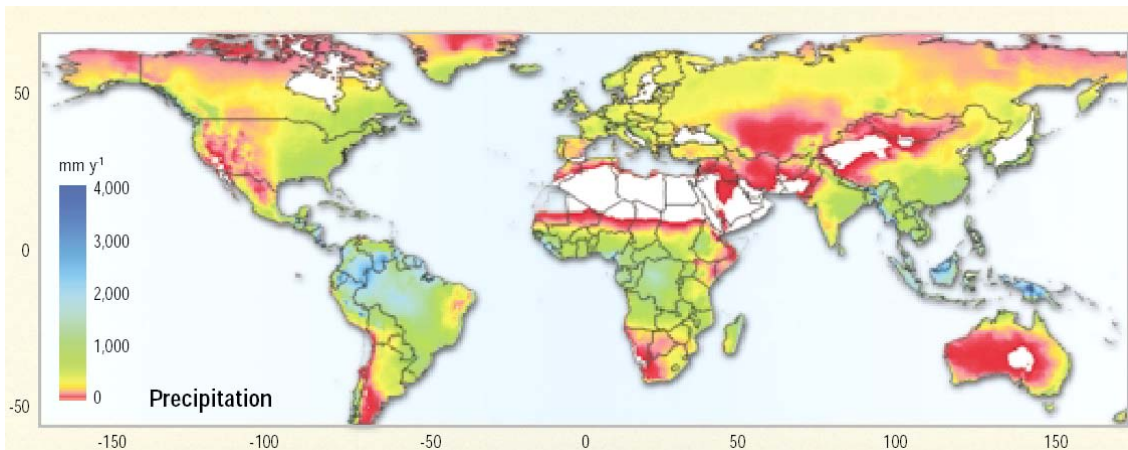


Figure 5 : World precipitations (source: <http://www.iwmi.cgiar.org/WAtlas>)



1.3 State of the art of water stress in the industrial sector

1.3.1 Industrial water use

Every year about 25,400 million m³ of water is used in the European Union for industry, excluding cooling, about 14 % of total European water abstraction (EEA, 1999). Large variations can be observed among countries and industrial sectors. In the industrial sector water is used for many very different purposes and depending on the application different requirements on the freshwater quality are set (van de Worp, 2002). Main water users are chemical, iron, steel, metal and pulp and paper industries (EEA, 2000b). The boundaries for industrial water use can be set as in Figure 6, including pre-treatment, in-process treatment for recycling and wastewater treatment before discharge. Water can be part of the product (raw material) as in the food and beverage industry, but also be used as transport or cooling medium in the pulp and paper and metal industry or can be used for washing or rinsing in the metal and textile industry (WSSTP, 2005). Cooling water is mainly returned to the water cycle unchanged, apart from increased temperature and some contamination by biocides. The amount of cooling water exceeds the amount of water used for the rest of industry (EEA, 2000a).

In the industry water can leave the system either due to consumption or due to discharge into surface water or sewage network after use and recycling. Evaporative losses and water as part of the product are considered as consumptive use (Figure 7).

In Figure 8 total water abstractions and water consumptions as a percentage of total renewable freshwater resources in Europe are presented. Very high water consumptions compared to total water abstraction are observed in Italy, Spain and Greece where large amounts of water are used for irrigation and often inefficient irrigation systems are applied (Figure 10).

Figure 6: Water in Industry, according to TWG3 of WSSTP (WSSTP, 2005)

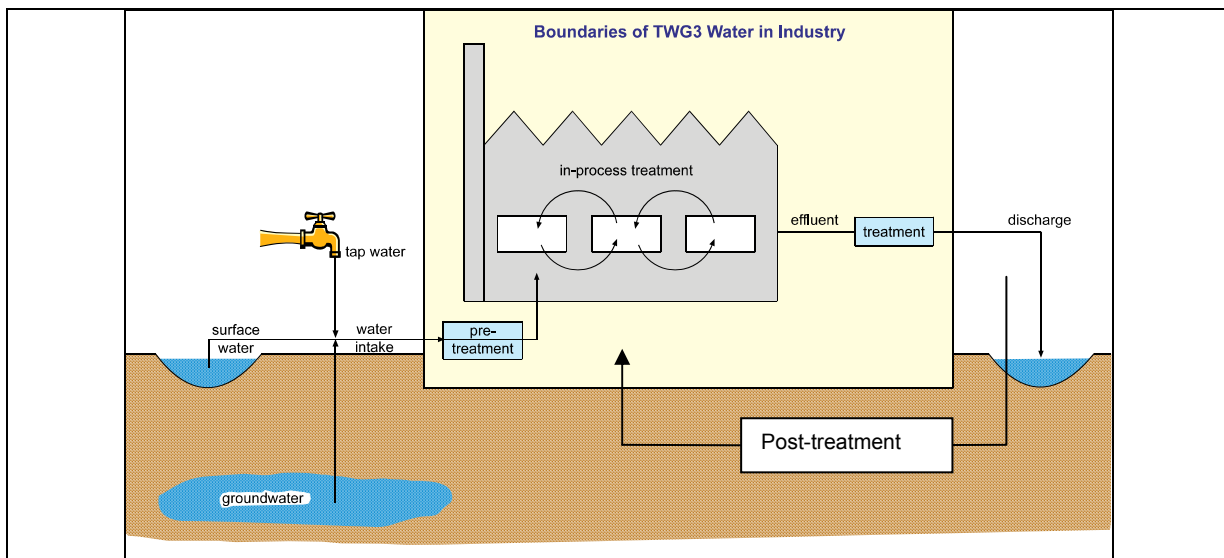


Figure 7: Water use in industry (CH2M Hill, 2003)

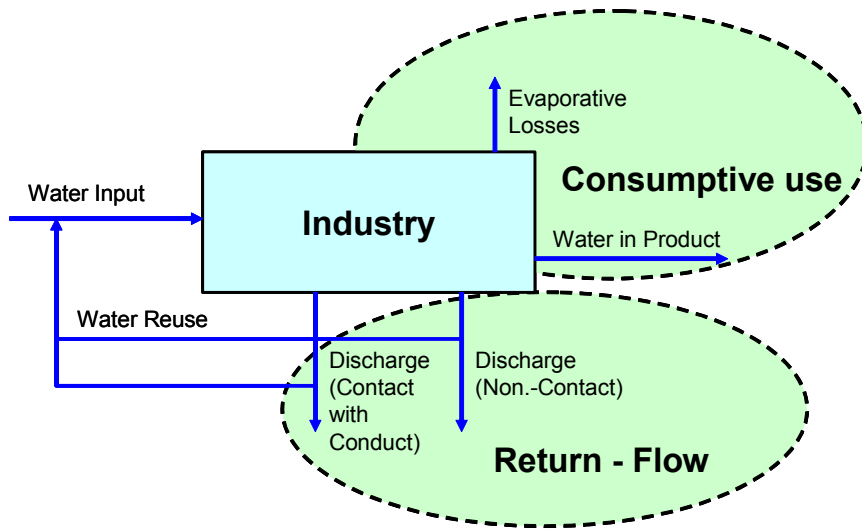


Figure 8: Water abstraction and consumption in Europe (EEA, 2000a)

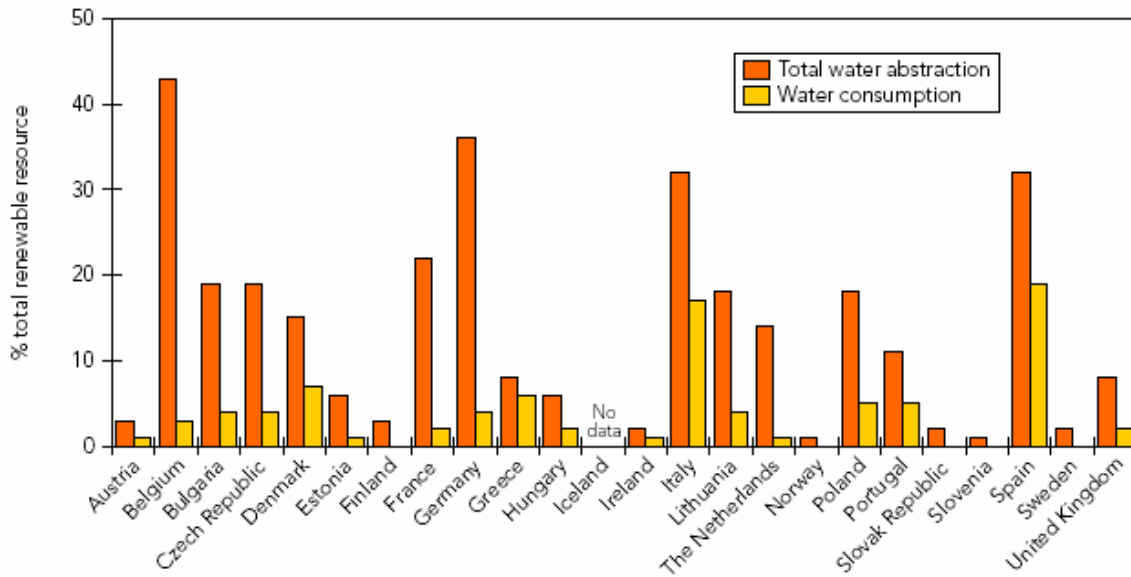
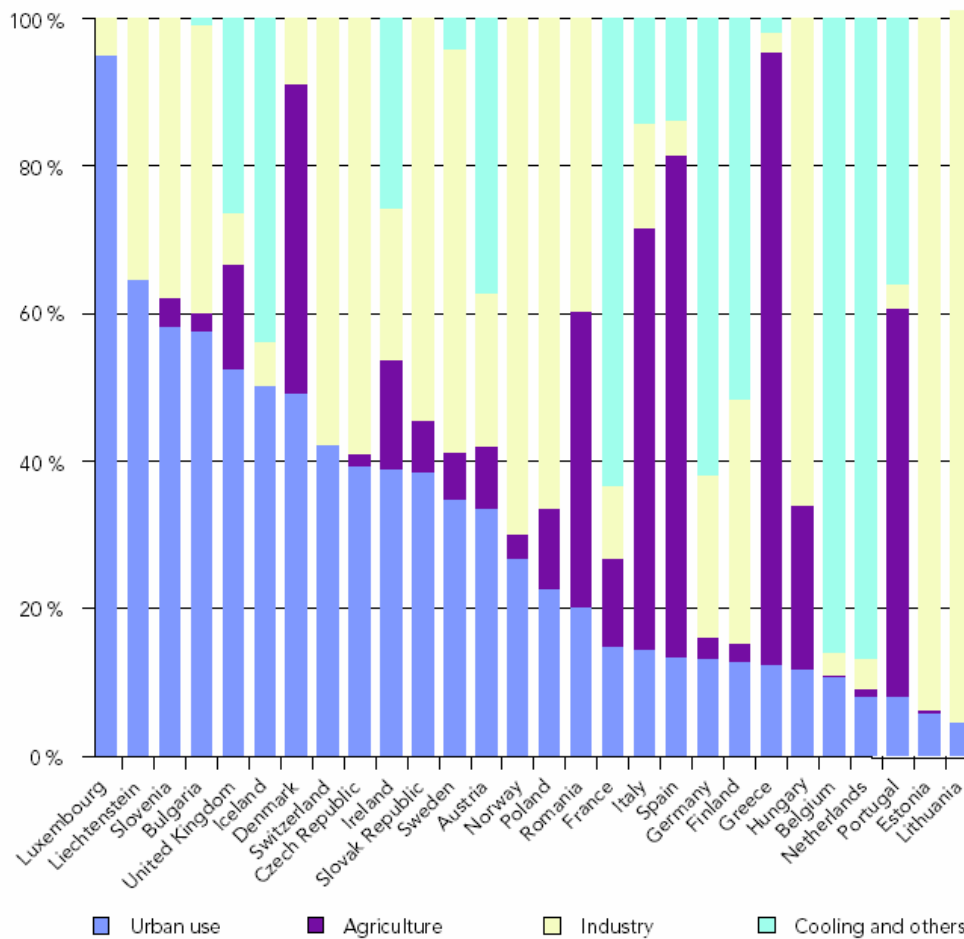




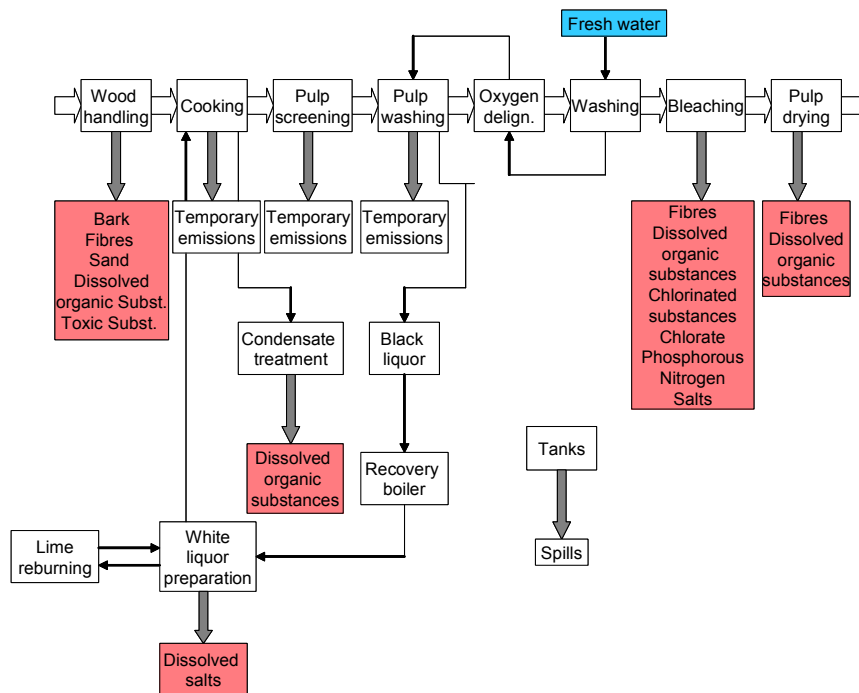
Figure 9: Sectoral water use in Europe (EEA, 2000a)



In countries with high industrial water use (France, Czech Republic, Germany, Belgium, Netherlands, Norway etc.) water consumption is comparably low (Figure 8) since water is mainly used for cooling (Figure 10).

Depending on the industry various requirements for water quality are defined. High quality standards are required in the food industry but also for boiler feed water for high pressure tanks (EC, IPPC, BREF Documents) but also in other industry types certain water quality is required or recommended (e.g. in DIN norms). Depending on the application and the industry type water can be contaminated with various pollutants (organic and inorganic substances, heavy metals, hormones, biotoxic substances, micro-organisms, finishing chemicals etc., Figure 10, example for pulp and paper industry, WSSTP, 2005). Especially when water is in direct contact with chemicals and additives its quality is altering and wastewater can not be directly discharged into surface water or be recycled in the process without any additional treatment. Innovative and complex and often very energy and cost intensive treatment technologies are necessary to ensure the removal of all contaminants from the wastewater and high recycling potential (EEA, 2001).

Figure 10: Processes and water flows with contaminants within a kraft pulp mill (EC, IPPC, 2004)



Many companies are covering their freshwater demand either with water from public supply system, or surface water or are using own water sources such as own wells or treated wastewater and recycling. The wastewater is often pre-treated in own wastewater treatment plants and after that directly discharged into surface waters or discharged in the sewerage system to be treated with municipal wastewaters. In many countries wastewater qualities are strictly regulated and fees for exceeding the quality limits are risen for the companies to enforce the general compliance of the parameters.

1.3.2 Determination of water use efficiency

Due to the large variety of industrial processes and products, often accompanied by insufficient data availability the determination of water use efficiency is often difficult. Two approaches are mainly used to compare and calculate the water use:

- 1.) Specific water use related to product (m^3 water/t or l product)
- 2.) Specific water use related to output of the sector in monetary terms (m^3 water/ € added value) (EEA, 1999)

1.3.3 Water stress in the industrial sector

One of the main pressures on water stress is high water abstraction for all sectors. Considering the water stress definition used in the AQUASTRESS project ("Water stress occurs when the functions of water in the system do not reach the standards (of policies) and/or perceptions (of the population) of an appropriate quantity and quality, at an appropriate scale and the adaptability for reaching those is not given", D2.1-1, 2005) water stress in the industrial sector can appear in different forms.

Water stress due to the industrial sector to other sectors:

- Wastewater discharge into the surface waters without adequate treatment
- Large water quantities abstracted for industry limit other water users

Water stress to the industrial sector:

- Water delivery is not guaranteed, cut-offs, production stops
- Not adequate freshwater quality, costly pre-treatment is required

Often water consuming industry plants have a bad reputation and regional population has a negative attitude towards industry and its impact on the water cycle, even if this position is not justified. Companies have often to invest a lot of money to be regarded as environmentally friendly and get the population's acceptance.

Some economically less important industries have to cope with additional problems compared to big companies. The investments to save water and optimize their processes are often too expensive and the companies can not stay competitive.

1.3.4 Reasons for industrial water stress

In many Central and Eastern European countries poor industrial performance and old installations lead to pollution problems. Contaminated wastewaters can be released in an uncontrolled way and adequate treatment can often not be ensured. Inefficient water use and discharge of toxic substances into the environment are promoted by lack of transparency and strict regulations. The main challenge of industry is to make profits without abandoning high environmental standards and often compromises in benefits are required. (Jimenez-Beltran, 2005)

Water intensive and inefficient processes lead to high water abstraction for industry and limit other water users in their activities. Optimization of processes and efficient water management in a plant can lead to decreased water abstractions and saving water.

In some Southern European countries agriculture is the dominant economic sector and industrial activities have to be limited due to high water demand for agriculture. In drought periods water delivery for industry is not guaranteed and cut-offs and production stops are the result.

Due to the use of pesticides in the agriculture and other pollutants in the highly urbanized region ground- and surface waters are polluted and freshwater for industry does not reach required quality level. In this case costly pre-treatment of freshwater is needed and investments are made.

1.3.5 Strategies to cope with water stress within the industrial sector

Water stress in the industrial sector often **promotes development** of water saving processes and measures, as well as new wastewater treatment technologies for specific pollutants. **Guidelines, supporting software tools and decision supporting systems** for water and wastewater management are elaborated to help companies in decreasing freshwater demand and contaminant loads in the wastewater. In the last decades in the European Union **stricter regulations** on wastewater discharge and industrial water management have been established. European legislation has established with the Directive on Integrated Pollution Prevention and Control (96/61/EC) a common set of rules for industrial processes to prevent and control pollution of the environment. In many cases the positive development can be observed. For example, organic matter discharge from the pulp and paper industry decreased in the last years as more mills now have secondary treatment of their effluents. In order to reduce heavy metal contaminations of surface waters control and reduction of point sources, modernization and construction of sewage treatment plants has taken place (EEA, 2003). **Reference Documents** on Best Available Techniques for different industrial sectors were developed by expert groups and best practices to prevent pollution are recommended. In the United States the Cleaner Production strategy is promoted.

In water scarce regions **water intensive productions are avoided** and certain **shift of technologies** and change of water use patterns is the result. In other processes water is recycled or alternative media to water are searched. The trend in industrial water use is therefore since many years already decreasing.

Charges for abstraction and effluent discharge promote companies to invest in water saving and pollution prevention. Regulations to reduce pollution lead to reduction of water use as a means to reduce contaminant loads (EEA, 1999; EEA, 2001).

1.4 State of the art of water stress in the tourist sector

The Mediterranean is the main tourist destination in the world. Every year millions of people flock to the Mediterranean coasts, with the number likely to reach between 235 and 355 million people per year by 2025. Tourism activity peaks in summer, coinciding with the time when natural water

availability is at its lowest. Storing water in dams and extracting groundwater have, until now, been the solutions to satisfying the ever-increasing thirst for water by ever-increasing numbers of tourists. As a consequence, tourism is making a major contribution to the degradation and destruction of water ecosystems as rivers are being fragmented, groundwater levels are sinking and wetlands are drying out. Lower groundwater levels are not only causing habitats to disappear but are having a negative impact on human communities as the groundwater that is used for drinking water and irrigation is becoming saltier and requires treatment or the total abandonment of the resource.

Every tourist consumes between 300 and 850 litres of water per day. This rate could be reduced by 50%, a daily total of 273.000.000 cubic meters of water basically compensating for the forecasted increase in tourist numbers and associated water consumption by 2025. Hosting, entertaining and supplying the increasing number of tourists along the limited space of the Mediterranean coast will push urban boundaries further inland, most likely destroying in the process the few remaining coastal wetlands and lagoons.

Reducing water consumption and preventing encroachment into wetlands can only be achieved if the tourism industry, the government and individual tourists take concrete measures, such as installing water saving devices, reusing water, enacting water saving policies and adopting a land use plan that respects environmental considerations. Saving water does not have to incur additional costs but can be economically advantageous as hotels save on their water bills. In addition, protecting wetlands means maintaining one of the attractions that people come to see.

Below we give an overview of the current impact of tourism on freshwater resources and freshwater ecosystems and the underlying causes in the Mediterranean. Moreover, facts, data and examples are given for tourism and water consumption in AQUASTRESS-relevant countries.

1.4.1 Overview of impacts of tourism on freshwater sources

Over-exploitation of groundwater. According to Plan Bleu (1999)¹, aquifer overexploitation is considerable in many Mediterranean countries: 13 % in Cyprus, 24 % in Malta (in 1990), 29 % in Gaza, 32 % in Israel (in 1994) and 20 % in Spain (25 % in the Júcar basin, 4 % in the Balearic Islands). Aquifer overexploitation was registered also in Egypt, Greece, Libya, Morocco, Turkey, and Tunisia (Plan Bleu, 2004, figure 1). Its main consequence is the decrease in the groundwater table, which negatively affects wetlands whose hydrological dynamics are directly linked to aquifers. Moreover, over-exploitation in coastal aquifers alters the equilibrium of the interface between freshwater and seawater in the groundwater body, which provokes saline water intrusion. Most Mediterranean coastal aquifers suffer from over-exploitation due to the concentration of agriculture and tourism in coastal areas.

Construction of new reservoirs or water transfer schemes. The growth of tourism is often associated with the search for complementary water sources to satisfy the great demands on water for this economic sector. The combination of water needs for agriculture and tourism has led to the construction of a significant number of dams. At present, in the Mediterranean basin there are at least 500 big dams, with a combined storage capacity of 230 km³. Countries having the most highly developed dam systems – the highest number of dams, with the highest total stored volume and having come closest to reaching the maximum number of dams the country can hold – are Cyprus, Spain, Italy, France and Egypt (Plan Bleu, 2004). Dams are certainly necessary for water supply, energy production and flood control, but they have negative effects on the environment and on people. The indiscriminate construction of dams is to be avoided. A recent study of the World Resources Institute, (WRI, 2004) highlights that dams alter the dynamics of rivers in terms of water flow regimes and transportation of sediments. Dams reduce the speed of the rivers' flow and provoke

¹ The Blue Plan is a process of reflection on the Mediterranean as well as a non-profit organization who leads this process and a research center. The objective of Blue Plan is to promote the sustainable socio-economic development of the Mediterranean region by providing countries with data, studies and proposals for action on the relationships between populations, the environment and development.

water stagnation, which decreases the capacity of the river to break down organic pollutants and therefore to combat water pollution. This leads to changes in the chemical and physical characteristics of rivers that adversely affect fish species, which also suffer from the alteration of their migratory patterns.

Another adverse effect of dams is related to altered water regimes in rivers. The artificial time and volume of water released by dams impacts on waterfalls, rapids and riverbanks and wetlands, which are essential feeding and breeding areas for many aquatic and terrestrial species. Dams hamper the movement of sediments to deltas, estuaries, flood forests, wetlands and lagoons, affecting the composition and productivity of species. Coastal fisheries depend on the rivers' input of nutrients to ensure good fish productivity.

According to Plan Bleu (2004), the concentration of water use along Mediterranean coasts has also led to the construction of water transfer schemes to the Mediterranean coast in several countries (e.g. Egypt, France, Greece, Israel, Libya, Morocco, Spain). The main water infrastructure of the Spanish Hydrological Plan approved in 2001 (and recently revoked due to social pressure) was a 900 km-long transfer of 1050 hm³/year of water from the Northeast to the Southeast of Spain, where the tourist sector has grown 50% in the last five years (WWF, 2003), increasing its competing role for water with intensive agriculture.

Pollution of surface and groundwater. Insufficient, inefficient or non-existent wastewater treatment systems have a direct negative impact on the quality of water and therefore on the ecosystems associated with them. According to a study of Ramsar² sites (Frazier, 1999), pollution, water regulation, and urbanization and settlement impacts are among the five most frequently recorded change factors in Ramsar wetlands over the world. Of these, pollution is the most important one in Eastern and Western Europe. In Greece, for example, hotels located near the coast are often not connected to any sewage system. For this reason, local authorities require hotels to build their own treatment plants, usually designed as pre fabricated units. However, the lack of staff training and the seasonal aspect of wastewater production is causing operational problems, which reduce the effectiveness of treatment (EC, 2000).

Another source of water pollution is leakage from solid waste. In isolated areas or where the normal solid waste disposal system is not able to absorb peaks in waste production caused by the seasonal influx of tourists, the quality of freshwater can be affected by leakages from uncontrolled or inadequate disposal of solid waste. Although Plan Bleu (2004) highlights that it is difficult to give any overview of water pollution due to the high variety of causes and processes (point or diffuse pollution, accidents or chronic pollution) as well as of the variety of temporal and spatial effects of pollution processes, it is clear that the pollution of water has a negative impact both on natural ecosystems and on economic activities directly related to tourism. The pollution of ground or surface water makes it necessary to increase the treatment processes to produce drinkable water and, in some cases, makes it impossible to use water for human supply (e.g. for its high salinity). The contamination of rivers, lakes, wetlands and other aquatic ecosystems, causes the decrease or even the disappearance of many terrestrial and aquatic species, and also prevents local people and tourists enjoying bathing and other leisure activities. Finally, polluted rivers and lakes, together with direct discharges of poorly

² The Ramsar Convention on Wetlands is an intergovernmental treaty, which provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. The Convention's member countries (Contracting Parties) commit themselves to:

- Designating at least one wetland that meets the criteria for inclusion in the *List of Wetlands of International Importance* (Ramsar List) and ensuring the maintenance of the ecological character of each of these Ramsar Sites. Parties are encouraged to include in the List as many wetlands that meet the criteria as possible. Listed sites do not necessarily require protected area legal status, provided their ecological character is maintained through a wise use approach;
- Promoting the wise use of all wetlands within their territory through their national land-use planning, including wetland conservation and management;
- Promoting training in wetland research, management and wise use;
- Consulting with other Parties about the implementation of the Convention, especially with regard to transfrontier wetlands, shared water systems, shared species, and development projects that may affect wetlands.

treated or untreated wastewater also affect the quality of the seawater into which freshwater drains. EEA (2000) estimated that tourism contributes to 7% of all pollution in the Mediterranean Sea (industrial and urban wastes, including sewage, polluted rivers draining into the sea, crude oil dumped by all activities, detergents, mercury, phosphates, eutrophication). Health problems such as infections of the ear, nose and throat, hepatitis and dysentery can result from swimming in polluted seawaters.

Occupation of wetlands areas. Coastal areas often host unique ecosystems in deltas estuaries and lagoons, where birds, fish and other aquatic and terrestrial species dwell and breed. More than 50% of the 25,000 plant species in the Mediterranean are endemic to the region (UNDP, 1999). Mediterranean wetlands are also critical areas for migratory birds: it is estimated that about 2 billion migratory birds of 150 species use the Mediterranean wetlands as seasonal sites or as a stopover before crossing the sea or the Sahara desert in their Africa-Paleartic flyway (UNDP, 1999). Overdevelopment of the coast means that attention is directed increasingly towards Mediterranean wetlands for accommodation and recreational facilities. In the Moroccan region of Saïdia Ras El Ma, the planned construction of a tourist resort on the estuary of the Moulouya estuary might severely affect a very important resting site for migratory birds.

Tourism has contributed to a significant occupation of flat shorelines and beaches. Hotel infrastructure, at first concentrated near seaside towns and has proliferated everywhere on the coast. According to estimates, the urbanized coastal areas cover 140 km and tourist areas occupied by hotels and second homes cover 80 km. This adds up to a total of 220 km of artificial coastline (18 % of the total Tunisian coastline). With ongoing projects, about 150 km of the shoreline will be occupied by tourist activities (e.g. hotels, leisure installations, and holiday villas). Building tourist infrastructures too close to the shore and especially on the shore dunes is accelerating the process of beach erosion and the alteration of water dynamics that, for example in case of flash floods, causes significant damage. Hence, urbanized areas and other economic activities are moving to wetlands, especially in coastal areas. Wetland disappearance or degradation contributes to the decline of species that depend on them to survive: the number of water birds has decreased by 46% during the last 15-20 years and twenty globally threatened bird species live in the region (UNDP, 1999).

Degradation of sensitive wetlands. Tourism intensity contributes to the degradation of certain sensitive wetlands near tourist hotspots. Recreation and tourism is listed as the second major use of Ramsar site wetlands both in Western Europe, Eastern Europe and in Africa (Frazier, 1999). This means that wetlands - especially the protected ones - are a tourist attraction and when their recreational use is not strictly regulated and monitored it can cause negative impacts on species dwelling in the area. Indeed, except for very specific and local cases (e.g. the degradation of small protected wetlands on the dunes of Doñana, Spain for the decrease of groundwater levels due to water supply for the tourist Matalascañas village), wetland degradation is due to a combination of causes (e.g. agriculture, tourist, industrial development). EEA (2003) reports a loss of habitats in transitional and coastal waters related to intense pressures due to "high human population densities", without specifying how much was lost and due to what. A study on wetland loss by Wetlands International (1996) concludes that it is not possible to draw an overview at a regional level due to the diversity of methodologies used to measure wetland loss, and the lack of coordination between studies in different countries or for different wetland types. According to the same study, in Africa, the only quantitative information arises from the wetland inventory of Tunisia, which reports an overall loss of 15% of wetland area, and 84% loss in the Medjerdah catchment.

1.4.2 Causes

The main causes of the impacts on freshwater ecosystems described in the previous section are:

High water consumption due to population increase. Tourist areas suffer from significant fluctuations in the number of local dwellers that have to be supplied with freshwater and consumption peaks normally occur in the dry season, when tourist demand overlaps with high water demand by agriculture. In the 1990s, it was estimated that nearly 135 million tourists (international and domestic) visit the Mediterranean coast every year, doubling the local population (EEA, 2000). In certain areas and at certain times of the year the population can increase two, three or even ten or more fold.

Higher consumption of water for associated facilities and leisure. Tourists require constant access to water. A tourist staying in a hotel uses on average one third more water per day than a local inhabitant (EEA, 2000). Moreover, extensive landscaping, water parks, swimming pools and golf courses are typical tourist facilities that require water during the dry season. In Cyprus, where water resources are very limited, eight golf courses are under construction. On average, a golf course needs between 10,000 and 15,000 m³ of water per hectare and year (similar to the requirements of a rice pond!). The surface of a golf course lies between 50 and 150 hectares, which means that the annual consumption of a golf course is around 1 million cubic metres per year or the equivalent of the water consumption of a city of 12,000 inhabitants.

Peaks in wastewater volumes, inefficient or non-existent wastewater treatment facilities. According to EEA (2000), tourists consume up to 300 litres and generate around 180 litres of wastewater per day. Indeed, the largest proportion of water is not consumed but used and disposed of as waste. The result is large volumes of sewage discharged to sewage treatment plants, or to the sea and rivers, because many tourist facilities are in isolated areas and are not connected to the water treatment network. In all cases, if water is not treated, recycled or disposed of properly, it will cause pollution.

Urban development associated with tourism. Tourism leads to urban development because it needs facilities not only to host, feed and entertain tourists, but also to transport them, care for them (e.g. hospitals), treat their wastes etc. Moreover, economic growth is normally associated with growth of the local population that provides services to tourists. All these facilities occupy land and transform the landscape and the natural dynamics of wetlands located near tourist resorts. Accommodation (80% of all tourism and leisure construction) has a major impact on water resources, land use and ecosystems. The growth of the number of second homes during the 1990s created more intense pressures on land and the environment, especially in coastal and mountain zones.

Transport infrastructures associated with tourism. The tourist industry requires efficient facilities to transport huge amounts of goods (food and all type of goods that can be sold to tourists) to tourist resorts and, of course, to bring tourists to their destination. The construction of transport infrastructures often negatively affects the water resources, as well as the environment as a whole.

1.4.3 Tourism activity and trends in water consumption

The Mediterranean is the world's leading holiday destination, accounting for 30% of international arrivals and 25 % of receipts from international tourism. Tourism activity along the Mediterranean coast has increased dramatically over the last decade. The number of tourists in Mediterranean countries is expected to reach between 440 and 655 million in 2025 (with 235 to 355 million on the coastal region), almost double the 1990 numbers (260 million, with 135 million on the coastal region). There has been and will be increased tourism activity in coastal areas where important wetlands are located (see above maps), as well as an expansion of tourism into wetland areas previously unvisited by tourists on a large scale. In southern western Europe (France Greece, Italy, Portugal and Spain) tourist arrivals increased by 91% between 1985 and 2000 (EEA, 2000). Over the last 40 years mass tourism has developed into an important source of income. At present, income through tourism accounts for about 1.2% of the total GDP in OECD countries (EEA, 1999) and, in countries with a strong tourist sector this share may rise to over 4% (Greece, Portugal, Spain).

In most countries there are no specific figures on water consumption by the tourist sector, which is normally included in the urban supply statistics. Even figures referring to urban supplies are estimates of consumption and not direct measurements and to get an overall picture of water consumption trends in tourism, we can only observe trends in water consumption for urban supply. According to Plan Bleu estimates (Plan Bleu, 2002; Plan Bleu, 2004) water demand for urban supply seems to be stabilizing in European Mediterranean countries, after a strong growth in the 1970s and 80s. It is expected that water demands will double in 20 years in Turkey, Syria, Libya, Algeria, Morocco. Growth has been slower and tending to stabilization in countries with a high water scarcity, like Israel, Cyprus and Malta (Plan Bleu, 2002). Where there is data on water consumption for tourism, a clear increase has been detected. In Tunisia water demand for tourism more than doubled between 1977 and 1996; the Balearic Islands (Spain) used 15 times more water between 1980 and 1995.

It is important to notice that tourism is not the main water consumer: water demand for human supply is 13% of the water demand in the Mediterranean, while for agriculture it is 63%. Although tourism exacerbates water supply problems by concentrating water demand in very short periods of time (Easter, Summer, Christmas, New Year) and in limited areas. Moreover, tourism has demanding standards in terms of quality and guarantee of supply. This means that facilities and water availability must be ensured with water infrastructures (reservoirs, water transfer schemes) that are “oversized” during most of the year. Moreover, A quite common trend in Mediterranean countries is the decrease of the share of water consumption by agriculture – which is still the main water consumer – and, in parallel, the increase of the percentage of water consumed by urban areas and tourism. Tourism demand in some cases can cause problems for the local population.

In general, Water Authorities answer water demands for economic sectors like tourism by applying a supply-oriented approach. This means that the Authorities work only on increasing water availability and, in this way, contribute to creating the false belief that water consumption can be endless. On the contrary, they should question (and increase) the efficiency of current water use and discuss the compatibility of economic growth based on the available water resources. This short-sighted approach has increased the pressure on conventional resources and has favored exploitation practices (groundwater over-exploitation, exploitation of non-renewable resources, construction of a high number of dams) that are unsustainable in the medium-long term because they are not able to ensure the present water supply levels. On the other hand there is an emerging trend to reuse water, which is particularly under development in Mediterranean countries where resources that are still available are becoming scarce.

1.4.4 Opportunities to reduce tourism water consumption and its impacts on the environment

Applying existing technology to save water in Mediterranean hotels could bring about a significant reduction in water demand and could possibly accommodate a further increase in tourism without more dams being constructed. According to the EEA (2001) water saving devices can save up to 50% of water. Assuming a doubling of the number of tourists in the Mediterranean by 2025, a savings potential of 50 % would amount to a total of 273.000.000 cubic meters of water per year. Many effective water-saving devices (e.g. can be purchased at a reasonable price with some of the devices not requiring any structural modifications. Temporised taps, water-saving devices for traditional taps, water saver for toilets

The tourism industry should be directly concerned with the impact of its activities on freshwater because: 1. decreasing overall water use can lead to cost savings; 2. reducing water use can conserve and protect the local water resources upon, which a hotel and the local community depend; 3. preserving the quality of local water resources can reduce the need for costly drinking water treatment processes; 4. water conservation can enhance reputation among guests and others who are concerned about reducing water consumption and protecting local resources.

According to UNEP (2001), around the world there are some 70 ecolabelling and certification programmes offering logos or seals of approval. These programmes focus on sustainable tourism in general, and wise use of freshwater in particular. Green certification programmes involve a combination of stakeholders – industry, consumers, NGOs, host governments and local communities – and cover a variety of geographical areas. Europe alone has about 30 programmes for accommodation services. Today the most popular EMS certification programme is ISO 14001, which is being used, for example, by Green Globe, IHEI, Green Flag for Green Hotels in Europe, and a number of individual hotels and chains around the world. Due to the variety of certification systems, it is difficult enough to evaluate the effectiveness of certification in reducing the impact of tourism on the environment, let alone on freshwater ecosystems. In Europe the EEA (2001) reported that there was a five-fold increase between 1990 and 2001 in the use of ecolabels for accommodation, but there is no evaluation of this data.

Let us turn to government involvement in tourism development. Traditionally tourism development depends to a great extent on initiatives taken by the private sector (i.e. all companies operating in the



tourism sector), but now authorities – especially the local ones - are increasingly involved in developing and managing tourism activities. National authorities also have an important role to play in creating conditions for more sustainable development of domestic tourism. To reduce the negative impact of tourism on freshwater ecosystems, competent authorities should: 1. prepare overall strategies for tourist destinations based on dialogue with the private sector, local authorities and NGOs: a kind of 'vision' of what kind of future each tourist resort aims at; 2. participate in the enhancement and management of tourist destinations, balancing the interests of the environment with those of residents, tourists, operators; 3. generate partnerships between public and private actors to foster the achievement of environmental objectives, 6. promote the re-investment of part of the profits of tour operators in local development projects; 4. launch campaigns to inform the tourist communities (tourists and providers of services and goods to tourists) about the advantages of embarking on strategies and action plans for sustainable tourism, and support them in their efforts; 5. strengthen capacity building in local communities and encourage networking, particularly between communities in the same major tourist region; 6. strictly regulate tourist growth taking into account its impact on freshwater ecosystems; 7. protect wetlands and areas with an high ecological value from pollution and construction; 8. Increase the efficiency of the water distribution system; 9. apply water use and sewage charges according to water consumption and including not only the total costs of capital, operation and maintenance of water infrastructures, but also associated environmental cost of supply and wastewater treatment; 10. improve water treatment network and plants; 11. oblige isolated tourist resorts to treat their wastewater and control the effectiveness of wastewater treatment systems; 12. install water saving systems in new or renovated buildings; 13. strictly enforce rules and regulations related to tourism (land use planning, water use and treatment); if the risk of being found guilty is low or the penalties are small compared to the profits, there is little incentive to abide by rules.

1.5 State of the art of water stress in the environment

Two approaches exist to assess environmental impacts of anthropogenic stressors. One is to determine standard guidelines for relevant abiotic variables and compare measured levels of these variables to the guidelines. Examples are critical loads of nitrogen deposition (Bobbink et al., 2002), minimal flow values for rivers (Smakhtin et al., 2004) or maximal pesticide concentrations (). The other approach is to measure the response, i.e. ecosystem health or a related concept, directly. Both approaches have advantages and disadvantages, and may be used complimentary (Pennings et al., 2002). A good example of the latter are the current guidelines for the Water Framework Directive, where biological indicators (based on species indicating the condition of the aquatic ecosystem) and abiotic indicators (based on water quality, quantity and morphological alterations) are used simultaneously to compare an aquatic system to a reference situation, and thereby determine its condition, linking it to specific issues that have to be dealt with to improve this condition.

1.5.1 Critical levels, loads and resilience

The advantage of the approach of using a comparison to set standards is that pressures on ecosystems are unambiguously identified, and goals for remediation can be agreed upon on a broad scale. Disadvantages are that it is often difficult to link the effects of not meeting the standards to biological impacts, especially when different pressures are acting synergistically or the degree of vulnerability to a certain pollutant depends on other environmental factors (Pennings et al., 2002). Furthermore, the effects of pressures on ecosystems are typically not linear. Very different types of responses exist, with effects building up or decreasing over different time spans, or even only occurring over a long term period.

The most simple responses are direct toxicity effects, where a certain critical level or concentration of a pollutant causes a certain type and extent of damage to certain organisms. These types of effects may be found in response to e.g. pesticides in aquatic environments, and are relatively easy to quantify.

Another type of standards are critical loads, as exist e.g. for atmospheric nitrogen deposition. The underlying assumption is that an ecosystem is able to absorb a certain amount of, in this example, nitrogen, without being affected in its ecological functioning. Loads higher than the threshold do not immediately lead to direct damage to certain organisms, but in time alter the competition between

species in such a way that the ecosystem is drastically changed (e.g. Lamers, 2000). Even if this assumption is actually met, determining the thresholds requires experimental ecosystem manipulation, at low doses and over a long period.

Once the balance between functional processes is affected compared to a “pristine” state, the resilience of the ecosystem changes and most typically decreases. However, most often this is not directly “visible” in the most easily identified properties of the system and if the state of the ecosystem would be assessed, no effects would be found. Only when a threshold is crossed, or an additional pressure (“trigger”) is added, a cascade of effects, each occurring over different time scales, may then alter the ecosystem to a new stable state (for a more extensive discussion see Folke et al., 2004). The trigger for this series of events would have no consequences in the “pristine” system but causes a complete collapse in the system with eroded resilience.

1.5.2 Assessment of ecosystem condition, integrity or health

The ecosystem health approach has as an advantage that it is possible to identify the (integrated) impacts on natural systems and it allows the assessment of ecosystem condition without the need for detailed measurements of each potential stressor. A standard monitoring could then be used on a wide variety of sites to determine which ones need more intensive and expensive study. The disadvantage is that it is often not possible to identify the causes of the variation in health of different ecosystems, and thus further investigations are needed before a path for remediation can be decided upon. (Pennings et al., 2002) A further complication is that there is as yet not a simple way to measure ecosystem health, even assuming a general societal consensus on its concept (but see discussions in e.g. Karr, 1999; Fairweather, 1999; Boulton 1999). Most ecologists agree that a healthy ecosystem is as “natural” as possible, with a minimum of anthropogenic impacts. The problem is how to reveal and express departure from this natural state exceeding background variability, especially if no (data on) unmodified reference systems are available (Boulton, 1999). Though especially for aquatic systems a large effort is made to develop indicators and indicator systems, there is not one “holy grail” and most are situation specific. But always the data must be collected especially for the purpose “is this river healthy” (Boulton, 1999), which restricts severely the use of existing data and adds to the financial burden of already overstretched budgets.

Carignan & Villard (2002) reviewed the concept and selection of indicator species for assessment of ecosystem condition. They conclude that due to niche separation, no single species should be expected to act as an indicator for an entire ecosystem, with different taxa representing different sensitivities to different impacts in different situations. Furthermore, many factors unrelated to degradation of ecosystem condition may affect the presence and abundance of an indicator species, and thus complicate the interpretation of the results and linking to anthropogenic pressures. It is stressed that the selection of indicator species should be at least partially based on quantitative rather than qualitative criteria, to reflect on site ecological conditions rather than a perception of species importance. (Carignan & Villard, 2002) This requires good databases with reliable data collected on site, something which may not always be available. Other approaches include the focus on communities or guilds as indicators or indices of ecosystem condition. These indices are very useful at a coarse level, but may not be appropriate to detect changes at a finer scale or as early warning signs (Carignan & Villard, 2002). Alternatively, the measurement of ecological processes has been proposed as a measurement of ecosystem condition. Carignan and Villard (2002) conclude that no single perfect method exists for a complete assessment of the ecological integrity of any particular system, however, a solid framework has been developed which should at least give insight in whether ecosystem condition is increasing or decreasing. By monitoring indicators at other organizational levels at the same time, interpretation of indicator species response to environmental changes can be improved.

2. Major knowledge gaps to characterize water stress in the different sectors

In 2005, WB1 and WB2 have made contributions which summarised the findings and assessments of recent research on water stress in the test sites³. Its aim was to heighten awareness of water stress as an issue for the test sites. Although there are still many gaps in our understanding of water stress, and of its likely impacts on the agriculture, domestic, industrial sector and the environment during the last reporting period there has been a considerable investment in research as a whole. The results of further research since then have also added to our increased understanding of the issues and likely impacts on the sectors. Large amounts of useful information have been gathered on the test-sites on the water situation in general but still main significant gaps in the knowledge base are there, much of the relevant knowledge for the characterisation on water stress that does exist is not widely shared, easily accessible nor well managed.

Especially in the following sections major knowledge gaps to characterise water stress will be figured out. Based on the work done by WB2 the sectors have been defined as:

- Domestic sector
- Agricultural sector
- Industrial sector (including the tourism as service sector)
- Environment

It is difficult as well to get records on the accuracy of data, timescales and adaptations of institutions. However, it should be emphasised that the confidence around the whole issue of adaptations and timescales is limited by knowledge gaps and the effects of other drivers of change.

2.1 General comments on gaps

2.1.1 In regard to water availability

The evaluation of the water availability in a site requires adequate data to fully describe water resources. It is well known that poor records are a major obstacle in proper water management. Moreover archives of hydrological data are not always easily accessible and many localised but still important sites (e.g. areas of intensive exploitation) are not monitored at all.

The conceptual model described above doesn't always fit to all situations depending on the quantity and quality and the spatial scale of the available data, and that's often the case independently of the scale. However it is usually easier to establish an acceptable balance for an entire river basin than for a smaller part of it, due to the existence of measuring devices at the closure of the main rivers in Europe.

Some of the AquaStress test site are lacking of sufficient data for this type of assessment, and other strategies for the evaluation should be foreseen.

In other cases data are available and many previous studies have been undertaken in order to establish the water budget in view of a sustainable management. Hence a preliminary assessment could be undertaken.

2.1.2 In regard to seasonal variation

In many climatic conditions but especially in the Mediterranean area, spring and river discharge can vary consistently from the dry season to the wet season. In all cases where the seasonal variation is not negligible the minimal availability should be considered, and compared to the demand in the same

³ See D1.1.1 and D2.1.1.

period which in general increases against the seasonal decreasing of resources. However seasonal variation is not always well reported while mean annual values are more often available.

2.1.3 How much of the recharge can be accounted for as available groundwater resource?

This is a question to which a satisfactory answer has not been given yet. There is a common opinion that this could be equal to the recharge, assuming that the entire volume of recharge entering the aquifer (via effective infiltration, lateral recharge, surface water leakage, etc.) could be abstracted by pumping or diverted from springs. In Sophocleous (2000) an extensive explanation of why this opinion is false is given.

Concerning groundwater issuing at springs, the most important limitation is the conflict with other downstream users, from the natural system demand (minimal vital flow) to the human's activity (agricultural, tourism, industrial, civil) demand. However the amount of water that can be diverted cannot exceed the natural discharge of the aquifer (eventually slightly increased with local technical improvements).

On the other hand, groundwater abstractions by pumping wells constitute supplementary outputs of the system which necessarily produce a disequilibrium of the groundwater table which starts to lower. In theory the lowering should stop when the new hydrodynamic equilibrium (chosen on the grounds of management decisions as well as ecosystems constraints) of the aquifer is reached. The time period needed for this depends essentially on the hydrodynamic characteristics of the aquifer and on the distance with a constant head boundary (e.g. a river or the sea).

From a theoretical point of view, which is obviously subject to some limitations but is not far from reality, the abstraction of an amount of groundwater which is equal to the recharge is not sustainable for a long period, because the only hydrodynamic equilibrium for the water table in this conditions is a piezometric field in which all the flow lines are directed towards the abstraction points and nothing is issuing towards the former natural springs.

2.1.4 In regard to quality of waters

Quality (natural and anthropogenic modified) is besides the availability the most important aspect of water resources. Water quality characterisation comprises several properties besides quantity, given by physical, chemical and biological parameters.

The origin of quality degradation is possibly due to point and/or non-point source issues, the latter being mostly related to agriculture (fertilisers, pesticides). A gradual shift towards non-point source pollution control in developed countries has been noticed (Somlyódy, 1995). Possible sources and mechanisms for water quality degradation (farming activities, untreated urban waste waters, industrial activities, unsustainable water management, but also natural contaminants and so on), should be known in order to plan a suitable monitoring activity.

As a general consideration, water management planning should take into account the destination of resources and compare it to their quality; an effort should be made to reserve good quality resources and less vulnerable for the human consumption and provide the already contaminated waters to other functions which need less stringent quality standards.

The water quality of rivers and reservoirs as well as that of ground waters must be monitored, both in order to track the evolution of natural quality and with regard to the different sectors of possible use. For the drinking water supply as so for agricultural purposes the water quality is even of high relevance.

Concerning surface waters, due to the widely occurrence of temporary waters in the Mediterranean region, with rivers regularly falling dry for several months, the monitoring and data collection is hampered. As only few knowledge and experience is available so far about the function of such

systems the adaptation of water management and monitoring schemes according to their specifications is at a starting point.

Even if there are also various models for simulating water quality in streams and reservoirs available, mostly they are not feasible for representing the characteristics of semi arid and arid regions. Based on this, the need for improved monitoring systems and simulation models became apparent in order to improve the knowledge and understanding of systems suffering under water stress.

Groundwater monitoring is usually well developed (i.e. an acceptable density of measuring points is frequently reached) on phreatic alluvial aquifers, due to the existence of several wells reaching the water table which can be included in the network with a low effort by public boards; much less information is available on the deep levels of these aquifers. In mountain regions (e.g. karstic aquifers, fissured crystalline aquifers, etc.) monitoring activities generally consider the natural outlets (springs). A further problem exists when aquifers feed directly into the rivers ("linear" springs) which are very difficult to monitor due to the interaction with surface waters,

An important knowledge gap concerns the effects of polluted waters on human health, especially of the so-called "new generation contaminants" (e.g. endocrine disrupters, pesticide metabolites, antibiotic) which are rarely measured in waters. Epidemiologic research exists but long term effects are rarely taken into account. Most of the available data on water quality deal with the "traditional" pollutants, e.g. nitrates, pesticides, bacteria and sometimes certain heavy metals.

2.2 Knowledge gaps to characterize water stress in the different sectors

2.2.1 Domestic sector

2.2.1.1 Increasing household demand

Human drivers of increasing household and per capita water consumption include population growth (EEA, 2001; Ofwat 2000a), higher household numbers (Ofwat, 2000a; AWWArf, 2001), lower household occupancy (Mitchell, 2001; Ofwat, 2000a), and lifestyle changes related to technology, personal habits and affluence (Princen, 1999; EEA, 2001). The domestic sector has the largest number of individual water users among the three human use sectors (i.e. agriculture, industry, and domestic) and each household has its own disaggregated water use characteristics which make identifying causes of inefficient use and mitigation measures in the domestic sector a major challenge to the water manager. This is a major knowledge gap and is listed in Table 2 (below).

Water services in the domestic sector are concerned with the distribution of water for household consumption and removal of sewage. Domestic water stress occurs when water is not supplied in the necessary quantity (i.e. due to supply interruptions), or quality. Supply interruptions are most commonly caused by intermittent drought. Faced with rising demands and increasing supply uncertainty there is a pressing need to engage governments, water utilities and the public on domestic water conservation issues if future water shortages and environmental problems are to be avoided. However, up until recently the main solution to addressing water shortages was to exploit new sources of supply. The growing consensus that reducing human demand is a more sustainable method of addressing the imbalance between supply and demand has led researchers (see Michelson et al, 1999; Renwick and Archibald, 1998; Maddaus, 2001; Howarth and Butler, 2004) and environmental organisations (UK Environment Agency, 1997; USEPA, 2002; Read, 2005); to recommend that municipal and private water utilities adopt an Integrated Water Resource Management (IWRM) approach in which Demand-Side Management (DSM) options are employed in conjunction with conventional supply activities to address water shortages.

Water savings from domestic water conservation strategies are prone to uncertainty due to variation in uptake of water conservation tools (e.g. low-flush toilets and other water efficient household appliances) among different demographic groups and, as already mentioned, variation in water consumption among different demographic groups in different household types. Achieving coverage of water conservation tools depends on a number of factors. These include financial factors such as the

cost of installing vs. the potential savings, willingness to make lifestyle changes, access to suitable technology etc. In order for water conservation tools to reach the target population it may be necessary to introduce specially designed policies to encourage uptake. Lack of knowledge about institutional and societal receptivity to water conservation tools is considered to be a major knowledge gap and is included in Table 2 (below).

2.2.1.2 Infrastructure leakage

Unaccounted for water (UFW) (e.g. leakage losses, unlicensed abstraction) is a major problem for water suppliers in many areas of Europe. In some regions UFW is over 50%. The financial investment required in detection of causes of UFW (i.e. cracked underground pipes) remains the major barrier to reducing UFW. In the UK, leakage has decreased from 31% in 1995 to 21% in 2000 following endorsement by OFWAT, the water sector regulator, in 1989 of the view that water companies should reduce their leakage to a level known as the economic level of leakage (ELL). This is the level of leakage that balances the cost of controlling leakage - which tends to rise as the level of leakage is reduced - with that of replacing water lost through leaks. The economic level of leakage differs from company to company depending on factors such as the condition of their water supply system and the availability of local supplies of water. Reducing leakage to the economic level minimises the cost of meeting customers' requirements for water (NAO, 2000). The difficulty in detecting leakage, as already mentioned, makes identifying the economic level of leakage (ELL) particularly problematic and open to uncertainty. As such this remains a major knowledge gap and is listed in Table 2 (below).

2.2.1.3 Public involvement

Implementation of mitigation options inevitably requires public interaction and co-operation leading to uncertainty about the impacts of any mitigation strategy. Meanwhile the objective of maintaining sustainability principles (i.e. equity, socio-economics, and environment), which sometimes raises conflicting issues, needs to be addressed. Privatisation, as a means of rehabilitating and updating water supply networks and attending to the complex management issues, is a path that is now considered necessary in many countries undergoing development (Jamati, 2003; Howarth, 1999). However, privatisation brings its own problems. The cost of rehabilitation and expansion is inevitably reflected in increasing water bills for the domestic consumer. If this is not managed sensitively it can lead to negative public perceptions of the water company, resulting in lower public co-operation. Public-private partnerships, where the existing public owned water network is taken over by a private organisation for a limited concession, is now considered to be the way forward in countries undergoing development. Concessions allow the public body to maintain some level of control by monitoring and regulating the private partner, whilst private involvement (hopefully) brings much needed investment and innovation.

2.2.1.4 Wastewater treatment

Drinking water quality parameters (i.e. nitrates, heavy metals) and domestic effluent quality have been discussed in detail in a previous AQUASTRESS report (see D2.1-1, Section 4b). One major wastewater effluent quality issue which should be reiterated here is the inability of some water utilities in different regions of Europe to meet the UWWTD effluent consent levels, which is in its self an indicator of water stress. This should be of particular concern in areas of environmental sensitivity, or where there is a high risk of polluting valuable groundwater sources through infiltration. Knowledge gaps exist relating these two factors (see Table 2, below).

2.2.1.5 External factors

External issues, which are generic to other sectors, impact on the domestic sector. The temporal availability of water is often at odds with domestic sector consumption patterns (i.e. higher summer demand). Groundwater is a major source of drinking water in many regions and may require specific management consideration (i.e. protection) depending on the aquifer characteristics and human

activities in the overlying region. Technological mitigation options may be impractical or unaffordable. Affordability is also linked to the price of water, which has a greater impact of lower income sections of society.

2.2.1.6 Crisis vs. risk management

Water allocation systems are challenged by hydrologic droughts, which reduce available water supplies and can adversely affect environmental systems and increase the risk of conflict between sectors. The need for a paradigm shift in local and national water drought management policy away from crisis management to risk management, suggested and described by Wilhite (2005), emphasises the need for a long-term planning approach to managing water resources in drought prone regions. He points out that, where the crisis management paradigm is used in policy-making, it can result in a relief-reliant culture which is, in effect, only rewarded for acting once the crisis is looming, thereby rewarding the poor resource manager. At same time the crisis management paradigm gives no incentive for good stewardship of natural resources. EU policies might be used to encourage this much needed paradigm shift from crisis to risk management. However, the pathways by which policies might encourage this shift can be considered a major knowledge gap.

Knowledge gaps to characterise domestic water stress identified in this report relating to: water consumption; water pollution; water conservation, and integrated options are and listed in Table 2 (below).

Table 2: domestic sector gaps

CATEGORY	KNOWLEDGE GAP
Domestic water consumption	<ol style="list-style-type: none"> 1. The impact of socio-economic development on domestic water consumption 2. Regional specific indicator variables of water consumption 3. Regional impact of urban growth on domestic demand? 4. Unaccounted for Water (UFW) and Economic Level of Leakage (ELL)
Domestic water pollution	<ol style="list-style-type: none"> 5. Method for evaluating wastewater pollution risks incorporating protection of environmentally sensitivity areas or vulnerable groundwater sources in areas of intensive regional development
Domestic water conservation	<ol style="list-style-type: none"> 6. The state of social and institutional receptivity to domestic water use efficiency 7. Top-down and bottom-up policy mechanisms to promote receptivity among consumers and the manufacturing and construction industry to water conservation tools. 8. The potential for metering to engage consumers in long-term water conservation programs 9. The impact of different pricing strategies on household water consumption and water utility revenues
Domestic sector integrated options	<ol style="list-style-type: none"> 10. Evaluation of domestic demand-side options vs. supply-side options 11. Impacts of climate changes, population growth, and increasing economic output on future domestic water stress? 12. Impacts of current EU laws and policies on the use of management approaches (i.e. crisis vs. risk management) in drought contingency planning

2.2.2 Agricultural sector

The major knowledge gaps to characterise water stress in the agricultural sector come from the complexity of this sector. It exists as many types of farmer water related behaviours as it exists specific physical and socio-economical characteristics. These characteristics are:

- The origin of the water resource used for irrigation: groundwater and/or surface water;
- The water leaching requirement;
- The hydro-geological, hydraulics and hydrological conditions;
- The water distribution technique: gravity and/or pressurized system;



- The irrigation technique : submersion, sprinkling or drip irrigation (several sub-types existing within these techniques);
- The management of the water distribution system: collective (irrigation network) and/or self water supply systems (wells or boreholes) not subject to water turns;
- The soils characteristics: depth, topography, physics and chemistry characteristics;
- The types of crops family: cereals and fodder on one hand and fruit and vegetable on the other hand;
- The diversity of variety within the same crop;
- The presence or not of breeding activities;
- The types of farms: size, technical orientation, average age of farmers...;
- The logic pursued by farmers: revenue maximisation, labour minimisation or simply land speculation.

A combination of the previous determinants, each one having an impact on water related behaviours and then on water stress, lead to a thousand of possibilities. This is the reason why most of the time, agricultural sector analysis requires several typologies to simplify the system.

Beyond the difficulty face to the plurality of determinants, it generally exist gaps in the data availability either because data are old, partial or inexistent. Furthermore, when data exist, it is frequently collected at an administrative unit scale and not at the water management scale.

Finally, it can exist complex interrelations within the agricultural sector that suppose to develop specific knowledge. An example of such interactions can be illustrated by the use of two different water resource on the same land, the first one coming from canals to irrigate by gravity the field and the second one coming from the superficial aquifer recharged by the over used of the first one. In this case, the same water is used several times in such a manner that it seems difficult to assess the relative performance of the system at a basin scale.

To prevent such errors at a large scale (Keller and Keller 1995; Keller, Keller et al. 1996) proposed a new concept called effective efficiency which take into account the quantity of water delivered from and return to a basin's water supply. It however required detailed information hardly available at local scale level.

Developing agricultural indicators to help in the characterisation and / or monitoring of water stress is full of pitfalls since according to several authors, indicators must depends on the location studied (Bos, Murray Rust et al. 1994), the level considered, field, irrigation service, basin or administrative units (Small and Svendsen 1990; Molden, Sakkthivadivel et al. 1997) and the time dimension at stake (World Bank 2005).

The previous listed characteristics, the lack or the inexistence of data (irrigated area, pumped volumes, respect of the law...) and the complexity of the relation within the agricultural sectors are the major gaps to characterize water stress and frequently justify a monographic analysis.

2.2.3 Industrial sector

In Europe, in the last decades many industrial activities are under transformation and many regions experienced reorientation closely linked to economic recession, political transformation or shift to other industry types, e.g. due to the decrease of activities linked to extracting industry (EEA, 1999). Many industrial processes have been optimized or are still in the process of optimization which leads to the reduction of water use due to application of higher technical standard, water saving measures and increasing of water recycling rates (EEA, 1999). Depending on the reasons decreasing water demand/use can be an indicator for increasing or decreasing water stress. Collapses in the industrial sector such as closure of companies lead to a general decrease of industrial water demand/use in the region and country and the closures can be an impact of water stress on the industrial sector.

Decreasing water demand as the result of process optimization and water saving implementation is a positive trend, leading to the mitigation of water stress.

The large variety of industry types and different process units within these industries make the determination or even estimation of water stress, water use efficiency or water demand to a very complex and difficult task. Additionally, the water use is very diverse and recycling rates and losses have to be considered. In the Aquastress project regions with very different industrial activities and with different technical standards are investigated.

2.2.3.1 Water demand in industry

The industrial water demand of a region is not only depending on the industry type and the process units applied but also on the technical standard of the industry. Higher standard often includes recycling and water saving measures and alternative less water intensive cooling and production systems. The determination of industrial water demand requires therefore very exact and huge amount of data and knowledge of the processes applied. In many processes water is an essential medium (e.g. for cooling or transport) and guaranteed water supply is crucial for the production, otherwise the company faces heavy losses (EC, BREF documents).

2.2.3.2 Illegal abstractions and discharge

The water required for the industrial sector can be either supplied from public water supply network (high costs and drinking water quality) or can be abstracted from own water sources (deep wells, groundwater). The amount supplied by the public network can be easily accessed from the water supplier. The amount of water from own resources is not always controlled and real water use/consumption in some countries or regions is not published and accessible to the public. Additionally, illegal water abstractions and wastewater discharges, especially in Southern and Eastern European countries are a common phenomenon to save water costs and avoid complicated and extensive procedure to get water abstraction and wastewater discharge permissions or penalties for exceeding quality limits. Illegal abstractions and discharges make the determination of water stress impossible or deliver imprecise numbers (D1.1-1, D1.2-1).

2.2.3.3 Lack of data

In some regions in Europe data on water use and abstractions is not accessible to the public. Environment or water departments dispose of this data; however do not publish them very often.

2.2.3.4 Losses in the production

The water consumption in the industrial sector is compared to the agricultural sector very low. Most of the water used is discharged as wastewater, is part of the product (in the beverage industry) or is reused in the cooling system or in some other processes (EEA, 2000b). Only a small part is regarded as evaporative (in the cooling system) or infrastructural losses (in old pipes and process units). However the determination of the amount lost in the process is not so easy and often cost intense. Mostly only estimations are made. However, for the determination of evaporative water losses energy balance can be used.

2.2.3.5 Water recycling and water saving measures

Most of the water used in the industrial sector is cooling water (about 80%). To save these great amounts water recycling is a widely known practice which results in low abstraction rates (only for make-up water). In complex industrial plants many water cycles are applied and the determination of water use in the plant requires the elaboration of a detailed water and energy balance, especially when implementation of water saving measures is aimed.

Indicators as “recycling coefficient” describe the scope of recycling in the plant, however it is not really an indicator for water stress since water is recycled also because of financial benefit not only because of water shortage in the region (not really an indicator for adaptive capacity).

In industrial activities water can also be saved while using freshwater only in process units where very high quality water is required and substituting freshwater in other processes with process water of lower quality. However, the determination of adequate water quality for some processes is also a demanding and time consuming task (Lens, 2002).

2.2.4 Tourism (service industry)

The major knowledge gaps as far as water stress characterization for the tourism sector is concern, are the following:

- What is the current importance of tourism (in terms of contribution to regional/national GDP and in terms of total water consumption) in each test-site?
- How efficient in terms of water use, is the tourism sector in each test site at present? How are seasonal variations and summer picks handled in terms of supply availability and demand management?
- What is the local reaction towards tourism as far as their water consumption is concerned? E.g. in Cyprus there is a perception that tourism is a big water user, whereas the truth is that tourism consumes a very small percentage of total water supply and per capita water consumption for tourism is again small.
- In most of the test-sites, water for tourism is charged at either domestic or industrial tariffs. That is, there is no special pricing structure for water consumed by tourism. Moreover, it is not always easy to identify whether water is used for domestic or tourism purposes. What is the current price structure for water consumed by tourism in each test-site and what kind of monitoring efforts are in place (if any) for identifying and charging water consumed by tourism?
- In some of the test-sites (especially the Cypriot test site), the following pressure can be identified: given the following profitability of agriculture and higher profitability of the tourism sector, farmers want to switch their land-use to tourism development. It will be very informative to identify if there exist any laws/other restrictions that characterize land use allocation in the test-sites, in order to understand whether such a switch is possible. If such a switch is possible, we should try to investigate how such a switch will translate in terms of water requirements.
- How will different tourism-population development scenarios impact on the need for water conservation in the different test-sites? For example, most test-site tourism strategies focus on quantity of tourism, whereas another (possibly more profitable and water efficient management) is to focus on quality tourism (i.e. attract tourists from higher income groups).
- What is the tourism-demand for water-related environmental amenities(e.g. conservation of lakes, rivers, etc.). Following from the point above, if tourism management in test-sites focused on quality tourism, such as demand might be increased; as a result an incentive for water conservation from local business will emerge.

Uncertainty comes in the picture through a number of parameters, relevant for all the test-sites:

1. Future tourism management (quantity vs. quality) and resulting tourism population growth and distribution
2. Relative future importance of tourism in relation to other sectors of the local economy
3. Possible changes in land use defined by future legislation at the EU and national level
4. Future changes in water supply due to climate change

5. Future changes in water demand due to possible changes in the pricing structure.
6. Adaptive capacity of the tourism sector, i.e. ability to respond to current water stress factors.

2.2.5 The environment

General availability of data for the sector Environment

The sector Environment comprises both the environment of the total catchment, and the natural ecosystems in the area. This leads to a list of indicators that is oriented on these two sides of the same medal. Some data have to describe the total catchment (catchment data), some data only have to describe the natural ecosystems or the other sectors (often local data).

Based on the requirements for the Water Framework Directive, each EU country has a number of reports that provide good quality data on a number of characteristics related to the environmental and ecological situation. There are indicators on water quantity, water quality and on institutional capacity (see appendix, or describe another way to find this list). In the list of indicators for the sector environment in AquaStress, a number of indicators are available through the WFD reports that each country has. These have been given priority in the assessment of the environmental quality. Other indicators with similar goals, but that need less data to compute a value for the indicator, have been described for countries where no WFD reports are available (Bulgaria, Morocco, Tunisia). So in general the amount of (easy accessible) data is larger in EU countries that already have WFD reports on environmental quality.

Next, the availability of data relates to the exact river catchments that are described in the WFD reports. The sites the AquaStress project has selected do not necessarily overlap with WFD report area's. Therefore, it is often necessary to re-calculate the environmental indicators through relative area size, after examination if a larger WFD area is homogenous enough for this calculation. Otherwise small scale data, e.g. from councils, have to be combined.

In countries with WFD reports, often data will be available on the environmental indicators described in the annex [or elsewhere] under E9 to E13. In other countries, the indicators E1 to E8 will be good replacements for the same aspects.

2.2.5.1 Data gaps for Environmental indicators

In most catchments data on Surface water flow are lacking, periods with high and with low flow, to indicate the variation in the availability of surface water.

For each site, we list additional gaps in data for the environmental indicators. See the list of indicators in the annex [when annex not available in the report, make a list of the indicators in a table? I can derive this from the spreadsheet.]

- Guadiana, Portugal:

Most environmental data for the indicators are available, except for groundwater use (local data) in relation to the total available upper groundwater (catchment data) and for water quality, data on thermic qualities (temperature), salinity and acidity of the streams are lacking.

- Limassol, Cyprus:

In Limassol, most data are available, e.g. for water quantity in natural ecosystems. For water quality, thermic quality of the streams and acidity is lacking.

- Tadra, Morocco:

Irrigation is very important in this area, so data related to irrigation are readily available. However, other environmental data are a problem.

- Flumendosa, Italy:

It is difficult to find data for environmental indicators, like toxic substances. WFD reports for the catchment area have not been found.

- Vecht, Netherlands:

Almost all essential data are available.

- Iskar, Bulgaria:

Almost all essential data are available.

- Przemsza, Poland (recent WFD country):

Almost all essential data are available.

The search for data is still going on, especially for Merguelil, Tunisia. In the final phase of producing the deliverables D2.2-2 (the eight site reports), possibly missing data for the indicators for all sites will surface.

2.3 What next? Using the results of the Aquastress WSM

Within deliverable D2.1.2 the AquaStress Water Stress Matrix (AWSM) has been developed as a tool to provide us with the adequate information on the water stress situation of a region. We still miss information on the water stress levels in the different sectors in the different test sites. The goal is to test the AWSM with the already existing information on the test sites and to get first insight in our accurate the matrix works. We expect to fill up the knowledge gaps on water stress in the test sites and to create a baseline for analysing and measuring the improvement or the deterioration of the water stress situation in the test sites. With the AWSM we aim to have a tool to analyse rapidly the water stress in the sectors and to provide a set of possible mitigation options.

The AWSM will provide the basis for:

- Characterisation of water stress
- Evaluation of implementation of options to mitigate water stress in the test sites and,
- Evaluation of the effectiveness of the AWSI itself as a tool for water management under conditions of water stress.

A first attempt of implementation of the AWSM will be done with data from the Moroccan test site. First results will give us insights in the possible modification of the tool and in the needs to be developed to fill the gaps for the characterisation of water stress. The tool can provide the project with a good frame for adaptive management in the test sites. Not only that, but also can be used to evaluate the results of the implementation of mitigation options in different timescales in the future

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Reference list

- Alcamo, J., Henrich, T., Rösch, T., 2000. World Water in 2025 – Global modelling and scenario analysis for the World Commission on Water for the 21st Century. Report A0002, Centre for Environmental System Research, University of Kassel, Germany.
- Anderson, V. (1991) Alternative Economic Indicators. Routledge, London and New York.
- AWWARf. Report, #90817. Socioeconomic Impacts of Water Conservation, 2001.
- Baumann, D. D., Boland, J. J., Haneman, W. M., 1998. Urban water demand management and planning. McGraw-Hill.
- Bos, M. G., D. H. Murray Rust, et al. (1994). "Methodologies for assessing performance of irrigation and drainage management." *Irrigation and Drainage System* 7: 231-261.
- CH2M Hill, July 2003, Water Use in Industries of the Future
- Carruthers, I., M. W. Rosegrant and D. Seckler (1997). "Irrigation and food security in the 21st century." *Irrigation and Drainage System* 11(2): 83-101.
- Chen, R. S. and R. W. Kates (1994). "World food security: prospects and trends." *Food Policy* 19(2): 192-208.
- Connolly, C. and Chisholm, M. (1999), The use of indicators for targeting public expenditure: the Index of Local Deprivation, *Environment and Planning C: Government and Policy*, 17: 463-482.
- Cosgrove W. & Rijbersman F. (2002) – The "World Water Vision". Earthscan Publications Ltd., London.
- D2.1-1, Aquastress project, August 2005, WB2: Bauer, Inman, Manez, Moors, Pahl-Wostl, Sullivan, Tarnacki, van den Wyngaert, Vurro et al. Common Framework for the Characterization of Water Stress
- Degree, K. B (1994): The Rocky Path to Complex-Systems Indicators. *Technological Forecasting and Social Change*, Vol 47(2), Oct. 1994.
- Department of the Environment UK (1996) Indicators of Sustainable Development for the UK. HMSO, London.
- EC, European Commission - Integrated Pollution Prevention and Control (IPPC) –Reference Documents on Best Available Techniques
- Edgeworth, F.Y. (1925) The Plurality of Index Numbers *The Economic Journal* 35:139:379-388
- EEA - European Environmental Agency, (2003). Dobris report - Environmental Assessment Report 10.
- EEA 2000b: Environment in the European Union at the turn of the century, Chapter 3.5 Water Stress
- EEA, 1999: Sustainable water use in Europe, Part 1 - Sectoral use of water, Environmental assessment report No 1
- EEA, 2000a: Sustainable use of Europe's water? State, prospects and issues, Environmental assessment series No 7
- EEA, 2001: Sustainable water use in Europe, Part 2 – Demand Management, Environmental issue report No 19
- EEA, 2003 – European Environment Agency indicator reports
http://themes.eea.eu.int/indicators/all_indicators_box
- EEA, 2003: Europe's water: An indicator based assessment, Topic report 1/2003
- EEA. Sustainable water use in Europe – Part 2: Demand Management. Environmental issue report No.19., 2001.
- Falkenmark, M. (1986). Fresh water - time for a modified approach. *Ambio.*, 15, 192–200.
- Falkenmark, M. and G. Lindh, (1974) Impact of Water Resources on Population Swedish contribution to the UN World Population Conference, Bucharest.
- FAO (1996). World Food Summit Fact Sheet. FAO, Ed. Rome.
- FAO (2002). Agriculture mondiale : horizon 2015 / 2030. Rome, FAO: 97p.
- Finkelstein, J.M.; Schafer, R.E. (1971). Improved Goodness-of-Fit Tests. *Biometrika*, 58(3), pp. 641-645.
- Fisher, I. (1922) The Making of Index Numbers. *Journal of the American Statistical Association*.

- Freeman, D.H and T.R. Holford (1990) Summary rates, *Biometrics*, 36: 195-205.
- Fritsch J.M. (2001) – Time variability of the hydrological cycle and implications for water resources management. Int.Conf. on Hydrological Challenges in Transboundary Water Resources Management. Koblenz, Fed.Rep.Germany, 25-27 Septembr 2001.
- Gleick P. (2002) – The world's water. The Biennial Report on Freshwater Resources. 2002-2003. Island Press, 334 p.
- Gleick, P. H., 1996. Basic water requirements for human activities: Meeting basic needs. *Water International* 21 2 81–92.
- Gustavson .K.R, Lonergan .S.C, Ruitenbeek .H.J (1999): Selection and Modelling of Sustainable Development Indicators: a Case Study of the Fraser River Basin, British Columbia. *Ecological Economics*, Vol.28(1), Jan 1999.
- Hammond, A., A. Adriaanse, E. Rodenburg, D. Bryant, and R. Woodward (1995), *Environmental Indicators: A Systematic Approach to Measuring and Reporting on Environmental Policy Performance in the Context of Sustainable Development*, Baltimore: World Resources Institute.
- Henninger (1998): Mapping and Geographic Analysis of Human Welfare and Poverty- Review and Assessment. World Resources Institute, Washington, D.C, U.S.A
- Hentschel, .J, Lanjouw P.(1998): Household Welfare Measurement and the Pricing of Basic Services. World Bank, Washington D.C
- Howarth, D., Butler, S., Communicating water conservation: How can the public be engaged? *Water Supply*, 2004, 4, (3). 33-34.
- Howarth, D., Privatisation - A help or a hindrance in managing water demand. *Water Resources Update*, 1999, 114, Winter.http://www.nao.org.uk/publications/nao_reports/9900971.pdf ???
- Jacobs, H.E., 2004. A conceptual end-use model for residential water demand and return flow. PhD thesis, Rand Afrikaans University.
- Jamati, C., 2003. Casablanca (Morocco): An Example of Public-Private Partnership. *International Journal of Water Resources Development* 19 (2).
- Jesinghaus, J. (1998), A European System of Environmental Pressure Indices, First volume of the Environmental Pressure Indices Handbook: The Indicators. Luxembourg: European Commission.
- Jimenez-Beltran, D., 2005: The EEA and the Industry – The State of the Environment in Europe and the EU, Annual NGO's Meeting with the Commission
- Kanakoudis, V. K., 2001 - Urban water use conservation measures. *Journal of Water Supply Research and Technology AQUA*, 51 (3). 153.
- Keller, A. A. and J. Keller (1995). Effective efficiency: a water use efficiency concept for allocating fresh water resources, Discussion paper No.22, Center for Economic Policy Studies: Winrock International.
- Keller, A. A., J. Keller, et al. (1996). Integrated water resources systems:theory and policy implication, Research report No.3, International Water Management Institute, Colombo, Sri Lanka.
- Lal, M., K. K. Singh, L. S. Rathore, G. Srinivasan, et al. (1998). "Vulnerability of rice and wheat yields in NW India to future changes in climate." *Agricultural and Forest Meteorology* 89(2): 101-114.
- Lens, P. (2002): Lens, P., Hulshoff Pol, L., Wilderer, P., Asano, T *Water Recycling and Resources Recovery in Industry*, IWA Publishing, 2002
- Maddaus, L.A., 2001. Effects of Metering on Residential Water Demand. MSc Thesis, UC Davis, California
- Michelson, A.M., McGuckin, J.T., Stumpf, D. Non-price water conservation programs as a demand management tool. *JAWWA*, 1999, 35, (3). 593-602.
- Mitchell, V.G., Modelling the Urban Water Cycle. *Environmental. Modelling and Software*, 2001, 16 (7) 615-629
- Molden, D., R. Sakkthivadivel, et al. (1997). Indicators for comparing performance of irrigated agricultural systems. Colombo, Sri Lanka, IWMI - Research report N° 20: 27p.
- Murphy, John J. (1999) *Technical Analysis of the Financial Markets*. Institute of Finance, New York
- NAO, 2000 – National Audit Office. Leakage and water efficiency. Report by the controller and auditor general - HC 971 Session 1999-2000: 1 December 2000.
- Noble, M., G. Smith, B. Penhale, G. Wright, C. Dibben, T. Owen and M. Lloyd (2000), *Measuring Multiple Deprivation at the Local Level: The Indices of Deprivation 2000*, DETR.London.

- OECD: Measuring Development Progress, A Working Set of Core Indicators, <http://www1.oecd.org/dac/Indicators/htm/slides.htm>
- Ofwat, 2000a. Patterns of Demand for Water in England and Wales: 1989-1999.
- Ofwat, 2002 - International comparison of water and sewage services 2000-2001
- Ohlsson, L. (1998) Water and Social Resource Scarcity. FAO issue paper, FAO, Rome.
- Parry, M., C. Rosenzweig, A. Iglesias, G. Fischer, et al. (1999). "Climate change and world food security: a new assessment." *Global Environmental Change* 9(1): S51-S67.
- Pereira, L. (1995). Sustainability challenges in water management. Economic aspect of water management in the Mediterranean area, Marrakech, CIHEAM.
- Princen, H., 1999. Consumption and environment: some conceptual issues. *Ecological Economics* 31, 347- 363.
- Rangeley, W. R. (1990). Irrigation at a crossroads. 4th Gulhati Memorial Lecture, ICID, Rio de Janeiro.
- Raskin, P., Gleick, P., Kirshen, P., Pontius, G., Strzepek, K. (1997). Water futures: Assessment of long-range patterns and problems. Stockholm: Swedish Environment Institute/United Nations.
- Read, C., Better buildings – design for water efficiency, by Caroline Read, 2005. Published by "Green Alliance", London.
- Rennings, K. and H. Wiggering (1997), 'Steps towards indicators of sustainable development: Linking economic and ecological concepts', *Ecological Economics* 20, 25-36.
- Renwick, M.E., Archibald, S.O., Demand-side management policies for residential water use: Who bares the conservation burden? *Land Economics*, 1998, 74, (3). 343-359.
- Rogers, P.R., Jalal, K.F. Lohani, B.N. Owens, G.M., Chang-Ching Yu, Dufournaud, C.M and J.Bi (1997): Measuring Environmental Quality in Asia. Harvard University Press, Harvard.
- Rosenberg, N. J. and M. J. Scott (1994). "Implications of policies to prevent climate change for future food security." *Global Environmental Change* 4(1): 49-62.
- Saaty, T.L. (1980) *The Analytical Hierarchy Process*. McGraw-Hill, New York.
- Salameh, E. (2000) Redefining the Water Poverty Index. *Water International* 25 no.3 Pp 469-473
- Seckler, D. (1999). Revisiting the "IWMI paradigm:" increasing the efficiency and productivity of water use. Colombo, Sri Lanka, International Water Management Institute (IWMI).
- Seckler, D., U. Amarasinghe, D. Molden, R. DeSilva, et al. (1998). World Water Demand and Supply, 1990 to 2025: Scenarios and Issues. Colombo, Sri Lanka, International Water Management Institute - Research Report 19: 41p.
- Seckler, D., D. Molden and R. Barker (1999). Water scarcity in the twenty first century. Colombo, Sri Lanka, International Institute of Management Irrigation (IIMI).
- Sen .A.K (1983): Poor, Relatively Speaking.. *Oxford Economic Papers*, No.35.
- Senior, M. (2002), 'Deprivation Indicators', in P. Rees and D. Martin (eds), *The Census Data System*, pp.123-139.
- Shiklomanov I.A. et al., (1997). Assessment of water resources and water availability of the world. Part of the Comprehensive Assessment of the Freshwater Resources of the World, World Meteorological Organization, Geneva.
- Shuval, H., 1992. A regional water for peace plan. *Water International* 17 3, 133–143.
- Small, L. E. and M. Svendsen (1990). "A framework for assessing irrigation performance." *Irrigation and Drainage System* 4: 283-312.
- Somlyody L. (1995) - Water quality management: can we improve integration to face future problems? *Wat.Sci.Tech.* Vol.31 No.8 pp 249-259, 1995.
- Sophocleous M. (2000) - From safe yield to sustainable development of water resources—the Kansas experience. *Journal of Hydrology* 235 (2000) 27–43.
- Streeten, P.P. (1996) Human Development – the Debate about the Index, *International Journal of the Social Sciences*
- Townsend .P (1985): A Sociological; Approach to the Measurement of Poverty: A Rejoinder to Professor Amartya Sen. . *Oxford Economic Papers*, No.37.
- UK Environment Agency, "Saving Water: Taking Action – The Responses to the Consultation Report on Water Conservation and Demand Management", prepared from the National Water Demand Management Centre, 1997.
- UK Environment Agency, "Saving Water: Taking Action – The Responses to the Consultation Report on Water Conservation and Demand Management", prepared from the National Water Demand Management Centre, 1997.
- UNICEF (1995): Monitoring Progress Toward the Goals of the World Summit for Children: A Practical Handbook for Multiple-Indicator Surveys.



- UNICEF (1997): Evaluation of Multiple Indicator Cluster Surveys: Division of Evaluation, Policy and Planning.
- United Nations Statistical Office (1993) Handbook of national Accounting. Integrated Environmental and Economic Accounting. Studies in Methods. Series F, No.61. United Nations Statistical Office, New York.
- United Nations. 1997. Commission on Sustainable Development. Comprehensive assessment of the freshwater resources of the world. Fifth session, April 5-25. Accessed at <<http://www.un.org/>>.
- USEPA, Cases in Water Conservation: How Efficiency Programs Help Water Utilities Save Water and Avoid Costs. United States Environmental Protection Agency Office of Water (4204M), EPA832-B-02-003. July, 2002 www.epa.gov/owm/water-efficiency/index.htm
- Uvin, P. (1994): The International Organisation of Hunger. Kegan Paul, London.
- Van de Worp, 2002, Sustainable water management in industry in: Water Recycling and Resource Recovery in Industry, IWA Publishing
- Van der Gaag, (1988): Confronting Poverty in Developing Countries: Definitions, Information and Policies. LSMS Working Paper No 48. World Bank, Washington, DC.
- Waggoner, P. E. (1994). How much land can ten billion spare for nature? New York, Council for Agricultural Science and Technology, The Rockefeller University.
- Walmsley, J (2002): Overview: Sustainability Indicators for Catchment Management in South Africa. Water Research Commission, South Africa.
- WHO/UNICEF, 2002. Joint Monitoring Programme for Water Supply and Sanitation
- Wilhite, D.A., 2005. Drought and Water Crises: Science, technology and management issues. Taylor & Francis, New York.
- World Bank (1996) A Guide to LSMS Surveys and their Datasets. World Bank, Washington DC.
- World Bank (1996a): Poverty Monitoring and Analysis Systems. World Bank, Washington DC.
- World Bank (1997) Expanding the Measure of Wealth Indicators of Environmentally Sustainable Development. Rio+5 Edition, discussion draft. World Bank, Washington DC.
- World Bank (1998) Standardised Welfare Indicators World Bank, Washington DC.
- World Bank (2005). Reengaging in agricultural water management: Challenges, opportunities, and trade-offs. World bank Report No. 32731-GLB, Agriculture and rural department, The World Bank, Washington D.C.: 146.
- World Health Organisation (1992): Health for All Database. WHO, Geneva.
- World Health Organisation: Environmental Health Indicators: Framework and Methodologies, p2. See: <http://www.northampton.ac.uk/ncr/who/index.html>
- World Resources Institute (2000): Linking Environment and Health: Indicators of Environmental Threats to Health.
- WSSTP, 2005, Water Supply and Sanitation Technology Platform, Technical Working Group: Water and Industry (TWG 3), Vision Document

Annex

Nr indicator Indicator description

ENVIRONMENT – applicable worldwide	
WATER QUANTITY	
E1	annual groundwater abstraction as percent of (10 years average) annual recharge (P) (+ve, i.e. more is more water stress) (m3 year-1 / m3 year-1)
E2	surface water low flow: nr of days of flow lower than 7Q10 low flow; for ephemeral streams: duration of dry period compared to 10 years mean (P) (+ve, i.e. more is more water stress)
E3	surface water high flow (flooding): nr of days higher than 7Q10 high flow (flow (P) (-ve, i.e. less is more water stress)
WATER QUALITY (neighbour effects = integrated over upstream area)	
E4	Volume of untreated waste water (industrial + domestic + tourism) as % of total run-off (data from other sectors) : proxy for load, load itself would be better but very difficult (D) (+ve, i.e. more volume of untreated waste water is more water stress)
E5	Diffuse eutrophication: Agricultural fertilizer use in the catchment (total N and P / ha catchment) (D) (+ve, i.e. more agricultural fertilizer use is more water stress)
E6	Diffuse toxic substances: pesticide use in agriculture per ha of agricultural land (substances site dependent-locally relevant) (D) (+ve, i.e. more is more water stress)
E7	Hazards with toxic substances: frequency of exceedance of a set concentration of hazardous substances (concentration and substances determined by stakeholders/based on (inter)national limits) (P) (+ve, i.e. more is more water stress)
INSTITUTIONAL AND ADAPTIVE CAPACITY	
E8	Surface protected by treaties / total catchment surface (R _c) (+ve, i.e. less is more water stress) (ha / ha)
ENVIRONMENT – based on primarily in EU available sources	
WATER QUANTITY	
E9	hydrological regime (WFD) (P) replaces surface water indices
E10	groundwater index (WFD) (P) replaces groundwater index
WATER QUALITY (neighbour effects = integrated over upstream area)	
E11	General fysical-chemical characteristics (WFD) (P):
E11a	thermic
E11b	oxygen
E11c	Salinity
E11d	Acidity
E11e	Nutrients