Water Scarcity and Droughts
Second Interim report

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Background:
Following the presentation of a first analysis of water scarcity and drought issues during the Water Directors meeting in June 2006 and the Environment Council meeting on 27 June 2006, Member States asked for further discussion on specific measures.

The Commission proposed to come back with an in-depth assessment identifying the magnitude of the problems linked to water scarcity and drought and the size of the residual gaps in the implementation of EU existing policies.

The Expert Network on Water Scarcity and Droughts supported the Commission's further data collection and analysis carried out through a questionnaire.
A first interim report was presented to the Water Directors in November 2006. The conclusions of the report pointed out the need to better assess the scope and the impacts of the issues.
A second questionnaire was disseminated to all Member States in early 2007 in order to fill in the gaps identified by Member States and the Commission.

This document is the second interim report on Water Scarcity and Droughts. It updates the first interim report on basis of Member State replies to the second questionnaire and information provided by other DGs of the Commission.

It is presented to the Water Directors on 18 June for discussion.

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WATER SCARCITY & DROUGHTS

IN-DEPTH ASSESSMENT

Second Interim Report – June 2007

Prepared by DG Environment – European Commission
FOREWORD

Following the presentation of a first analysis of water scarcity and drought issues during the Environment Council meeting on 27 June 2006, Member States asked for further discussion on specific measures. The Commission proposed to come back with an in-depth assessment identifying the magnitude of the problems linked to water scarcity and drought and the size of the residual gaps in the implementation of EU existing policies.

These issues were developed along the lines of the Information Note of the Commission presented during the June Environment Council meeting¹:

- "strengthen the diagnosis, on the basis of complementary data to be provided by Member States and stakeholders, in the coming months;"

- prepare a first Interim report at technical level to be discussed with the Water Directors in December 2006."

After the discussion with the Water Directors in December 2006, it was decided to deepen the analysis, use additional data and take advantage of existing experiences currently being developed at national level. The Commission therefore prepared a second interim report.

This is a technical document which includes the first part of the in-depth analysis. It is based on current data and contains information from various sources:

- Regional ones, from European Environment Agency, EUROSTAT, the Joint Research Centre and Blue Plan;
- National and local ones from Member States and stakeholders.

The analysis of the current information has been carried out by the Commission.

This version is presented to the meeting of the Water Directors on 18 June 2007 for discussion.

¹ European action on water scarcity and drought – Information from the Commission – ENV 372 - 21 June 2006
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SUMMARY

General outlines
The first part of the assessment presents the general outlines of water resources and uses at EU level, as well as prospective information related to possible effects due to climate change. The Eurostat database provides information on the total renewable freshwater resources for each European country. Water availability per capita and country can then be deduced. Malta, Cyprus and the densely populated European countries have the lowest water availability.

The national indicators are annual values which do not reflect the inter-seasonal variability. Some regions may face a large variation of water availability throughout the seasons. Natural conditions may also be significantly different from one year to another and result in large inter-annual variability.

Climate change is expected to have effects on water resources and therefore water availability across Europe. Average run-off in Southern Europe rivers is projected to decrease with increasing temperatures and decreasing precipitation. In particular, some river basins in the Mediterranean region, which often already face low levels of water availability, may see decreases of 10% or more below today's levels by 2030. In the longer term, changes in water availability are likely to develop more noticeably.

Changing temperatures and precipitation patterns may also change the frequency and intensity of droughts, particularly in Southern and parts of Central Europe. The impact of climate change on drought intensity and frequency attracts great attention and raises questions among Member States. They look forward to getting further investigation in this regard.

The information available at EU level on water uses help to identify the main sources of water abstraction and water consumption and their geographical and sectoral characteristics. Aggregated EU data highlight the significant part of the energy sector in the overall abstraction (44% compared to 14% for agriculture, 18% for public water supply and 14% for industry). Only part of the overall abstraction is truly consumed and this part is variable according to the sector. In terms of water consumption, agriculture is the most demanding sector (69% compared to 13% for public water supply, 10% for industry and 8% for energy production).

The sectoral analysis provides additional information on the evolution of water uses in past decades. Even if the data are aggregated, they provide an interesting overview of the main trends and sectoral characteristics.

Public water supply has generally given rise to rather stable uses in the last thirty years. But investigations point out the importance of network leakages in some countries, even though an updated monitoring of their evolution often lacks. Other data reveal the significant importance of tourism in some local and regional water uses, with consequences on the design of water supply infrastructure. Addressing both issues is made difficult by a lack of data.

Agriculture is a significant water user, in particular for irrigation. Irrigated areas increased from 1990 to 2000, with grain maize as the most important irrigated crop. In parallel, the

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2 Information sources: Eurostat, EEA Technical Reports, illustrations provided by Member States
water demand rate decreased slightly between 1990 and 2000 (from 6578 to 5500 m³/ha/year). The evolution from 2000 of the regional distribution of the irrigated area and the associated water demand will need further assessment.

The aggregated dated related to industry revealed a decrease in water uses in the 80s and 90s. Further investigation will be needed in the future in order to assess whether increases in water use can be expected in next decades, taking into account continuing growth in economic activity and output (more than 20% in thirty years in most countries) as well as increased water use efficiency with technological changes and IPPC implementation.

Cooling water for electricity production mainly concern Western Central and Eastern countries. It will be interesting to further investigate whether decreases in water abstraction can be expected from the possible replacement of older power stations by newer plants in the next thirty years. The activity can have impacts at the points of abstraction even if a large part then flows back farther into the environment.

### Water scarcity

Water scarcity is defined as a situation where insufficient water resources are available to satisfy long-term average requirements. It refers to long-term water imbalances, combining low water availability with a level of water demand exceeding the natural recharge.

Few indicators are today available to correctly illustrate the extent of water scarcity at river basin or national level. The sole indicator used so far at European level is the Water Exploitation Index. This indicator is today calculated at national level, on basis of Eurostat information provided by Member States. It indicates that at least all Mediterranean EU Member States (Cyprus, Malta, Italy, Spain, Portugal, Greece) are impacted by water scarcity, with a total population concerned of 130 million inhabitants (27% of the EU population). This indicator provides an initial illustration of the extent of the issue but it is not comprehensive and does not correctly reflect water scarcity situations at river basin level.

In response to questionnaires in the framework of this interim report, thirteen Member States provided a list of river basins particularly affected by water scarcity. The thirty three river basins where water scarcity has been identified represent 11% of the EU territory and 17% of the EU population. Agriculture represents the major water use (abstractions) in 17 of the all basins, followed by public water supply which is the major use in 4 basins. Most affected river basins are located in Southern Europe (Cyprus, Malta, Italy, Portugal, Spain, France). However, Northern and Eastern countries (Belgium, Denmark, Germany, Hungary, United Kingdom) also specified river basins. Water scarcity impacts are difficult to estimate due to a lack of information at EU, national and river basin levels. For the time being, research projects have not yet delivered any data and most inputs coming from Member States have been qualitative information. Cyprus, France and Spain provided information on the amount of investments carried out in order to face water scarcity, particularly the economic costs of new water supply infrastructures.

The information provided so far already stresses the effects of water scarcity situations. In some cases, economic impacts have been high and affected several sectors: deficiencies in public water supply, decrease in energy production and decrease in agricultural and industry productions with possible additional costs to be incurred. Water scarcity situations may also have led to social impacts (decrease in employment in some sectors, possible migration of industries) and have undoubtedly led to environmental impacts (decrease in groundwater levels with possible seawater intrusion, difficulty in ensuring minimum flows in surface waters, in parallel to possible increase in pollutant concentrations, desiccation of wetlands).

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1 In some cases, the differences displayed between national replies may partially be due to different interpretations given by countries in data questionnaires they responded to.
The assessment reveals that **further cost-analyses are urgently needed** in order to specify more precisely the impacts of water scarcity at EU level and go beyond qualitative assessments only. This way forward will require the definition of agreed indicators in order to deliver relevant and comparable data at river basin and national levels, as well as ensure that aggregated data will make sense at EU level.

**Droughts**

Droughts can be considered as a temporary decrease of the average water availability. Drought is a natural phenomenon. The assessment carried out in the past thirty years reveals that drought events have regularly occurred. The duration of each event, the area and population affected have been variable throughout this period.

Information provided by member States made it possible to identify **severe events** that on annual basis affected more than 800 000 km² of the EU territory (37%) and 100 million inhabitants (20%) in 1989, 1990, 1991 and more recently in 2003.

Information also revealed that at least Austria, Belgium, Cyprus, France, Hungary, Italy, Lithuania, Malta, Netherlands, Norway, Portugal, Spain and United Kingdom have been affected by droughts in the last thirty years, but with different degrees of intensity. Italy, Portugal, Cyprus, Spain and France have registered the highest frequency of droughts from 1976 to nowadays, with 8 to 21 events per country. However, several Northern and Eastern countries (Belgium, UK, Finland, Germany, Hungary, Lithuania, Netherlands, Norway, Slovakia,) have also experienced severe droughts, particularly in recent years.

Some countries have a large part of their territory being affected whenever droughts occur (Cyprus, Finland, France, Italy, Malta, Portugal, Spain), while some other countries may be frequently affected on a specific part of their territory (Belgium, Austria). Drought duration is largely variable from one country to another. In Cyprus, Italy, Portugal, Spain, droughts may last one or several years. In other countries, droughts have been predominant during one month (Hungary, Germany, Lithuania) or from two to six months (Austria, Belgium, France).

Finland was affected by a 270 day drought from August 2002 to April 2003.

Figures stress a **significant increase in annual average EU territory** (from 6% to 13%) and **population** (from 6% to 13%) **affected by droughts between the 1976-1990 period and 1991-2006 period**.

Information from Member States provides a first estimation of the main drought impacts. Some countries provided economic costs incurred due to specific drought events (see pages 30 to 33). The compilation of this data and the translation in unit costs made it possible to **estimate the overall economic impacts of drought events in the past thirty years to a total of 100 billion € at EU level.** Results show that the annual average impact has doubled between the 1976-1990 period and the next 1991-2006 period. It reached an average of 6.2 billion €/year in the most recent years, with an exceptional cost of 8.7 billion € in 2003. These estimations only cover economic costs. They do not include social and environmental costs due to an absence of data. Therefore, attention will have to be paid in a near future to the **enhancement of data collection at EU and national levels**, in order to improve the economic, social and environmental impact assessment.

**Use of EU and national instruments**

Keeping in mind water scarcity situations and drought events, a review of the extent to which existing instruments are being used by member States proved useful. Attention has been paid to EU funds particularly.
As regards the second pillar of the CAP and the rural development programmes, Member State replies and available evaluations on agro-environmental measures set-up in the 2000-2006 period, reveal that these programmes have very partially and sometimes not at all contributed to addressing water scarcity and drought issues. Only very few Member States have adopted agro-environmental measure directly aimed at addressing quantitative issues in the 2000-2006 programme. But Member States which adopted one or two such measures only covered a limited part of the area identified as priority area (2% in Greece, 10% in France). In most cases, priority was mainly given to measures aiming at mitigating water quality issues such as diffuse pollutions, to the detriment of quantitative issues.

Moreover, some investment supports have tended to encourage the development of new farming water supplies like irrigation networks and reservoirs. In these cases, the environmental impacts of the infrastructures have not been systematically assessed and the recovery of costs has usually not been ensured. It is also obvious that some Member States have largely used rural development funds in order to develop irrigation infrastructures when reduction in water uses needed to be encouraged first. The side effects of these measures may be exacerbated by the maintenance of some coupling supports in the framework of the first CAP pillar (France and Spain have kept a partial coupling of direct aids up to 25% of direct payments for arable crops).

The remarks drawn up for rural development programmes are also applicable to the structural and cohesion funds. The expenditures related to quantity issues have mainly aimed at setting-up new water supply infrastructures, giving rise to the same questions raised above. Quantity issues require the setting-up of appropriate links between the regional and river basin levels. These links should be further assessed.

As regards the other instruments (LIFE, European Union Solidarity Fund and Community Mechanism for Civil Protection), they have been rarely or even never used to address water scarcity and drought issues. In recent years, LIFE has mostly focused on programmes related to qualitative issues (waste water treatments, mitigation of point and diffuse pollutions) rather than quantitative ones. The European Union Solidarity Fund and Community Mechanism for Civil Protection have not been used at all to solve drought issues. Member States consider that these instruments do not offer conditions making it possible to do so. This point needs to be further addressed.

Water pricing information provided by Member States has been incomplete and made it difficult to have a whole and fair view of the issue. Nevertheless, the first available elements stress a large variability in national water pricing policies and above all, few examples of policies directly aimed at addressing quantity issues through consistent and effective water prices. In addition, some MS mentioned having no water charges for agriculture.

A first overview of other demand-side and supply-side measures available at national level gives interesting information but should be more developed. Good and valuable practices adopted at national and regional levels in order to mitigate water scarcity and drought issues should be further identified and shared at EU level.

The Water Framework Directive

Finally, the inputs provided by Member States shows the importance of the WFD in addressing issues of water scarcity, through the implementation of the water management plans and associated programmes of measures.

Some Member States highlight the importance of article 11 in building up the programmes of measures and taking into account quantity issues. Some stress that WFD implementation is an
opportunity to make demand-side measures a priority. Some also point out the importance of article 9 and annex III in solving water stress issues.

On basis of these points, some Member States ask for **deeper exchanges at EU level** on all types of possible **quantity measures** in order to provide river basin districts with practical tools when building up their programmes of measures. They are willing to go thoroughly into some issues such as priority given to demand-side measures, cost-benefit analyses of the foreseen supplementary measures, cost-effectiveness analyses, definition of adapted pricing policies and implementation of the cost-recovery principle.

As regards **drought events**, Member States that answered the questionnaire recognize the usefulness of the article 13.5 of the WFD, allowing to supplement river basin management plans by the production of a more detailed programme and management plan to deal with drought issues.

Some of them are interested in **further exchanges at EU level** on this specific point, in order to go deeper into the possible contents of drought management plans, including trans-national coordination.

Member States have also pointed out that some drought events can lead to a temporary deterioration in the status of bodies of water. In such cases, some of them are asking for a common understanding on the phenomena of "prolonged droughts" enunciated in the article 4.6 of the WFD.
Introduction

Concern about drought events and water scarcity situations arose among member States due to an increasing frequency of drought events in recent years. This led in 2003 to the emergence of a working group set up by the Water Directors, in charge of preparing a technical document on drought events and long-term imbalance issues. Water directors approved its main conclusions and recommendations in a policy summary in June 2006⁴. At the occasion of the Environment Council taking place in March 2006, some Member States claimed a European action on drought events and water scarcity situations. The Commission undertook to present a first analysis on the scope of these issues in June 2006⁵. The Environment Council held in June 2006 took note of the analysis but asked for further discussion on specific measures at EU level. The Commission proposed to strengthen the diagnosis, based on an in-depth assessment to consider what further action would be required at EU level.

Member States and the Commission stated that the in-depth assessment had to be fed by national contributions and additional inputs drawn up at EU level. Considering the importance and urgency of the issue, they also pointed out the need to get an interim assessment report before end 2006.

The Commission, with the help of the working group leaders (France, Italy, Spain), consequently built up a questionnaire, aimed at getting national information on water scarcity situations as well as drought events. It asked for data on the delineation of the problem and affected populations, the key players and causes, the economic, social and environmental impacts. It also invited member States to describe their use of EU funds for addressing the identified problems as well as their water pricing policies. It finally went into Member State expectations related to the Water Framework Directive.

A first questionnaire was sent to all Water Directors in July 2006 and nineteen member States provided a reply in October 2006. The Commission compiled the information and looked for thorough available data in recent studies or research works at EU level.

Following the presentation of a first interim report at the meeting of the Water Directors in November 2006, the Commission committed itself to address the remaining data gaps on the scope and impacts of the issues with the cooperation of Member States. A new questionnaire was disseminated to the Water Directors in early 2007. The analysis of the replies provided by Belgium (Flanders), Cyprus, Finland, France, Germany, Hungary, Lithuania, Netherlands, Portugal, Slovakia, Spain Sweden, UK and Eureau in March and April 2007, as well as information provided by other DGs of the Commission, made it possible to update the first interim report.

This second interim in-depth assessment therefore attempts to present an updated overview of drought events and water scarcity situations at EU level, whenever quantitative data are available at national⁶ and European levels.

It also gives an insight into national uses of EU funds and water pricing. Expectations on WFD are described in some cases when member States answered the questionnaire.

⁵ European action on water scarcity and drought – Information from the Commission – ENV 372 - 21 June 2006
⁶ In some cases, the differences displayed between national replies may partially be due to different interpretations of the questions included in the questionnaire by Member States.
A. General outlines of the situation and context

1. Water resources

   - Water availability

   The total renewable freshwater resource of a country is the total volume of river run-off and groundwater recharge generated annually by precipitation within the country, plus the total volume of actual flow of rivers coming from neighbouring countries. This resource is supplemented by water stored in lakes, reservoirs, icecaps and fossil groundwater.

   Dividing the total renewable freshwater resource by the number of inhabitants leads to water availability per capita.

   Up to the present, only national figures have been available. But, it will be worth in a near future going further and estimating water availability per capita at river basin level, in order to duly reflect local and regional vulnerability.

   ![Water availability per capita and country](image)

   The information presented in the diagram reflects the data provided by Member States to the Eurostat database. The figures reveal a large variability of the water availability among countries.

   Annual average run-off from rainfall varies from more than 3 000 mm in Western Norway to less than 25 mm in Southern and Central Spain, and is about 100 mm over large areas of eastern Europe. In absolute terms, the total renewable freshwater resource in Europe is around 3 500 km³/year.

   Thirteen countries have less than 5 000 m³/capita/year while Nordic countries generally have the highest water resources per capita.
The Mediterranean islands of Malta and Cyprus and the densely populated European countries (Germany, Poland, Spain and England and Wales) have the lowest water availability per capita.

Inflows from transboundary watersheds can be a significant percentage of the freshwater resources in some countries, either as surface flow or as groundwater flow. The downstream countries of the Danube basin have the highest dependency on external resources. The Netherlands, Luxembourg and Portugal also receive significant inflows from upstream rivers.

The water availability is an annual data which therefore does not reflect at all seasonal variations.

- **Inter-seasonal and inter-annual variability**

Information provided by Portugal makes it possible to illustrate this inter-seasonal and inter-annual variability.

Portugal has an average annual precipitation between 800-1000 mm similar to most of EU Member States. However, the temporal precipitation variability within the year frequently leads to serious problems of water scarcity in some regions, during the dry season (6 months). In this season the amount of precipitation is only 25% of yearly amount. Analysing the whole country, the temporal precipitation distribution in an average hydrological year in Portugal is given by the following figure.

As it can be observed, in the summer season the precipitation values are significantly reduced and the evapotranspiration values very important. This leads to low runoff levels in this season and creates important problems in some regions in terms of water availability.

If precipitation has in Portugal a large variability, the runoff case is more dramatic. The average runoff in dry semester is in some basins less than 10% of the average annual runoff. It is in general less than 20% or 25%.
The variability between dry and wet years is also very high, as illustrated in the following graph.

Therefore indicators defined on an annual basis are clearly inefficient to demonstrate the problem of water availability, the inter-seasonal variability and the inter-annual variability particularly due to the runoff variability during the year and along the years.

• **Impacts of climate change on water resources**

There is an increasing body of evidence of the ongoing global warming. Each of the five years since 2001 belongs to the six globally warmest years in the 165-year observation period and the two warmest years on record are 1998 and 2005. The future warming will depend on scenarios of socio-economic development and on adopted mitigation policies (curbing the greenhouse gas emissions). Different climate models and scenarios foresee that the temperature in 2011-2030 is to be higher than the temperature in 1980-1999 by 0.64-0.7°C. In 2100, the 65% probability range of warming for various SRES scenarios is 1.5-5.8°C, compared to 1980-1999.

Climate change models project more frequent and intense summer droughts, due to a joint effect of a rise in temperature and a drop in precipitation across many part of Europe, particularly in the Southern part (Goodess et al., 2007).

Often the presently dry areas are likely to become drier, and those presently wet - wetter. Mean annual precipitation is likely to decrease over much of Europe (in particular, over the
Southern and the Central Europe). However, intensity of rainfall events is projected to increase even in regions where the mean annual precipitation is likely to decrease. Changes in extremes are likely to be more dramatic than in the means.


Climate change is expected to reduce water availability and increase irrigation withdrawals in Mediterranean river basins. Under mid-range assumptions on temperature and precipitation changes, water availability is expected to decline in southern and south-eastern Europe (by 10 % or more in some river basins by 2030).

Observations indicate a lower recharge of groundwater, partly because of climate variations (Eckhardt and Ulbrich, 2003) as well as higher abstractions. Further decreases in groundwater levels are projected because the lower recharge is (partly) caused by a shorter length of the recharge season and the drop in water retention as snow. While an increase in winter rainfall could in principle increase groundwater recharge, saturated soil conditions could mean more immediate surface run-off of water instead of infiltration into the ground. UKWIR (2003), for example indicates a 5-15% lower recharge of the groundwater layers throughout the UK mainly due to a shorter recharge period in winter.

In coastal areas, especially in Southern Europe, where the pressure on water demand is already very high, the reduced availability of surface water during dry periods and the reduced groundwater recharge will increase the pressure on groundwater considerably. Some groundwater bodies will not be suitable any more as drinking water because of saline intrusion due to rising sea levels.

The latest IPCC Assessment Report confirms all trends. It reiterates that nearly all European regions are anticipated to be negatively affected by some future impacts of climate change. According to this report, climate change is expected to magnify regional differences in Europe's natural resources. In Southern Europe, climate change is projected to worsen conditions. In Central and Eastern Europe, summer precipitation is projected to decrease,

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7 Climate change and water adaptation issues, EEA Technical report, N°2/2007
8 Climate change and water adaptation issues, EEA Technical report, N°2/2007
9 Working Group II Contribution to the Intergovernmental Panel on Climate Change – Fourth Assessment Report, April 6th, 2007
causing high water stress. In Northern Europe, climate change is initially projected to bring mixed effects.

This report also points out that climate change is projected by the mid-century to reduce water resources in many small islands.

Information provided by Cyprus confirms this point.

Cyprus has a semi-arid climate and limited water resources which almost entirely depend on rainfall. Rainfall is highly variable with considerable regional variations. Two or three, or sometimes up to six consecutive dry years are observed. Statistical analysis of rainfall in Cyprus reveals a stepped drop in the early 70s, which has persisted. An analysis of the situation indicates a reduction of approximately 20% in the precipitation, which results in a 40% reduction in surface runoff. Furthermore, Cyprus has small catchments that do not provide any perennial flows.

The impacts of climate change on drought intensity and frequency attract great attention and raise questions among member States.

Several researchers led by DG RTD have provided a first contribution with further information on the links between climate change and droughts. The whole contribution is presented in Annex 4.

2. Water uses

Attention is being put on both water abstractions and water consumptions as they give a complementary illustration of each sector's water demand.

Data have been collected on the Eurostat database and cover the 1992-2003 period.

Then information is provided on the evolution of water use in the main economic sectors in latest years and for next years whenever prospective data on economic growth and development are available.

2.1 Sectoral distribution of water abstractions

On average, 44% of total water abstraction in EU is used for energy production, 24% for agriculture, 17% for public water supply and 15% for industry.

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10 Definition of water use:
Three types of water use are distinguished: (a) withdrawal, where water is taken from a river, or surface or underground reservoir, and after use returned to a natural water body, e.g. water used for cooling in industrial processes. Such return flows are particularly important for downstream users in the case of water taken from rivers; (b) consumptive, which starts with withdrawal but in this case without any return, e.g. irrigation, steam escaping into the atmosphere, water contained in final products, i.e. it is no longer available directly for subsequent uses; (c) non-withdrawal, i.e. the in situ use of a water body for navigation (including the floating of logs by the lumber industry), fishing, recreation, effluent disposal and hydropower power generation. Definition source: ETC/CDS. General Environmental Multilingual Thesaurus (GEMET 2000)

11 Definition of water abstraction:
Volume of water which is physically removed from its natural site of occurrence

12 Water used to absorb and remove heat in course of the processes for electricity generation, Eurostat.
Graphs 1 and 2 (in annex 1) present sectoral water abstractions by Member States, in absolute value and percentage. They reflect a significant variability away from the average between Member States.

Cyprus, Greece, Portugal and Spain use more than 60% of their abstraction for agriculture.

Belgium, Bulgaria, Estonia, France, Germany, Hungary, Lithuania, Netherlands and Poland use more than 50% of their abstraction for energy production.

The analysis at national level hides variability at river basin scale.

### 2.2 Sectoral distribution of water consumptions

The topic report of the EEA entitled "Europe's water: an indicator-based assessment" assumes that 80% of the water abstracted for agriculture, 20% for public water supply, 20% for industry and 5% for energy production are consumed and do not return to the water bodies where they come from. It is obvious that a large part of the water used in agriculture is either absorbed or evaporated from fields.

On average, 13% of the water consumed in EU is used for public water supply, 69% for agriculture, 10% for industry and 8% for energy production.

Greece, Portugal and Spain devote more than 90% of their overall water consumption to agriculture. This figure is between 50% and 90% for Bulgaria, Cyprus, Denmark, France, Latvia and Romania.

Public water supply accounts for more than a quarter of the overall water consumption in Austria, Czech Republic, Denmark, Germany, Ireland, Luxembourg, Netherlands, Slovakia, Slovenia and Sweden.

### 2.3 Evolution of water abstraction for public water supply

Apart from eastern countries, available data points out rather stable abstractions for public water supply in the last ten years [graph 5 - annex 1].

In eastern countries, data highlight a 25% decrease in abstraction for public water supply. In most of them, the new economic conditions led water supply companies to increase the water price and set up water meters in houses and industries. These measures resulted in a reduction of water abstractions by inhabitants and industries.

- **Level of leakage**

The capacity and quality of a water network can notably be evaluated in terms of leakage. Information provided by networks' capacity indicators is helpful in this regard.

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13 Definition of water consumption:
Volume of water which remains with users and does not return to the water body where it was abstracted (EEA states that 80% of total water abstracted for agriculture, 20% for urban use, 20% for industry and 5% for energy production are consumed).

The following graph illustrates the estimated leakage for public water supply networks due to failing infrastructures (EEA, 2003).

Percentages are far from being insignificant for most Member States represented in this graph, with leakage comprised between 10% and 50%.

Thorough analyses would be required to get updated data and estimate the overall impact of the leakage on water resources. Such work will have to be carried out in the future.

- **Impacts of tourism**

Special attention also needs to be paid to the impacts of tourism on public water supply needs.

The European Union is one of the world largest tourist destinations, with 60% of international tourists. This percentage grows by 3.8% a year. France, Spain and Italy respectively receive 75 million, 59 million and 40 million visitors a year. 

Increases from 40% to 60% have been observed since 1990. In Southern Western Europe (France, Greece, Italy, Portugal and Spain) tourist arrivals increased by 91% between 1985 and 2000.

The greatest activity is noticed along the Mediterranean coasts, where peak population densities have reached 2 300 people per km² and doubled the local populations.

Large abstractions are being carried out in summer in reaction to peak demands, while the equipments and water supply facilities are proved oversized in winter. Indirect health effects also need to be stressed.

In most countries, there are no specific figures for water abstraction due to the tourism sector. The use of water for tourism has usually been included in the public water supply statistics. In
addition, recreational activities (swimming pools, golfs) require large volumes of water which are not metered.

The table 1 presented in annex 1 provides information collected in some Member States and the two following maps illustrate the development of golf courses from 1990 to 2000.

![Map 1](Image1.png)

![Map 2](Image2.png)

Source: EEA, 2006

The example of the Spanish Jucar river basin also illustrates the extent of tourism at local level.

In the last thirty years, the tourism sector has experienced an exponential growth in the Júcar RB. The number of hotels, apartments, camping and rural houses has increased substantially: 23% increase in hotel lodging from 1996 to 2002, 35% increase in total stays from 1994 to 2002 (the most important increases being noticed in Valencia and Castellon), construction of 260 000 second homes in past twenty years.

The following table provides interesting figures of water consumption per category of hotel.

<table>
<thead>
<tr>
<th>Type of hotel</th>
<th>Water mean consumption per person and day (l/p/day)</th>
<th>Water mean consumption per seat and day</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 star</td>
<td>174</td>
<td>105</td>
</tr>
</tbody>
</table>
Knowing the distribution of the hotels per category in the river basin as well as the number of visits per year would make it worthwhile estimating the overall water consumption due to hotels at river basin scale.

The same work could be carried out with second houses, on basis of the following unit data.

<table>
<thead>
<tr>
<th>Type of house</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apartments without garden nor swimming pool</td>
<td>Average: 163 l/d</td>
</tr>
<tr>
<td></td>
<td>Summer maximum: 363 l/d</td>
</tr>
<tr>
<td>Family houses with garden and swimming pool</td>
<td>Average: 865 l/d</td>
</tr>
<tr>
<td></td>
<td>Summer maximum: 2,068 l/d</td>
</tr>
</tbody>
</table>

Next figures represent the scope of municipal water uses at river basin level. This use oscillates from 150 l/capita/day to values of 350-400 l/capita/day in municipalities of greater size and industrial activity. The data clearly show that values along the coast are greater due to an increase in tourism activity.

An increase in golf courses, especially in Northern Europe, is noted, making it obvious that tourism may have an impact on water resources beyond Mediterranean countries. It is clear that an impact assessment of tourism activities need to be further developed in the future.
2.4 Evolution of water abstraction for agriculture

Agriculture is a significant user of water resources in the EU, in particular for irrigation.

The impact of irrigation differs between countries and regions, due to climatic conditions and land uses. Its scale and importance are significantly greater in Southern Member States but far from negligible in most Northern Member States.

In terms of area irrigated and amount of water used, water demand for irrigation is relatively insignificant in Ireland and Finland, modest in Sweden, Luxembourg and Denmark, of increasing regional importance in the UK, Belgium, the Netherlands, Germany, Austria and France and nationally significant in Portugal, Spain, Italy and Greece. Irrigation for agriculture accounts for over 80% of total water abstractions in Greece, 72% in Spain, 60% in Italy and 59% in Portugal.

- Evolution of irrigation in the nineties

This graph illustrates the increase in irrigable areas from 1990 to 2000, especially in France (but with a small decrease in 2000), Greece, Italy, Spain and to a smaller extent after 1995 in Netherlands and United Kingdom. The irrigable area in EU-12 increased from 12.3 million hectare to 13.8 million hectare between 1990 and 2000 (increase of 12%). This is fully accounted for by Southern European countries: France, Greece and Spain, where the irrigable area increased from 1.8 million ha during the same period, representing an increase of 12% (EEA, 2005b: 34, 47). This evolution is partly the result of the Common Agricultural Policy.

Source: IRENA Project, EEA

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15 Source: The environmental impacts of irrigation in the European Union – a report to DG ENV by the Institute for European Environmental Policy, March 2000

rules that were in place until 2003. These rules included incentives for the production of irrigated crops and therefore supported increasing irrigated areas across Europe.

Distribution of irrigable areas at national level is also uneven, according to river basin information.

- **Evolution of irrigation in latest years**

The assessment of the latest evolution of the irrigated area remains difficult due to insufficient information available at national and European levels. It will be worthwhile going thoroughly into this issue with appropriate follow-up in order to clearly reflect the most recent trends.

One of the main elements of the latest reform of the Common Agricultural Policy is 'decoupling' under the single farm payment scheme (SPS). Fully decoupled policy does not influence production decisions by farmers and permits free market determination of prices. In other words, a farmer who received a large entitlement in the past for a particular type of production, e.g. for irrigated land or maize, is no longer obliged to continue with this favoured type of production in order to take advantage of the higher payments.

However, when introducing the single payment system, Member States could opt for full decoupling or its partial implementation (partial decoupling). In this last case, aid is paid to farmers partly as a single payment (independent of production volume) and partly as an additional payment (dependent on the output produced). For arable crops, France and Spain are the two sole countries which decided to adopt partial decoupling and therefore allocate per-hectare payments of 25% of the total amount.

Several studies show that full decoupling of supports for arable crops leads to a reduction in irrigated crops. In case of partial decoupling, a reduction occurs but its extent remains more limited. The implementation in France of a model\(^\text{17}\) (comparing the situation in 2002 to two scenarios respectively integrating partial decoupling and full decoupling) leads to a respective decrease of 7.9% and 10.1% in the nine administrative regions mostly concerned by irrigation.

In case of full decoupling, a decrease by 14.6% of maize crop is estimated, contributing to 72% of the total reduction of the irrigated area. South West regions would know the most important decreases in irrigated crops. Midi-Pyrénées, Poitou-Charentes and Aquitaine would represent three quarters of the overall decrease. These regions indeed mostly irrigate maize and have the most important proportions of irrigated crops (respectively 81%, 86%, 73%). Estimated decreases in case of full decoupling would be the result of reorientation from supported crops to non-supported crops and reorientation from irrigated crops to rain-fed crops.

As regards water consumption, full decoupling would lead to a reduction in water volumes consumed of 7.5%, which is inferior to the reduction in irrigated area previously estimated to 10.1%. Indeed, maize can also be partly replaced by vegetables which consume more water. Or water consumption on remaining irrigated areas could increase following a possible intensification of maize on the most favourable areas for this crop\(^\text{18}\).

\(^{17}\) Les effets de la réforme de la PAC de 2003 sur la demande en eau par l'agriculture, G. Buisson, D4E, Ministère français de l'écologie et du développement durable, décembre 2005

\(^{18}\) Sécheresse et agriculture, synthèse du rapport d'expertise réalisé par l'INRA, octobre 2006
Today, irrigation practices remain attractive for French and Spanish farmers, even if the incitation to raise irrigated crops tends to decrease. A comparative analysis based on French data bases\(^{19}\) reveals that the gross margin of irrigated maize remains higher than the gross margin of the nearest rain fed crop. Therefore only a move towards full decoupling would provide the best added value of the principles introduced by the last CAP reform.

- **Data gaps**

There are significant gaps regarding the data of water use for agricultural purposes. In addition, with regard to the national syntheses of the article 5 reports submitted so far, a number of unregulated activities of water abstraction and their impacts are not known but might be significant in certain cases (WRc, 2005: 21). The impacts of the private wells should be further addressed in this respect.

- **Types of irrigation**

Within the EU, many of the crops subject to irrigation consist of fruits, vegetables and other high value produce. Potatoes are one of the main irrigated crops in northern Europe.

The irrigation of crops receiving support under the CAP market regimes, including maize, rice, tobacco and olives is also significant. In Southern Europe, there is information on selected crops that are irrigated at least once a year. The most important irrigated crop is grain maize. The area of irrigated grain maize increased by 23\% (0.3 million ha) between 1990 and 2000, mainly in France, Spain and Northern Italy. The area of irrigated grain maize has decreased by 20\% in France since 2004. But the recent increase of the world price of maize could put an end to the decrease of the irrigated area in 2007.

The role of irrigation differs between countries and regions because of climatic conditions. In southern European countries, it is an essential element of agricultural production and irrigable areas are irrigated throughout the whole growing season each year. In central and northern European countries, irrigation is generally used to improve production in dry summers. There are also lowland regions where water supply to agricultural land takes place during summer by leading river water into canal networks across the land. This water management activity is needed, even in normal years, to avoid upward flow of saline groundwater which is present in the underground (for instance, near the coastline of Flanders and the Netherlands).

- **Water abstraction rates and regional variability**

Within the IRENA assessment, the regional water abstraction rates for agriculture were estimated by weighing national reported water abstraction rates by regional irrigable area (see above). The estimates are based on the assumption that water requirements for irrigation are abstracted from local water supplies, and thus resulting in regional pressures on water resources. In some cases however, large-scale water works include the transfer of water across large distances. Given the estimation method, it is not possible to draw direct conclusions on water use intensity per hectare of land in different regions from these figures, but they show the spatial distribution of potential abstraction pressures across the EU-15.

\(^{19}\) Etude sur l'irrigation et son évolution en Poitou-Charentes, ASCA, Septembre 2006
Regional water abstraction rates for agriculture in million m$^3$/a (2000)

The map provides a good indication of those regions among the 332 analysed for this assessment that have a high abstraction demand.

The 41 regions with the highest use of water for agricultural purposes (more than 500 million m$^3$ per year) are located in Southern Europe, 21 of which are estimated to require more than 1 000 million m$^3$ water per year for agriculture (EEA, 2005b: 48). Conversely, in Northern Member States, 90% of the regions are estimated to have abstraction rates of between 0 and 50 m$^3$ per year (EEA, 2005c: 4).

Based on abstraction rates and irrigable area, the IRENA assessment prepared by EEA estimated the annual water allocation rates for irrigation. They were grouped into two broader regions, each with different amounts of water allocated for irrigation: Northern and Southern EU-15 Member States.\(^\text{20}\)

In Southern EU-15 MS, the water allocation rate decreased slightly from 6 578 to 5 500 m$^3$ per hectare per year between 1990 and 2000. During the same period, the water abstraction rate decreased from 69 103 to 66 424 million m$^3$ per year, while the irrigable area increased from 10.5 to 12 million hectare (EEA, 2005b: 48). This reduction in water application rates per hectare of land irrigated likely can be either due to an increase in water use efficiency and/or partly be the consequence of restriction in use due to water shortage. The reasons of this reduction need to be further addressed.

In Northern EU-15 MS, the water allocation rate was halved from 757 to 349 m$^3$ per hectare per year between 1990 and 2000: both the water abstraction rate and the irrigable area decreased: from 1 622 to 716 million m$^3$ per year and from 2.1 to 2.0 million hectare, respectively (EEA, 2005b: 48)\(^\text{21}\).

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\(^{20}\) Northern EU-15 comprises AT, BE, DK, FIN, DE, IE, LUX, NL, SWE and UK; southern EU-15 comprises FR, GR, IT, PT and ES.

\(^{21}\) Source: WFD and Agriculture – Analysis of the pressures and impacts – Broaden the problem's scope – version 5 – 4 September 2006 – Ecologic, Warsaw Agricultural University
2.5 Evolution of water abstraction for industry

Because of the limited availability of data and the variety of sectors and products considered, it is extremely difficult to evaluate the volumes and efficiency of industrial water uses. Industrial use of water varies between countries. In most EU Member States, industrial abstractions have decreased through the 1980s and 1990s. In France, abstractions fell from 5107 Mio m³/year between 1985 and 1995. A variety of possible reasons help to explain this trend. Some of them are directly related to improvements in efficiency while others refer to external factors influencing industrial activity (economic conditions, strict checks and charges, legislation, policies of individual companies and industries, availability of new technologies)\(^{22}\).

In parallel to the general decreasing trend, it has been observed that demand for better quality and a great variety of products may increase water requirements in certain industrial sectors (e.g. more colours in the textile industry, greater variety and different qualities of paper products, larger numbers of chemical products).

Increases in water abstraction for manufacturing are also expected with continuing growth in economic activity and output. Although future water-use estimates for different industries entail considerable uncertainty, the increases are expected to be significant (more than 20% in some countries). In the faster-growing countries, where current abstraction for manufacturing is relatively low, water use may even double. The large uncertainties in this estimate relate to the uptake of new less water-intensive technologies such as electronics, the future of existing water-intensive industries, and the possible emergence of more water-intensive manufacturing processes\(^{23}\). The implementation of the IPPC Directive as part of the WFD also encourages reduction in water consumption as part of the best available techniques reference documents (BREF).

2.6 Evolution of water abstraction for energy

The production of energy can require the abstraction of large volumes of water and can therefore have impacts at the abstraction points. Most of the abstracted water then flows back to the environment and the final water consumption is estimated to not exceed 5%.

Western Central and Eastern countries are the largest users of water for energy production. In particular, Belgium, Germany and Estonia use more than half of the abstracted water for energy production. In Germany, power generation uses 28.8 billion m³ of water per year. This is the largest water user, followed by the manufacturing sector.

Decreases in water withdrawal for electricity production are likely. Many older power stations rely on once-through cooling systems, and newer plants are expected to replace many of these over the next thirty years. The newer plants usually operate with tower cooling systems\(^{24}\), which should result in substantial reductions, of 50% or more, in water withdrawal, despite an expected near doubling of thermal electricity production in Europe between 1990 and 2030\(^{25}\).

\(^{24}\) Tower cooling systems need the same volume of water abstraction but the net consumption is lower than for other systems.
B. Water scarcity issues

1. Definition and delineation of the problem

Water scarcity occurs where there are insufficient water resources to satisfy long-term average requirements. It refers to long-term water imbalances, combining low water availability with a level of water demand exceeding the supply capacity of the natural system.

Water availability problems frequently appear in areas with low rainfall but also in areas with high population density, intensive agriculture and/or industrial activity.

Large spatial and temporal differences in the amount of water available are observed across Europe.

Beyond water quantity, a situation of water scarcity can also emerge from acute water quality issues (e.g. diffuse or punctual pollutions) which lead to reduce water availability.

1.1 National Water Exploitation Indexes – Data coming from EEA and Eurostat

The Water Exploitation Index (WEI) in a country is the mean annual total demand for freshwater divided by the long-term average freshwater resources. It illustrates to which extent the total water demand puts pressure on the water resource. It points out the countries that have high water demand compared to their resources. Its calculation is based on national data provided by Member States to Eurostat. However, this Index is a national value and does not reflect at all possible high regional pressures on water resources.

Source: Eurostat, 1992-2003

It should be kept in mind that this index does not reflect the diverse situations that occur at river basin level.
The index for instance estimated for France does not reflect the water scarce river basins identified by national authorities and reported in table 2 of annex 1. An analysis at river basin level is therefore required to get a more specified picture of the situation in terms of water scarcity.

1.2 River Basin Water Exploitation Indexes

- **Data coming from the EEA**

These maps provide an overview of the river basins that currently face high levels of water stress.

The calculations were made with the global scale hydrological model WaterGAP. This model is designed to give long term (30-year) assumptions of water availability and water use. The water availability considered is the average assumed value between 1991 and 2020. It is necessary to mention that the model is not valid for a detailed investigation of river basins smaller than 20,000 km² (for freshwater availability) and below country level for water uses. Therefore model results like water stress or changes in freshwater availability have to be analyzed for large regions (i.e. sub continental descriptions).

The maps show that water scarce river basins are mainly the dry and irrigation-intensive river basins located in Southern Europe and hot-spots around urban centres. Large parts of Central Europe also have relatively high levels of water withdrawal compared with availability, but these often include large withdrawals for electricity production.

- **Data coming from Member States - Added value provided by River Basin Water Exploitation Indexes and limitations**

Thirteen Member States that answered the questionnaires provided a list of river basins considered as particularly affected by water scarcity (Belgium, Cyprus, Denmark, France, Germany, Hungary, Italy, Malta, Portugal, Slovenia, Slovakia, Spain, United Kingdom) [Table 2- annex 1].

Four countries – Austria, Finland, Netherlands and Sweden – declared not being affected at all by the issue.
The analysis of Member State replies shows that various methodologies were used in order to identify these river basins and that data comparability is finally difficult to ensure. Most Member States carried out rough estimations, taken into account assessments available at regional or river basin levels.

Due to the difficulty to get a representative view of water scarcity through national WEI, the need to calculate a WEI at river basin level has progressively emerged.

Member States carried out this calculation for the river basins previously identified as water scarce.

The results are summarized through the following graph.

Most river basins initially identified as water scarce by Member States have a WEI above 10%.

But for some river basins, the WEI is below 10% whereas they are impacted by water scarcity. The River Basin WEI therefore does not always reflect correctly the current situation. The WEI of the Adour Garonne basin is for instance estimated to 7% although it is largely affected by water scarcity.

The work carried out in France illustrates how an appropriate index can be set up for aquifers and fully reflect their level of water scarcity.

A first approach to calculate an Exploitation Index has been carried out in France on basis of abstractions of 2001. Data of efficient precipitations and abstractions of ground water have been compiled and attached to the corresponding aquifers. The pressure due to abstractions has been calculated through the ratio 'abstractions in the aquifer/sustainable water resource'. The sustainable water
resource means the part of efficient precipitations which recharge the aquifer, expressed in volume per unit of time.

Finally, for the purpose of this assessment, river basins will be considered water scarce whenever their Water Exploitation Index is above 10% \(^{26}\) or expert judgements identify them as such.

The overall area affected by water scarcity can be estimated to 418 600 km\(^2\) and the overall population to 76 375 000 inhabitants. In other words, at least 11% of the EU territory and 17% of the EU population have been affected so far by water scarcity situations.

The following map illustrates all water scarce river basins identified by Member States. For each concerned river basin, the European Environment Agency has mentioned the River Basin WEI and illustrated it with a range of different colours.

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\(^{26}\) See foot note 18.
The table 2 (annex 1) and the above map confirm that most affected river basins are located in Southern Europe, representing 62% of the total estimated EU area being affected. Apart from Southern countries, it is obvious that some river basins in Northern and Eastern countries are being affected by water scarcity.

England identified significant area (26 300 km²) and population (17 Mio inhabitants) affected by water scarcity in Europe. The area covers South East and Thames river basin districts.

Belgium has pointed out water scarcity situations in the Western part of Flanders. The imbalance between pumped amounts of groundwater and the limited recharge through the thick Ypresian clay layer has locally caused a great decline in piezometric heads in the aquifer of the primary rocks, cretaceous layers and landenian sands. Groundwater levels dropping up to 165 m were observed.

Denmark declared being almost entirely affected by water scarcity. Abstraction exceeds sustainable recharge by up to 300% around Copenhagen and other large towns and that irrigation is dominant in Western Jutland and exceeds sustainable recharge by up to 70%.

In the Eastern part of Slovakia, drinking water supply is being ensured with surface water reservoirs, as scarcity problems have arisen in groundwater.

1.3 Information included in article 5 reports

In addition to all previous information, attention needs to be put on article 5 reports.

A review of these reports notably highlights that over-exploitation of groundwater occurs in Cyprus, Malta and Portugal.

Cyprus report identifies that thirteen groundwater bodies (68%) are at risk due to over-pumping.
Malta report states that 30% groundwater bodies are at risk as a result of groundwater abstractions. Three main types of abstraction sources were identified in the pressure analysis: 1. public sources providing groundwater for the municipal supply; 2. abstraction sources utilised by the private sector; 3. low yield shallow wells utilised for secondary domestic purposes.

Portugal report indicates that groundwater abstraction is important in three river basin districts (30%). One water body (included in one of these districts) is considered at risk and represents 4.35% of the district. Some of the water bodies classified at doubt are significantly impacted by water abstraction.

1.4 Methodological considerations

Getting a global picture of the water scarcity situation at the EU scale requires aggregated information based on one hand on pressure exerted on water resources (volumes abstracted) and on the other hand, on water resources available. The only global index available based on harmonised EU data, the Water Exploitation Index, is not appropriate for describing the scope of water scarcity situations in Europe.

In order to set up a more appropriate indicator, methodological considerations must be discussed among specialists, including the following aspects:

- Geographical scale: national, regional or river basin or sub river basin scale. The diversity of water scarcity situations requires an indicator to be set up at least at the river basin scale.
- Freshwater resources:
  - Agreement is required between hydrologic and statistic services in order to have the most reliable data available;
  - The notion of 'exploitable' freshwater must be considered rather than 'freshwater resources'. That means that technical and economic aspects have to be introduced;
- For groundwater, abstractions should be considered for the aquifer where the volume is abstracted. That means that data must be geo-referenced.

Based on an agreed definition of water scarcity situations at the appropriate scale, areas and populations affected could be easily deduced.

**SUMMARY BOX**

- For the purpose of this assessment, a river basin is considered water scarce whenever its water exploitation index (calculated at river basin level) is above 10% or it is identified as such by expert judgement.

- The information provided by national authorities show that at least thirty European river basins located in thirteen Member States are impacted by water scarcity. Four Member States declared not being impacted. Ten Member States did not reply.

- The overall area affected by water scarcity is estimated to 418 600 km² and the overall population to 76 375 000 inhabitants. A minimum of 11% of the EU territory and 17% of the EU population have been therefore affected by water scarcity situations so far.
The limitations attached to the water exploitation index (WEI) will require further investigation in order to progress towards the definition of relevant indicators and thus a consistent representation of this issue at European level. The WEI can not be used to compare national situations.

2. Causes

2.1 Main features

Water scarcity is the result of an imbalance between water supply and water demand. Therefore increasing problems of water scarcity can result either from an increase of volumes abstracted or decreasing water resources. Structural reduction of water resources, as observed e.g. in Cyprus water scarcity, cannot be prevented directly by water managers, as it is linked to climate and effects of its changes. However, human activity can be adapted and abstractions can be limited to some extent in sectors where water is scarce.

Current water use (see chapter A) expressed as percentages of total available resources can easily illustrate the extent of the problem. However, calculations at national level may not be relevant or sufficient for some countries, as water scarcity may take place in some river basins with a great impact without occurring in other river basins. A focus at river basin level appears necessary to identify the sectors concerned and take appropriate actions in order to limit the causes of water scarcity situations.

2.2 Information available at river basin level [Table 3 - annex 1]

Among all identified river basins:

- Agriculture represents the major use in sixteen river basins.
- Energy represents the major use in five river basins.
- Public water supply represents the major use in three river basins.
- Industry represents the major use in one river basin.

In addition, it is obvious that tourism data are particularly lacking. There are difficulties in assessing the real contribution of tourism in total water use. Most Member States explained that water use for tourism was included in public water supply data. This issue will probably need to be further considered in the future, in order to assess the full impact of tourism on water resources.

3. Impacts

Through the questionnaire, Member States were invited to specify all impacts due to water scarcity situations identified at national level:
- The economic impacts endured by consumers and households, tourism, industry, energy and agriculture,
- The social impacts (employment, equality of treatment, public health and safety, others)
- The environmental impacts on surface water, groundwater, coastal water, wetlands, soils, biodiversity and others.

### 3.1 Economic impacts

#### Water supply

Needs for public water supply, have always driven investments and planning, but contribution of water scarcity in the overall financial burden is hardly singled out. Supply security is however one of the main criteria of decision in any strategic water supply scheme.

Water supplier surveys show that coastal areas and islands are the most exposed to interruptions in water supply.

In **Cyprus**, Water Boards operating in Nicosia, Limassol and Larnaca that serve more than two thirds of Cyprus population had to apply severe restriction measures in the late 1990s. In Nicosia, only 80% of the quantities supplied to consumers were provided under normal conditions of continuous flow (86% in Limassol and 70% in Larnaca). Water restrictions also resulted in high operation and maintenance costs. Similar conditions prevailed in the rest of the island. Farmers located in Cyprus still bear higher water costs today, due to deeper groundwater pumping and insufficient surface water resources. The situation results in income losses and in decrease in agricultural competitiveness.

The situation has also resulted in a heavy investment strategy in order to bring the number of interruptions down.

Desalination has been introduced in order to increase water security. As a consequence, prices for domestic water supply and products were put up. In the late 1990s, two desalination plants were erected to cater for domestic needs of Nicosia, Larnaca and Famagusta inhabitants.

The first desalination unit was commissioned in 1997 and has a production capacity of 40 000 m³/day.

The second began operating in 2001 and has a maximum capacity of 51 667 m³/day. The 2001 value for the water infrastructure investments in place (Government Water Works) was estimated to 1.74 billion € (2 175 €/inhabitant). The annual running costs are of 12.2 million € (15.25 €/inhabitant) and the annual water purchases from the desalination units are of 22.6 million € (28.25 €/inhabitant).

In parallel, the use of the two desalination plants also led to higher energy consumption.

In **Malta**, desalination represents 8% of the total electricity consumption (As a comparison, UK water and wastewater is 2% of total electricity consumption in England & Wales).

In addition to Mediterranean islands, several Member States have reported difficulty to ensure water supply (**France, Finland, Italy, Portugal, Spain, UK**).

In **Spain**, supply problems regularly occur in the Jucar basin during summer. In Segura basin, water scarcity has resulted in increase of water prices by 30% for households. Northern countries are not spared at all. In **England**, water prices have increased in the South East and Thames river basin districts in order to ensure security of supply but also meet directives' requirements, reduce leakages and implement water demand measures. Industry, energy sector and agriculture are encouraged with tax incentives to invest in water efficient
technology and water harvesting/alternative supply sources. They also have to cope with higher abstraction costs.

France has estimated the amount of investment carried out in the last twenty years in order to secure drinking water supply (production and distribution) at river basin level\(^27\).

<table>
<thead>
<tr>
<th>River basin</th>
<th>Overall amount of investment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adour Garonne (1)</td>
<td>Since 1987: 1.1 billion €</td>
</tr>
<tr>
<td>Artois Picardie</td>
<td>Since 1987: min of 500 million €</td>
</tr>
<tr>
<td>Loire Bretagne (2)</td>
<td>Since 1992: 1.2 billion €</td>
</tr>
<tr>
<td>Rhin Meuse</td>
<td>In the past three years: 5 million €</td>
</tr>
<tr>
<td>Rhône Méditerranée &amp; Corse</td>
<td>Since 1987: 1 billion €</td>
</tr>
<tr>
<td>Seine Normandie (3)</td>
<td>Since 1987: 1.5 billion €</td>
</tr>
</tbody>
</table>

(1) From 1987 to 2002, 25% of the investments related to drinking water aimed to secure water supply. 4% aimed to support water savings. 2% of the investments carried out in the industrial sector consisted in increasing water savings (10% for the period 2002 – 2006). From 1997 to 2002, 33% of the investments related to resources (including agriculture) aimed to increase water savings in agriculture and included the setting-up of metering.

(2) From 1992 to 1996, investments in transfers, interconnections, leakage reductions and water savings amounted to 190 million €. 45 million € were devoted to new boreholes and reservoirs for drinking water. 12 million € were spent for wide spreading water savings in industry.

Two dams were built up in the 80s to ensure a minimum flow in summer: Naussac in 1983 with a cost of 100 million € and Villerest in 1984 with a cost of 150 million €. For Villerest, only one third of the investment is related to water scarcity.

(3) In the period 2000-2006, 2 million € were devoted to water reuse in the industrial sector. As regards this basin, large investments for water storage have been undertaken since 1950. The overall storage capacity is about 800 million m\(^3\). The total costs of the four main dams (Pannecière, Seine, Marne, Aube) is about 1.6 billion € (2007 value). Amortizing these dams requires an amount of about 32 million € a year. The maintenance requires 14 million € a year.

- **Agriculture**

In **Spain**, impacts are being notable on agriculture. Some irrigated areas have been reconverted due to water scarcity. Agriculture is now experiencing limited developments: extraction costs are increasing, agricultural margins are reducing and a greater uncertainty is being put on production, leading to loss of competition.

In **Germany**, agriculture is affected in some regions, especially in the East of the country.

- **Other sectors**

\(^{27}\) Source: French Water Agencies
Impacts on energy production have been reported especially by Spain.

Expressing economic impacts through estimated financial costs remains difficult, as the costs of water scarcity mitigation measures have been mostly embedded into the cost of infrastructure provision. These data describe only a part of the overall economic impacts.

3.2 Social impacts

Employment in the farming sector seems to decrease in water scarcity areas (Spain, Cyprus). But this information needs to be further addressed, notably by comparing this evolution with evolutions in other areas and with future mid-term or long-term evolutions in areas where production is profitable but water is being used unsustainably.

In some regions, water-intensive industry could possibly migrate (South East of England and Thames river basin).

Potential problems could also arise on public health and safety, due to higher water pricing.

3.3 Environmental impacts

- Ground water

The overexploitation of groundwater and surface water usually results in large depletion of aquifers (Cyprus, France, Spain, UK). Cyprus reports that heavy over-pumping in reaction to increasing water demand or to mitigate drought effects explains this deterioration and in addition often leads to seawater intrusion in many coastal aquifers (also reported by Spain for the Segura basin). The Spanish contribution specifies that priority given to public water supply with the need to overcome demand peaks may give rise to environmental impacts. But agriculture can also be responsible of acute stress and lead to over-exploitation as it is the case in several Mediterranean river basins. As regards northern countries, UK reports that groundwater levels are continuously low and aquifers are shrinking.

- Surface water

In case of water scarcity, minimum river flows are not always ensured. In Cyprus, current water management approaches consist in storing water volumes that do not affect recharge downstream of the dams. However, due to frequent water shortages with demands exceeding resources, this principle is not always respected. In Jucar river basin, surface waters are affected by transfers from the Tajo basin.

Wetlands may be directly impacted by water scarcity. In Spain, great impacts were noticed on the Tablas de Daimel wetland and other wetlands.

Problems of water quality and rising pollutant concentration can also arise from a reduction in water flows (mentioned by Italy). The minimum flow needed for water ecosystems may not be guaranteed.
Water scarcity can also affect **biodiversity**. In England (South East and Thames river basin), unsustainable abstractions have caused low river flows, poor quality and loss of wildlife including fish.

**SUMMARY BOX - Water scarcity impacts**

- **Economic impacts**
  - Public water supply may be deficient and have impacts on related activities like tourism.
  - Energy production may decrease as river water is too warm for use as cooling water. This can result in income losses but needs to be further assessed.
  - Agriculture may be affected by insufficient water resources, deeper pumping, greater uncertainty on yields, possibly leading to income losses.

France estimated the amount of investments carried out in the last twenty years in order to secure public water supply to € 5.3 billion. Cyprus estimated the 2001 value of all water infrastructures in place (Government Water Works), excluding desalinisation units, to € 1.7 billion.

- **Social impacts**
  - Water prices can increase due to the implementation of compensating measures.
  - In some regions, water-intensive industry could possibly migrate.

- **Environmental impacts**
  - Groundwater: aquifer depletion due to over-pumping resulting in seawater intrusion.
  - Surface waters: minimum water flows are not always being ensured. Concentration in pollutants may increase due to less dilution.
  - Wetlands: the main features of some wetlands are being deteriorated.
  - Impacts on soils with increasing erosion and desertification
  - The introduction of alternative solutions aimed at keeping the same level of water abstractions, such as desalination units, leads to increase energy consumption.

Whatever the type of impacts, it is obvious that many data are lacking at EU, national and river basin levels. It is therefore difficult to give a comprehensive estimation of the costs incurred by all the European Union to face water scarcity.
C. Drought events

1. Definition and delineation of the problem

Droughts can be considered as a temporary decrease of the average water availability. Droughts can occur anywhere in Europe, by definition in both high and low rainfall areas and in any seasons. The impact of droughts can be exacerbated when occurring in a region with already low water resources, with mismanagement of water resources and with imbalances between water demands and the supply capacity of the natural system. In some regions, the severity and frequency of droughts can lead in the future to water scarcity situations due to overexploitation of available water resources. Consequently, attention needs to be paid on the synergies between the phenomenon of drought and the phenomenon of water scarcity, especially in the river basins being affected by water scarcity.

In introduction, it should be highlighted that progress still needs to be made in terms of methodology for identifying and describing drought events. Similarly to water scarcity issues, it is obvious that Member States used different criteria to estimate durations, populations and areas affected by drought events. A common understanding of these parameters, including a sector by sector approach, should be particularly useful.

Nevertheless, this first assessment makes it possible to draw some first conclusions.

Member States' answers to the questionnaire show different degrees of exposure to droughts.

- The extent of droughts is variable all over EU. The information provided so far reveals that at least Austria, Belgium, Cyprus, France, Hungary, Italy, Lithuania, Malta, Netherlands, Norway, Portugal, Spain and United Kingdom have been affected by droughts, in the last thirty years but with different degrees of intensity. Italy, Portugal, Cyprus, Spain and France have registered the highest frequency of droughts from 1976 to nowadays, with 8 to 21 events by country.

- However, several Northern and Eastern countries have experienced droughts in last years, such as Belgium, UK, Finland, Germany, Hungary, Lithuania, Netherlands, Norway and Slovakia.

- Some countries (Cyprus, Finland, France, Italy, Malta, Portugal, Spain) have a large part of their territory being touched whenever droughts occur, while some other countries may be frequently affected within a specific part of their territory (Belgium : area under influence of Meuse canal system - Austria : Eastern, Southern and South Eastern regions).

- Drought duration is largely variable from one Member State to another. In Cyprus, Italy, Portugal, Spain, droughts may last one or more successive years. In other countries, droughts have been predominant during one month (Hungary, Germany, Lithuania) or from two to six months (Austria, Belgium, France). Finland was affected by a 270 day drought from August 2002 to April 2003.

- Several indicators can be taken into account in order to illustrate the severity of a drought event. The level of precipitation may be one of these indicators. Tables available on http://forum.europa.eu.int/Public/irc/env/wfd/library?l=framework_directive/scarcity_drought
ts (public library of CIRCA, file entitled "scope of droughts in some Member States") present an overview of drought events at national level for Member States that provided information.

This graph points out that drought events have occurred every year since 1976. But drought intensity and coverage have largely varied from one year to another.
Droughts affected more than 800 000 km² of the EU territory and 100 million inhabitants in 1989, 1990, 1991 and more recently in 2003.

Qualitative information from some Member States was impossible to include in graphs. For instance, UK has provided figures for the 2004-2006 droughts but no figures for a series of less recent droughts in 1984 (most severe in North West and South West England, in Wales and Midlands), 1989 to 1992 (most of England and Wales and then focused on groundwater in the South and North of England), 1992 (North of England), 1992 to 1995 (mainly groundwater in Eastern England), 1995 to 1996 (North of England, Midlands, South of England and Wales), 1997 (East Anglia) and 2003 (national but most intense in South East and North West England). These events need to be kept in mind even if no figures are available.

<table>
<thead>
<tr>
<th>Average EU area affected a year (km²)</th>
<th>% of EU area</th>
<th>EU population affected a year (Mio inhabitants)</th>
<th>% of EU population</th>
</tr>
</thead>
<tbody>
<tr>
<td>1976-1980</td>
<td>213 106</td>
<td>5%</td>
<td>29</td>
</tr>
<tr>
<td>1981-1985</td>
<td>116 351</td>
<td>3%</td>
<td>12</td>
</tr>
<tr>
<td>1986-1990</td>
<td>433 154</td>
<td>10%</td>
<td>48</td>
</tr>
<tr>
<td>1991-1995</td>
<td>725 142</td>
<td>17%</td>
<td>52</td>
</tr>
<tr>
<td>1996-2000</td>
<td>199 285</td>
<td>5%</td>
<td>19</td>
</tr>
<tr>
<td>2001-2006</td>
<td>662 910</td>
<td>15%</td>
<td>81</td>
</tr>
</tbody>
</table>

This table shows a significant increase in annual average EU area (from 6% to 13%) and population (from 6% to 13%) affected by droughts between 1976-1990 period and 1991-2006 period.

2. Causes

Droughts generally result from a combination of natural factors that can be enhanced by anthropogenic influences. The primary cause of any drought is a deficiency in rainfall. High air temperatures and evapotranspiration rates may act in combination with lacking rainfall to aggravate the severity and duration of drought events. High air temperatures in summer, when associated with clear skies and sunshine, increase evapotranspiration to the extent that little or no rainfall is available for groundwater or river recharge.

Winter droughts are caused by precipitation being stored in the catchment in the form of snow and ice, preventing any recharge of rivers or aquifers until air temperatures rise again and snow melting starts.

Drought is also related to the timing (i.e. principal season of occurrence, delays in the start of the rainy season, occurrence of rains in relation to principal growth stages) and the effectiveness of the precipitation (i.e. rainfall intensity, number of rainfall events).

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Other climatic factors such as high wind velocities and low relative air humidity are often associated with a drought event in many regions of the world, and can significantly aggravate its severity.

3. Impacts

Similarly to water scarcity issues, the questionnaires sent to member States included a part on drought impacts. Member States were invited to provide information on economic, social and environmental impacts.

The following table summarizes the information provided by Member States on the impacts of several drought events.
# Examples of costs incurred by Member States due to past droughts (Mio €)

<table>
<thead>
<tr>
<th>Period</th>
<th>Member State</th>
<th>Economic impacts</th>
<th>Social impacts</th>
<th>Environmental impacts</th>
<th>Others</th>
<th>Overall impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Public water supply</td>
<td>Industry</td>
<td>Energy</td>
<td>Agriculture</td>
<td>Navigation</td>
</tr>
<tr>
<td>1975-1976</td>
<td>Portugal</td>
<td></td>
<td>147</td>
<td>53</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1976</td>
<td>Belgium**</td>
<td></td>
<td>350</td>
<td>5</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>1961-1990</td>
<td>Hungary</td>
<td></td>
<td>50</td>
<td>300</td>
<td>200</td>
<td>4000</td>
</tr>
<tr>
<td>1981-1983</td>
<td>Portugal</td>
<td></td>
<td>14</td>
<td>238</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>1989-2002</td>
<td>France</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1540</td>
</tr>
<tr>
<td>1990-1995</td>
<td>Spain</td>
<td></td>
<td>22</td>
<td>210</td>
<td>1800</td>
<td></td>
</tr>
<tr>
<td>1992-1993</td>
<td>Portugal</td>
<td></td>
<td>22</td>
<td>426</td>
<td>241</td>
<td></td>
</tr>
<tr>
<td>1995</td>
<td>UK***</td>
<td></td>
<td>352</td>
<td>265</td>
<td>24</td>
<td>324</td>
</tr>
<tr>
<td>2002-2003</td>
<td>Finland</td>
<td></td>
<td>10</td>
<td>1</td>
<td>50</td>
<td>17</td>
</tr>
<tr>
<td>2003</td>
<td>Belgium**</td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.05</td>
</tr>
<tr>
<td>2003</td>
<td>France</td>
<td></td>
<td></td>
<td></td>
<td>300</td>
<td>590</td>
</tr>
<tr>
<td>2003</td>
<td>Germany</td>
<td></td>
<td></td>
<td></td>
<td>1000</td>
<td></td>
</tr>
<tr>
<td>2004-2005</td>
<td>Portugal</td>
<td></td>
<td>9</td>
<td>32</td>
<td>261</td>
<td>519</td>
</tr>
<tr>
<td>2005</td>
<td>France</td>
<td></td>
<td></td>
<td></td>
<td>270</td>
<td>250</td>
</tr>
<tr>
<td>2005</td>
<td>Spain</td>
<td></td>
<td></td>
<td></td>
<td>713</td>
<td>2500</td>
</tr>
<tr>
<td>2006</td>
<td>Netherlands</td>
<td></td>
<td>10</td>
<td>600</td>
<td>72</td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td>Lithuania</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* During the 2004-2006 drought, Portugal had to spend 23 Mio € in urban water supply. In 66 municipalities (100 500 inhabitants), urban water supply was supplemented by 22 850 water tank operations.

** These figures are the results of simulations. For 1976, damages have been estimated taking into account actual water uses (2002).

*** Costs are related to the 1995 hot dry summer and drought together. The impact of the 1995 drought itself was around € 140 Mio.
3.1 Economic impacts

3.1.1 Consumers and households

Droughts can result in various impacts on consumers and households.

The first impacts directly relate to water supply but other impacts may come into sight, such as damages on habitations due to changes in soil structure.

- Water supply

The population affected by restrictions in water uses expresses the impact of droughts on public water supply.

The following table presents the estimated population affected by restriction uses in 2003, 2004, 2005 or 2006 (Mio inhabitants).

<table>
<thead>
<tr>
<th></th>
<th>BE</th>
<th>CY</th>
<th>DE</th>
<th>DK</th>
<th>FI</th>
<th>FR</th>
<th>IT</th>
<th>NL</th>
<th>NO</th>
<th>PL</th>
<th>PT</th>
<th>ES</th>
<th>SW</th>
<th>UK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total connected</td>
<td>6.5</td>
<td>0.85</td>
<td>60</td>
<td>5.2</td>
<td>4.7</td>
<td>60</td>
<td>75</td>
<td>16</td>
<td>4</td>
<td>35.5</td>
<td>10.3</td>
<td>43.5</td>
<td>8</td>
<td>60</td>
</tr>
<tr>
<td>Impacted</td>
<td>1</td>
<td>0.85</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>≤20</td>
<td>n.d.</td>
<td>&lt;0.1</td>
<td>0.8</td>
<td>0.5</td>
<td>&lt;0.1</td>
<td>&lt;10</td>
<td>&lt;0.1</td>
<td>16&lt;sup&gt;29&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Altogether, the European population affected by water use restrictions is 50 million inhabitants in the most sensitive years, which represents a substantial increase since the 70s. On basis of recent examples, restrictions have led to a reduction in water consumption by an average of 10%.

Belgium assessed that if a 1976 drought event occurred under current circumstances of water demand, the country would face a shortage of infiltration capacity for drinking water production for 44 days with an associated cost of 1.87 Mio €.

[In Finland, during the drought of 2002-2003, 10 000 scattered private houses (equivalent to 40 000 inhabitants) usually getting their water from private wells, suffered from insufficient water for household consumption. Approximately 200 000 m³ of water were carried by canisters or brought by tank trucks, for an estimated cost of 5.5 Mio €.]

In France, Belle-Ile was impacted in summer 2005 by a unique and extreme situation, where water supply could not be ensured with a satisfactory water quality. The five thousand customers were supplied with bottles of water, while water supplies were transported from the mainland by tankers.

Due to the 2004-2006 drought, Portugal spent 23.2 M€ in urban water supply. In 66 municipalities (100 500 inhabitants), urban water supply was supplemented by 22 850 water tank operations.

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<sup>29</sup> Number of people who could not use a hosepipe to water gardens or wash cars
In **Finland**, all water suppliers have to provide alternative supplies of 50 litres per inhabitant per day in a situation where the main water intake is out of use. In 1997, 69% of water suppliers met this target. In 2005, the government emergency response working group proposed that all suppliers should meet this target by 2012. The construction of new emergency connections between communities is foreseen.

In Sweden, problems have emerged from the summer of 2000 in coastal areas and islands. Most of the islands now have to cope with salt-water intrusion, due to abstraction in groundwater. In Gotland, it has been decided to use surface water, but the municipality still needs to issue restrictions on water use in summer.

- **Damages on habitations**

In France, from 1989 to 2003, the annual average cost of drought damages caused to houses has been estimated to 330 Mio €. The 2003 drought impact was particularly high, as the amount of compensations for house damages came to 1.68 billion €.

### 3.1.2 Tourism

Little data has been so far available on this issue. France reports losses of 144 million € during the winter 2006-2007 in the Alpes, Savoie.

Portugal took action during the drought of 2004-2005 in order to mitigate the impacts on tourism.

### 3.1.3 Industry

Belgium estimated that if a 1976 drought event occurred under current circumstances of water demand, two important companies would stop their production for 80 to 100 days. The associated cost is estimated to 350 Mio €.

Finland reports that during the drought of 2002-2003, pulp and paper industries suffered from deficiencies due to drought conditions. Financial losses were estimated to 1 million €.

Portugal reports that in 2004-2006, fertilizer industry as well as pulp and paper industry faced an additional cost of 32.25 Mio €.

### 3.1.4 Energy

- **Hydroelectricity**

Several Member States have reported reduction in hydroelectricity production due to drought events (Finland, France, Portugal, Spain). As hydroelectricity production is related to the amount of water stored in the upper reservoirs, the production level can be lower during a drought. Peak demands then need to be satisfied by other means available in a short term (gas turbine, etc).

France has reported the impacts of the 2003 summer heat wave on the national French utility EDF.

The 2003 summer combined both a lack of water (few rain periods, high temperature since May) and a period of very high temperature (hottest summer in France since 150 years\(^{30}\)). It is the combination of both factors which led to a crisis.

Concerning the electricity sector, the following difficulties were encountered in August 2003:
- Low level of water in the reservoirs (lakes, etc) leading to a loss for hydroelectricity power of about 1 000 MW for current flow and 600 MW for lake production,
- Loss of thermal electricity potential production, up to 16 000 MW due to decrease in the cooling power of rivers (high water temperature and low river flows). This loss of production capacity occurred while the energy needs were 5 to 10 % higher than usually at that period of the year due to high temperature (supplementary cooling needs). The increase in temperature also led to other problems (e.g. power cuts due to temperature around underground wires) which are out of the present scope.

As a consequence, electricity price rose up to 1000 €/MWh on the market on August, 10\(^{th}\). EDF company reported for itself a cost of about 300 Mio € (exceptional material and human resource costs, electricity purchase on the market).

The graph presented below shows the impact of the 2005 drought on the level of hydroelectricity production\(^{31}\) (about 10000GWh less than 2004 - which corresponds to the yearly electricity consumption of a town of 1.4Mio inhabitants including industry). The 2003 production is not as low as 2005: the network crisis during the summer was due to a combination of 2 difficulties: relative drought (when compared to years like 2000 or 2001) and high temperature. The graph shows that drought has an important impact on the level of hydropower production. 2003 and 2005 are clearly the lowest years of production since 1991.

Agreements on water management between energy production and other uses include a cost for water which is generally based on the amount of water used and on the corresponding energy loss. Therefore higher demands in water (e.g. for irrigation) result in higher costs.

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\(^{30}\) Rapport d’information du sénat n° 195 « La France et les Français face à la canicule : les leçons d’une crise »

In Spain, the 2005 drought led to a reduction of 36% in national hydroelectric power production (equivalent to 12 876 GWh), with respect to the past five year average. The decrease in hydraulic and nuclear production has been compensated by an increase in fuel-gas plant production and combined cycles that increased their production by respectively 28% and 66%, compared to 2004. This extra production led to an additional cost of 713 Mio €. It is also worthwhile to mention that replacing hydro-electricity by fossil fuel gave rise to environmental impacts.

Belgium reports that if a 1976 drought event occurred under current circumstances of water demand, two energy suppliers would fail 8 to 13 days, resulting in a cost of 5.4 Mio €.

- **Thermal production**

France reports that rivers with lower regimes have a lower cooling power. In some cases, this situation can lead to reduction in the potential of electricity production.

### 3.1.5 Agriculture

The first impact of drought on agriculture is a decrease in productivity. In Portugal the drought of 2004-2006 resulted in a cost of 39 Mio € for the farming sector.

<table>
<thead>
<tr>
<th><strong>In Spain, the reduction in farm incomes following the 1990-1995 droughts was estimated to 1800 Mio €.</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>In 1994, estimated losses in Segura basin for non-irrigated and irrigated crops were respectively of 34.4 Mio € and 121.5 Mio €, while the impacts on sectors depending on agriculture came to 176 Mio €.</td>
</tr>
<tr>
<td>From 1991 to 1993, Tagus basin spent 22 Mio € in emergency measures related to water supply and irrigation. This amount reached 26 Mio € from 2004 to 2006 for similar measures.</td>
</tr>
<tr>
<td>From 1992 to 1966, 24 Mio € were spent in Jucar basin for loss in tree coverage and 160 Mio € for decrease in herb and citric productions.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>In 2005, agricultural inputs decreased by 12%. Vegetal production decreased by 13% while stockbreeding decreased by 2.6%. In vegetal production, cereals and wine respectively decreased by 42% and 20%. Non-irrigated crops and pastures suffered important losses reaching 2 500 Mio €. Compensations by farm insurances went up to 541 Mio € with 70% of the land used for agriculture and livestock being affected during eleven months. Payments to the livestock sector added up to 1 000 Mio €.</strong></th>
</tr>
</thead>
</table>

In France, impacts of droughts slightly vary from one region to another and also depend on the type of crop. For cereals, the yields and quality of 2005 crops were not too far from the average. For autumn crops, an average decrease of about 10% of the yield has been observed. For maize, the decrease in yield was estimated to about 20% in 2005 compared to 2004. In 2003, 83 departments received such subsidies. In 2005, 17 departments received « calamity fund » subsidies from the Ministry of Agriculture. The cost of the 2003 drought for French farms has been estimated to 590 Mio € (24 Mio € in 2004, 250 Mio € in 2005). From 1989, drought impact on agriculture has cost an average of 110 Mio € per year to France. Impact on fishery has been estimated to 3 Mio € a year.
In Lithuania, losses in agricultural production accounted to 12 Mio € in 2002 and came to 180 Mio € in 2006.

Further impacts can include additional costs due water transportation to farms. Finland reports that such expenses have amounted to 0.3 Mio € for the drought of 2002-2003.

3.1.6 Transport

Belgium reports that if a 1976 drought event occurred under current circumstances of water demand, navigation would be made impossible on the canal system during 115 days, resulting in a cost of 123 Mio €. The estimated damage is only based on the direct damage experienced by the sector itself and thus does not include a very important part of economic damages borne by all the industries depending on this mode of transport.

In 2003, navigation was hindered during 22 days on the canal system, with an associated cost of 0.05 Mio €.

In UK (South East and Thames river basin districts), low flow rivers gave rise to navigation problems. Locks could not operate normally due to insufficient water.

3.1.7 Others

Finland estimates that in 2002-2003, the expenses for water transportation and the building of new wells were estimated to 5.5 million €.

In 2004-2006, Portugal spent 0.7 Mio € for public awareness campaigns.

3.2 Social impacts

In 2002-2003, Finland bore water quality problems in 42 waterworks and in many private water wells.

In 1995, Spain estimated to 12 Mio the number of inhabitants suffering from restrictions, with acute problems in Seville, Cadiz and Palma de Mallorca.

From 1992 to 1996, the Spanish Jucar basin experienced a decrease in employment, with 70 Mio € of not yielded wages.

In England (South East and Thames river basin districts), about two hundred job losses were attributed in part to restrictions on the use of hosepipes.

3.3 Environmental impacts

3.3.1 Surface waters

Direct impacts of droughts on surface waters include sharp decrease in river flows and associated eutrophication.
In Portugal, reservoirs significantly lowered during the 2004-2006 droughts. Alga blooms occurred. In the southern province of Algarve, two major reservoirs – Funcho, Arade – ended to be totally empty. Decreasing flows in rivers gave rise to problems with migrating species (such as the lamprey in Minho river) and in abstractions. The average flow in Finland is usually about 3 200 m³/s per year. In 2003, the flow dropped to 2 100 m³/s. Due to the low oxygen concentration in shallow and eutrophicated lakes, fish mortality increased.

3.3.2 Groundwater

Significant decreases in aquifer levels are the main expression of drought impacts on groundwater. These decreases can also be accompanied by further risk of sea intrusion (see next paragraph).

In Portugal, the level of some major aquifers significantly lowered during the 2004 – 2006 droughts.

In Belgium, the lowest water levels for the period 1970-1985 were observed in the phreatic wells in 1976. In 2001 and 2003, water levels severely dropped in most phreatic wells.

In Finland, at the beginning of 2003, 30 km³ less in groundwater aquifers and 30 km³ less in lakes and soil moisture, compared to the average situation.

In UK (South East and Thames river basin districts), some groundwater reached historic low levels (2005-2006).

3.3.3 Coastal waters

In Portugal, upstream migration of saline concentration occurred in transitional waters (Tagus estuary, Lima River) during the 2004 – 2006 droughts. This migration is often the result of groundwater abstractions exacerbated by drought events.

In Belgium, if a 1976 drought event occurred under current circumstances of water demand, salted water could infiltrate into the downstream part of the Channel system – with impact on raw intake for drinking water supply during 131 days.

3.3.4 Wetlands

Belgium reports that if a 1976 drought event occurred under current circumstances of water demand, infiltration would stop during 130 days in 6 valuable areas. Under normal circumstances, water is being used to mitigate desiccation.

UK has identified a wetland bird reserve in North Kent affected by droughts.

3.3.5 Soils

Soil degradation is a serious problem in Europe. It is driven or exacerbated by human activity such as inadequate agricultural and forestry practices, industrial activities, tourism, urban and industrial sprawl and construction works. These activities have a negative impact, preventing the soil from performing its broad range of functions and services to humans and ecosystems.
This results in particular in loss of soil fertility and lower water-retention capacity. It can also impair the health of European citizens and threaten food security. Although soil degradation processes vary considerably from Member State to Member State, with different threats having different degrees of severity, soil degradation is an issue all over the EU.

An estimated 115 million hectares or 12% of Europe’s total land area are subject to water erosion, and 42 million hectares are affected by wind erosion. An estimated 45% of European soils have low organic matter content, principally in Southern Europe but also in areas of France, the UK and Germany.

The Corine Land Cover database shows significant changes in land use in Europe which have an impact on soil. Between 1990 and 2000, at least 2.8% of Europe’s land was subject to a change in use, including a significant increase in urban areas. Big differences exist between Member States and regions, with the proportion of the surface sealed during that period ranging from 0.3% to 10%. It is difficult to extrapolate current trends into the future based on the limited existing data. However, the human-induced driving forces causing the threats are showing an upward trend. Climate change, in the form of rising temperatures and extreme weather events, is exacerbating both greenhouse gas emissions from soil and threats such as erosion, landslides, salinization and organic matter decline. All this suggests that soil degradation in Europe will continue, possibly at a faster pace.

A combination of some of these threats can ultimately lead arid or sub-arid climatic conditions to desertification.

### 3.3.6 Biodiversity

Biodiversity may be highly affected by drought events. Droughts may for instance lead to desiccation of wetlands, disappearance of species and/or fires.

In the Netherlands, loss of nature value may be noted, as it is influenced by the amount of water, the seepage level, the quantity of salt in groundwater and surface water as well as features of the water coming from outside the area.

- **Impacts of forest fires**

In recent years, large areas of forest have been destroyed by fires and led to enhanced soil erosion and deficiency in water retention. On the other hand, it should be further considered that some forests, such as forests of eucalyptus, do not appropriately ensure the preservation of biodiversity and sustainable water management.

In Portugal, droughts of 2004-2006 led to costs of 8.8 Mio € linked to forest fires. In Spain, fires on 28 822 ha during 1994-1995 droughts gave rise to expenditures of 36 Mio €. In France, a significant increase in fired areas has been noticed from 1976 to 2003 (+ 17 000 ha). The average cost for a fired hectare is estimated to 8 550 €. The average cost due to fires in years with outstanding drought can be estimated to 145 Mio €. The exceptional features of the 2003 drought led to a total cost of 370 Mio €. In 2002-2003, drought enhanced the presence of dead wood in Southern Finland, more than doubling the number of forest fires, compared to average years.
• Impacts on species

In 2004-2006, Portugal spent 0.3 Mio € for biodiversity and ecosystem protection. To prevent water resource quality deterioration caused by fish mortality, 140 measures were undertaken on the field and 220 tonnes of fish were removed. Several measures were applied in the Guadiana River Basin, particularly due the low level of tributaries such as Caia, Terges and Vascão, a great part of them being included in Natura 2000 sites. These rivers have high rates of endemic, threatened and protected cyprinid fish species including the critically endangered Anaecypris hispanica. During spring, summer and autumn of 2005, conservation actions were carried out in the Guadiana Basin, including an emergency campaign which allowed the rescue of more than one thousand threatened cyprinids including two hundred Anaecypris hispanica.

In France, even if it is difficult to estimate fish mortality during summer 2005, around 400 km of permanent rivers were totally dry resulting in fish mortality. In all the French territory, 67 departments put into place an ecosystem observation network. A lot of fish mortality was registered within the two following districts: Loire-Bretagne, Rhône-Méditerranée. But the mortality of fishes was less important than in 2003, because the temperatures of water were not so high. The fish species the most in danger were cyprinids and salmonids. In a lot of rivers, ecosystems suffered from alga development and increased eutrophication inducing the asphyxia of certain rivers. The low level of flows combined with higher temperatures disturbed the migration of salmonids in some departments and rivers such as Manche, Morbihan, Finistère, and Garonne river basin.

In Belgium, several ecological valuable aquatic species temporarily disappeared in 1976 due to desiccation of channels and ponds.

In UK, recent droughts resulted in a number of fish deaths in ponds, lakes and streams, due to hot and dry weather, depleted oxygen levels and algal blooms.

3.3.7 Other environmental impacts

Spain reports impacts on air pollution. In 2005, 14 268 GWh have been produced by thermic energy, instead of hydroelectricity, resulting in extra gas and particle emissions, estimated to 5.7 Mio tons of CO₂ and an extra cost of 114 Mio €.

3.3.8 Synthesis – estimation of the EU overall impacts due to droughts

| All the information provided by member States made it possible to build up unit costs linked to droughts, in particular for public water supply (unit cost/inhabitant) and agriculture (unit cost/ha). The application of estimated unit costs to member States which did not provide any cost assessment helped to provide an overall picture of the impact of droughts at EU level. |
The estimation of the overall impact of droughts at EU level results in a cost of 100 billion € in the last thirty years. The annual impact due to droughts is estimated to have doubled between the 1991-2006 period and the previous 1976-1990 period. It reached 6.2 billion € in last years.

**SUMMARY BOX**

- **Extent of droughts**

In the last thirty years, EU has been affected by major droughts, in particular in 1989, 1990, 1991 and 2003.

Information provided by Member States also reveals that at least Austria, Belgium, Cyprus, Finland, France, Germany, Hungary, Italy, Lithuania, Malta, Netherlands,
Norway, Portugal, Spain and United Kingdom were impacted, with different degrees of intensity, in the last thirty years. The other Member States did not provide information.

Italy, Portugal, Cyprus, Spain and France have registered the highest frequency of droughts from 1976 to nowadays, with a range of 8 to 21 events by country.

While southern countries have been the usual and main member States suffering from drought effects, some northern countries are becoming increasingly affected.

In 2000-2006 period, 15% of the EU territory and 17% of the EU population have been concerned on an annual basis.

- **Economic impacts**

  Depending on national or local situations, economic impacts may include sudden difficulty in public water supply (with the need to reduce some water uses and even in some cases supply populations with tanks), income losses for industries and agriculture, decreases in energy production and disturbance in transport through navigation.

  The annual impact on the economy due to droughts is estimated to have doubled between the 1991-2006 period and the previous 1976-1990 period. It reached 6.2 billion € in last years.

  The overall impact of droughts in the last thirty years is estimated to 100 000 Mio €.

- **Environmental impacts**

  Droughts may also give rise to serious environmental impacts, including the deterioration of surface waters and groundwater, salinization of coastal waters and desiccation of wetlands. A further quantification of the environmental impacts of droughts is required.

  Whatever the type of impacts, it is obvious that many data are lacking at EU, national and river basin levels. It is therefore difficult to give a comprehensive estimation of the costs incurred by all the European Union to face droughts.
D. Implementation of existing measures to address water scarcity and droughts

1. Use of EU funds

1.1 CAP and rural development programmes

2000-2006 programmes [Table 4 - annex 1]

Member State answers and available evaluations on agro-environmental measures set-up in the 2000-2006 period, reveal that these last programmes have partially and sometimes not at all contributed to addressing water scarcity and drought issues. Only very few Member States have adopted some agro-environmental measures aimed at addressing quantitative issues in the 2000-2006 programme. But Member States which adopted one or two such measures only covered a limited part of the area identified as priority one (2% in Greece, 10% in France). In most cases, priority was mainly given to measures aiming at mitigating qualitative issues such as diffuse pollutions, to the detriment of quantitative issues.

Moreover, some investment supports have tended to encourage the development of new farming supplies like irrigation networks and reservoirs. In these cases, the environmental impacts of the infrastructures have not been systematically assessed and the recovery of the costs has usually not been ensured. The side effects of these measures may be exacerbated by the keeping up of some coupling supports in the framework of the first CAP pillar (France and Spain have kept a partial coupling of direct aids up to 25% of direct payments for arable crops).

2007-2013 programmes

Preliminary analyses carried out by DG Environment on the national strategy plans (required by the regulation on rural development) led to identify some weak points in the drafting.
- Draft of plans (Hungary, Portugal, Spain) suggest an intention to support the development of irrigation or use of desalinated waters, but without making clear that WFD provisions on groundwater (balance between abstractions and natural recharge) and surface water (WFD article 4.7 on new modifications) need to be respected. In addition, no information is given on how the principle of the recovery of costs of water prices will be applied to farmers (WFD article 9) and how environmental costs are integrated.
- Some plans (Greece) intend to improve the efficiency of irrigation systems but do not provide any funding figures, making the statement not easily credible.
- Some plans (Greece) foresee the maintenance of highly water consuming crops, like beetroots, converted to energy crops. The sustainability of such plans is to be questioned.
- Some plans (Spain) do not clearly include agro-environmental measures related to WFD (whereas contribution to achieving WFD objectives is one of the EU priorities in framework of rural development).
- Some plans do not clearly intend to support water saving measures in agriculture.
- Some plans (France) plan a low level of payment for agro-environment (no more than 17,5% in France) and do not well address water quantity issues – in particular problems of over-abstractions near wetlands.
1.2 Structural and cohesion funds

2000-2006 Programmes [Table 5 - annex 1]

The remarks drawn up for rural development programmes are also applicable to structural and cohesion funds. The expenditures related to quantitative issues have mainly aimed at setting-up new water supply infrastructures, given rise to the same questions raised above.

2007-2013 programmes

For the period 2007-2013, the European Social Fund and the Cohesion Fund offer several possibilities to address the issue of water scarcity and drought. Therefore Member States should ensure their National Strategic Framework and Operational Programmes reflect those opportunities. No information is available to date on this issue.

1.3 LIFE

According to questionnaire answers, Member States make little use of LIFE for addressing water scarcity and drought issues. Among the fourteen countries which answered the questionnaire, eight did not provide any information. For these countries, there is still a doubt on the actual use of the instrument or not. The five other countries declared they have not had any project supported by LIFE in the framework of the 2000-2006 programme and related to quantitative issues. It seems that most supported projects (Cyprus, France) dealt with qualitative issues such as waste water treatments, diffuse and punctual pollutions.

According to the information provided by the Member States that answered the questionnaire, Spain is the only country where projects linked to water scarcity and droughts were supported by LIFE. These projects aimed to improve management of irrigated areas and water use reductions. Total costs of these projects came to 5,5 Mio €.

1.4 European Union Solidarity Fund

The analysis of Member State answers leads to the conclusion that this fund does not help to address water scarcity and drought issues. Seven Member States did not answer to the question (no use of the fund?) while the others declared they did not use it.

Portugal indicated that the criteria of 1000 M€ or 0.5 % RNB of damage costs to get access to the fund were too high for and prevented it from applying for financial support in case of drought damages.

Example of France:
From the starting of the fund (11 November 2002), France has not received any support for drought events. The only supports obtained in this framework were related to floods in 2002 (Gard) and 2004 (Rhône). The French request for funds due to forest fires (link with drought event) in 2003 was rejected.
Forest fires are a special case due to their own nature that generally involves a limited part of population directly affected. It is rarely possible to fill the condition depending on whether at least half of the region population is being touched.
1.5 Community Mechanism for Civil Protection

Similarly to the last instrument, it appears that this mechanism is not used to deal with water scarcity and drought issues. Nine Member States did not answer the question. Five Member States indicated they did not make use of it.

Example of France:

France did not use this mechanism in case of drought events, but only once in order to face strong flooding in December 2003, looking for high capacity pumps. The Community Mechanism for Civil Protection is adapted to cases of urgent situations in order to give quick material and human supports to member States. This tool is not totally adapted to drought and water scarcity events.

2. Water pricing

Water pricing information provided by Member States [Table 6 - annex 1] have been somehow partial and makes it difficult to have a whole and fair view of the issue. Nevertheless, the first available elements stress a large variability in national water pricing policies and above all, few examples of policies directly aimed at addressing quantitative issues through consistent and effective water prices.

3. Other instruments

3.1 Policies at EU level

- Research Framework Programmes

The Commission has been supporting research on droughts and water management in arid areas through its successive Framework Programmes for Research and Technological development.

Regarding the on-going programme, several projects are linked to WS&D. One of the most important one is AQUATRESS\textsuperscript{32} which is dealing with mitigation of water stress through new approaches to integrating management, technical, economic and institutional instruments. Complementary projects are also focussing on water scarcity and droughts mitigation measures, such as:

- ALERT: sustainable management of water resources by automated real-time monitoring\textsuperscript{33}
- GABARDINE: groundwater artificial recharge based on alternative sources of Water\textsuperscript{34}
- RECLAIM WATER: water reclamation technologies for safe artificial groundwater recharge\textsuperscript{35}
- MEDINA: Membrane-based desalination: an integrated approach
- MEDESOL: seawater desalination by innovative solar-powered membrane distillation system
- PLEIADeS: participatory multi-level EO-assisted tools for irrigation water management and agricultural Decision-Support

\textsuperscript{32} http://www.aquastress.net
\textsuperscript{33} http://coastal-alert.bgs.ac.uk
\textsuperscript{34} http://www.ewre.com/Gabardine/Home.aspx
\textsuperscript{35} http://www.reclaim-water.org/
- FLOW-AID: Farm level optimal water management: assistant for irrigation under deficit

As regards Climate research, the most relevant project of the current programme is WATCH, whose objective is to evaluate the response of global water cycle to climate change and assess the future vulnerability of water as a resource.

In 7FP on droughts (climate change impact on droughts), two major actions are foreseen:

- Investigating Europe’s risk from droughts (coordinate network for the definition and potential implementation of a research strategy, contributing to a European drought approach taking into account relevant related policies and climate trends including economic and social variables)
- Effectiveness of adaptation and mitigation measures related to changes of the hydrological cycle and its extremes (adaptation and mitigation measures related to changes of the hydrological cycle and its extremes in Europe).

- Green paper on Climate change and adaptation

The impact of climate change on Europe's water resources is being analysed by the Commission and a green Paper for a 'European strategy for adapting to the impacts of Climate Change' will be issued by the Commission in June 2007. References to water scarcity and drought are included in the paper. Four priority areas are proposed in the paper: planning process, economic stimuli, disaster risk management and knowledge information.

- Sustainable tourism initiative

The Commission has recognised the role of sustainable tourism in the preservation and enhancement of the cultural and natural heritage in an ever expanding number of areas. DGENTR is working towards the development of a proposal for European Agenda 21 for Tourism by 2007. Recognition of the need to minimise the resources use and in particular water should be included in the proposals. Recommendations for actions at various levels will be included: EU, MS governments and regions, local authorities, tourism business, etc.

- Water efficiency in building

As regards coverage by Community law of the issue of water efficiency in building and the installation of more efficient water-using equipment in buildings, the situation is as follows:

- Water efficiency is not included among the essential requirements which buildings have to satisfy in application of Council Directive 89/106/EEC on construction products; this aspect might be re-considered in a future revision of this Directive.
- Council Directive 92/75/EEC of 22 September 1992 on the indication by labelling and standard product information of the consumption of energy and other resources – e.g. water - by household appliances aims at influencing end-users to buy more resource efficient appliances; it applies inter alia to dishwashers, dryers and washing machines.

37 OJ L 297, 13.10.1992, p.16
- Directive 2005/32/EC\textsuperscript{38} of 6 July 2005 of the European Parliament and of the Council allows for the setting of ecodesign requirements for energy-using products, aiming at improving their environmental performance – including water consumption – throughout their life cycle. Implementing measures are currently under consideration for several appliances used in buildings like dishwashers and washing machines.

### 3.2 Other initiatives at international level

At international level, it is worthwhile to mention the UN Convention to combat desertification (UNCCD), issued in Paris in 1994. National Action Programmes (NAP) are one of the key instruments in the implementation of the Convention. The Commission will assess the measures under the Action Plans adopted by Member States pursuant to the UNCCD. This study will produce its results in 2007. So far, at least three MS have issued their national plans: Greece in 2001; Italy, in 2000; Portugal in 1999. An example of the National Action Plans is provided in Annex 3.

Within the context of this UNCCD convention, Slovenia is hosting a Drought Management Centre for South-Eastern Europe\textsuperscript{39}.

The aims and objectives of the Centre include the following:

- To serve as an operational centre for South-Eastern Europe for drought preparedness, monitoring and management.
- To prepare drought monitoring and forecast products and make them available on near real-time basis to relevant institutions in participating countries.
- To promote and strengthen technical and scientific capacity for drought preparedness, monitoring and management in participating countries.
- To help implement UNCCD in drought preparedness, monitoring and management, in particular to work out national drought strategies.

### 3.3 Other measures at Member State level or below

A first overview of other demand-side and supply-side measures available at national level gives interesting information but should be further developed. Good and valuable practices adopted at national and regional levels in order to mitigate water scarcity and drought issues should be further identified and shared at EU level.

#### Demand-side measures

- Setting-up of drought management plans. See the example of Spain in Annex 2.

- Reduction of leakages in the distribution networks
  - In Sweden, each municipality has a leakage reduction programme, which objective is to limit network leakage in the area of 10-20% of the total drinking water production.

  - In England and Wales, each water undertaking has a regulatory target for leakage reduction, based on economic principles.

\textsuperscript{38} OJ L 191, 22.7.2005, p.29

\textsuperscript{39} Other countries making up the region: Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Former Yugoslav Republic of Macedonia, Greece, Hungary, Republic of Moldova, Romania and Turkey
Water savings
- Germany has been designing appliances and water efficiency building standards in order to enhance the number of low water consumption installations.
- Cyprus has adopted a law banning the use of hosepipes for the washing of cars or pavements and established subsidies for water reuse.

Use of new technologies and changing processes in industry and agriculture to get a wise use of water resources

Natural storage improvement

Improvement of irrigation technologies by improving agricultural management, optimizing soil water utilisation and irrigation, and setting up new programmes of practical research in order to reduce water consumption

Moving from public supports for irrigation development to public supports directly aimed at improving existing infrastructures and lowering agricultural uses (through a reduction in water consumption per ha or a reduction in irrigated areas)

Promotion of improved waste water reuse where appropriate
- Over 230 installations are in operation in Europe (www.aquarec.org) including one of the world largest in Barcelona.
- Several cities in Northern Europe rely on indirect potable reuse for 30% to 70% of their potable resource during dry summers (through rivers, lakes, aquifers and reservoirs).
- A first quantitative estimates calculated by the model set up through the AQUAREC project suggest a wastewater reuse potential of 3.222 Mm³/year which would represents around 1% of the total water abstraction. Despite the fact that this potential does not represent a high part of the global European demand it can constitute a significant part of water regional demand in some specific water stress basins. While for most countries the substitution potential is less than 0.5%, Malta, Cyprus and Spain could replace approximately 26%, 20% and 3% of their future water abstractions respectively. However, to implement this potential, two major barriers must be overcome: facilitating financial support and setting clear implementation criteria.
- Water recycling in Cyprus is estimated to increase up to 52 Mm³/year by 2012 (28.5% of agricultural water demand).

Setting-up water banks and quota systems
- Cyprus has put into place a quota system for the allocation of government irrigation water in combination with penalty charges for over-consumption.
- Spain has got a recent emergency legislation including the use of market instruments for improving the technical efficiency of the irrigation networks.

Setting-up adapted pricing policies
- The French draft water law states that water use fees need to be assessed on volumes abstracted over the year. Rates have to be adapted to the resource status. They will need to be higher in zones experiencing a shortfall between supply and demand. A fee
discount is agreed when water abstractions are carried out through a collective management body. This measure aims at encouraging a collective management of the resources. The same draft intends to adapt fee rates according to the main issues identified in water management plans. An article also aims at making sure that costs of possible substitution reservoirs will be borne by all agricultural water abstractors in the affected river basin, either they are to benefit from the project directly or indirectly.

- Awareness campaigns

- **Supply-side measures**

  - Preservation of the functioning of natural catchments and aquifers
  This objective can be partly fulfilled through the use of EU funds, such as the rural development programmes which make it possible to design adapted agro-environmental measures and focus them on sensitive areas as regards water scarcity and vulnerability to droughts.

  - Improvement of the efficiency in the use of existing water infrastructures

  - Water recharge aquifers

### E. The Water Framework Directive

#### 1. Water scarcity

Member States that answered the questionnaire consider WFD will help address issues of water scarcity, through the implementation of the water management plans and associated programmes of measures. Some Member States highlight the importance of article 11 in building up the programmes of measures and taking into account quantity issues. Some stress the fact that WFD implementation is an opportunity to make demand-side measures be a priority. Some also point out the importance of article 9 and annex III (principle of recovery of costs for water services, in accordance in particular with the polluter pays principle) in solving water stress issues.

On basis of these points, some Member States ask for deeper exchanges at EU level on all types of possible supplementary quantity measures in order to provide river basin districts with practical tools when building up their programmes of measures. They are willing to go thoroughly into some issues such as priority given to demand-side measures, cost-benefit analyses of the foreseen supplementary measures, cost-effectiveness analyses, definition of adapted pricing policies and implementation of the cost-recovery principle.

#### 2. Droughts

Member States that answered the questionnaire recognize the usefulness of the article 13.5 of the WFD, allowing to supplementing river basin management plans by the production of a more detailed programme and management plan to deal with drought issues.
Some of them are interested in further exchanges at EU level on this specific point, in order to go deeper into the possible contents of drought management plans, including trans-national coordination.

Member States have also pointed out that some drought events can lead to a temporary deterioration in the status of bodies of water. In such cases only, some of them are asking for a common understanding on the phenomena of "prolonged droughts" enunciated in the article 4.6 of the WFD.

Finally, impact of climate change on drought intensity and frequency also attracts the attention of Member States. They look forward to getting further investigation in this regard.
**F. Conclusions**

The information collected for the in-depth assessment refines and updates the first analysis provided by the Commission in June 2006, thanks to Member States' efforts in collecting data for the assessment of the scope and impacts of water scarcity and droughts.

However, some data gaps remain (Member States not covered, lack of consistency of some information). Additional work will therefore be needed in order to deliver a comprehensive overview of the extent and impacts of water scarcity and droughts at European level.

- Prior indicators need to be set-up and agreed at European level in order to ensure the collection of relevant and comparable data at national and European levels and therefore reflect the true situation at river basin level.

- The impacts of climate change on the future evolution and extent of water scarcity and droughts need to be further assessed, as they will directly affect the water availability across Europe and are expected to exacerbate the water stress in already sensitive river basins.

- The economic, social and environmental impacts of the issues need to be better quantified. Impacts due to water scarcity have been hardly estimated so far, partly in reason of the difficulty to identify the amount of investments or costs related to this phenomenon only. Member States have assessed the impacts on the economy of droughts but results should be considered as minimum due to data gaps.

In the light of these shortcomings, the following next steps and deadlines are foreseen.

- **By the end of 2007**
  - Carry on the activity of the Expert Network on water scarcity and droughts in order to share good practices, discuss the steps needed and start working towards the establishment of an effective EU drought information system.
  - Take into account the future results of research projects on the impacts of climate change on droughts.
  - Take into account the outcomes of a JRC research project in progress and related to the impacts of droughts (agriculture not covered by the project).
  - Explore the possibility to complete the JRC work on agricultural aspects with a supplementary study.

- **From 2008 onwards**

  Set-up a European drought information system

This objective entails the following actions:
- Set-up a range of indicators related to the extent and impacts of these issues, agreed at European level.

- Organise the collection of information within Member States, according to the set indicators.

- Ensure the dissemination by the Commission of an annual in-depth assessment on basis of Member State information.

The Communication on water scarcity and droughts planned for adoption in July 2007 will emphasize these issues and reiterate the need to progress in the direction described above.

The Water Directors will be regularly informed of the outcomes of the work.
Annex 1

Graphs and Tables


Graph 1 - Source: Eurostat, 1992-2003

Sectoral water abstraction in % (Eurostat, 1992 to 2003)

Graph 2 - Source: Eurostat, 1992-2003
Evolution in public water supply from 1992 to 2003

Graph 5 - Source: Eurostat, 1992-2003

Evolution of water abstraction in agriculture from 1992 to 2003

Graph 6 - Source: Eurostat, 1992-2003
Graph 7 - Source: Eurostat, 1992-2003

Evolution of water abstraction in manufacturing industry from 1992 to 2003
### Table 1 – Tourism information available at MS level

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of tourists per year</th>
<th>Tourism impacts</th>
</tr>
</thead>
</table>
| Balearic Islands - Spain |                             | Water consumption in July 1999 was equivalent to 20% of the consumption by local population in a whole year. The volume used for tourism has increased by about 80% since 1994.  
Calvia:  
- Population of 50,000 inhabitants  
- 1.2 million tourists every year  
- An increase of 70% in water use for the period 1995-2007 has been predicted due to the increase in population and the construction of new buildings |
| Spain                 | 51,748 million tourists in 2002 (WTO) | Plan Bleu (1999) points out that the population of 27 municipalities on the Costa Brava (Spain) swells from 150,000 in winter to 1.1 million residents in mid-August.  
Tourism in the South East of Spain (Alicante, Almeria, Murcia provinces) has grown 50% in the last five years and a further increase is foreseen.  
Murcia province plans to double its tourist potential in next years, to reach nearly one million hotel places and one hundred thousand new residences.  
Second-house tourism has the greatest growth potential in the tourist industry of the South East. 60% of the houses built in Alicante are second-houses.  
In the Valencia province, the number of golf courses is expected to multiply by three in the next 10-50 years and the Murcia province is expected to host 39 golf courses in the next ten years. |
| Italy                 | 32,329 million tourists in 2002 | The Alps receive 60 million arrivals per year.  
According to the EEA, during 2000, 15% of Italian families suffered irregularities in their domestic water supply, a figure which was higher in regions with a high presence of tourist like Sardinia (47.3%) and Calabria (47.9%). |
| Greece                | 12 million foreign tourists in 2000 | Between 1987 and 1997, international tourist arrivals increased by 31.5% and the accommodation capacity in terms of number of beds increased by 49.5%.  
In some Greek islands (Cyclades), water demand in summer can be from 5 to 10 times higher than in winter (Plan Bleu 2004). |
| France                | First world tourist destination over 77 million tourists a year | Plan Bleu (1999) reports that Provence-Côte d'Azur Region receives 1.7 million tourists every summer. This implies an increase of 50% of the total population, which can reach peaks of 2.5 million people during the summer vacation periods and leads to double the normal water demand. |
| Malta                 | More than 1 million tourists a year | The annual number of tourists represents three times Malta permanent population. |

Source: Freshwater and Tourism in the Mediterranean, WWF, June 2004
Table 2 – River basins identified by MS as affected by water scarcity

<table>
<thead>
<tr>
<th>Member State</th>
<th>River basin</th>
<th>Area affected</th>
<th>Population affected</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Km²</td>
<td>inhabitants</td>
</tr>
<tr>
<td>Belgium (Flanders)</td>
<td>Western part of Flanders</td>
<td>7 100</td>
<td>2 500 000</td>
</tr>
<tr>
<td>Cyprus</td>
<td>Whole country</td>
<td>9 251</td>
<td>854 300</td>
</tr>
<tr>
<td>Denmark</td>
<td></td>
<td>43 000</td>
<td>5 200 000</td>
</tr>
<tr>
<td>France</td>
<td>Adour Garonne Basin</td>
<td>29 186</td>
<td>1 664 907</td>
</tr>
<tr>
<td>France</td>
<td>Rhône Méditerranée Basin</td>
<td>19 406</td>
<td>2 079 293</td>
</tr>
<tr>
<td>France</td>
<td>Loire Bretagne Basin</td>
<td>15 692</td>
<td>1 186 050</td>
</tr>
<tr>
<td>France</td>
<td>Seine Normandie Basin</td>
<td>9 429</td>
<td>1 724 050</td>
</tr>
<tr>
<td>Germany</td>
<td>Donau</td>
<td>2 250</td>
<td>269 7000</td>
</tr>
<tr>
<td>Germany</td>
<td>Rhein</td>
<td>10 240</td>
<td>11 455 000</td>
</tr>
<tr>
<td>Germany</td>
<td>Ems</td>
<td>1 280</td>
<td>6 750 000</td>
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<tr>
<td>Germany</td>
<td>Weser</td>
<td>92 20</td>
<td>200 2000</td>
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<tr>
<td>Germany</td>
<td>Elbe</td>
<td>11 700</td>
<td>3 440 000</td>
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<td>Germany</td>
<td>Oder</td>
<td>4 810</td>
<td>5 520 000</td>
</tr>
<tr>
<td>Hungary</td>
<td>Danube-Tisza interstice</td>
<td>10 000</td>
<td>900 000</td>
</tr>
<tr>
<td>Italy</td>
<td>Sicily</td>
<td>25 710</td>
<td>5 000 000</td>
</tr>
<tr>
<td>Italy</td>
<td>Sardinia</td>
<td>24 090</td>
<td>1 600 000</td>
</tr>
<tr>
<td>Italy</td>
<td>Central-Southern Italy               Not reported</td>
<td>Not reported</td>
<td></td>
</tr>
<tr>
<td>Italy</td>
<td>Northern Italy</td>
<td>Not reported</td>
<td>730 000</td>
</tr>
<tr>
<td>Malta</td>
<td></td>
<td>316</td>
<td>405 387</td>
</tr>
<tr>
<td>Portugal</td>
<td>Algarve basins</td>
<td>3 747</td>
<td>389 512</td>
</tr>
<tr>
<td>Portugal</td>
<td>Ave</td>
<td>1 480</td>
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<td>Portugal</td>
<td>Guadiana</td>
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<td>Portugal</td>
<td>Leça</td>
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<td>416 847</td>
</tr>
<tr>
<td>Portugal</td>
<td>Lis</td>
<td>850</td>
<td>197 985</td>
</tr>
<tr>
<td>Portugal</td>
<td>Mira</td>
<td>172 8</td>
<td>22 204</td>
</tr>
<tr>
<td>Portugal</td>
<td>Mondego</td>
<td>694 2</td>
<td>707 404</td>
</tr>
<tr>
<td>Portugal</td>
<td>Sado</td>
<td>8 359</td>
<td>294 312</td>
</tr>
<tr>
<td>Portugal</td>
<td>Tagus</td>
<td>25 285</td>
<td>3 241 446</td>
</tr>
<tr>
<td>Portugal</td>
<td>Vouga</td>
<td>3 685</td>
<td>705 666</td>
</tr>
<tr>
<td>Portugal</td>
<td>Western basins</td>
<td>2 412</td>
<td>655 249</td>
</tr>
<tr>
<td>Slovenia</td>
<td></td>
<td>20 273</td>
<td>2 000 000</td>
</tr>
<tr>
<td>Slovakia</td>
<td>Eastern part</td>
<td>Not reported</td>
<td>Not reported</td>
</tr>
<tr>
<td>Spain</td>
<td>Guadiana Basin</td>
<td>18 900</td>
<td>570 000</td>
</tr>
<tr>
<td>Spain</td>
<td>Segura Basin</td>
<td>19 120</td>
<td>1 555 690</td>
</tr>
<tr>
<td>Spain</td>
<td>Jucar Basin</td>
<td>17 046</td>
<td>1 840 000</td>
</tr>
<tr>
<td>Spain</td>
<td>Andalusian Mediterranean basins</td>
<td>17 950</td>
<td>2 100 000</td>
</tr>
<tr>
<td>UK (England)</td>
<td>South East</td>
<td>10 202</td>
<td>3 267 910</td>
</tr>
<tr>
<td>UK (England)</td>
<td>Thames</td>
<td>16 145</td>
<td>13 542 700</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>418 600</td>
<td>76 374 500</td>
</tr>
<tr>
<td>% of the total EU area and population</td>
<td></td>
<td>11%</td>
<td>17%</td>
</tr>
</tbody>
</table>
Table 3 – distribution of sectoral water abstractions in river basins affected by water scarcity

<table>
<thead>
<tr>
<th>Member State</th>
<th>river basin</th>
<th>public water supply</th>
<th>public water supply</th>
<th>agriculture</th>
<th>industry</th>
<th>electricity production for cooling</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>without tourism</td>
<td>for tourism</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Belgium (Flanders)</td>
<td>Western part of Flanders</td>
<td>33%</td>
<td>10%</td>
<td>50%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cyprus</td>
<td>Whole country</td>
<td>20%</td>
<td>69%</td>
<td>1%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>Adour Garonne Basin</td>
<td>29%</td>
<td>42%</td>
<td>17%</td>
<td>12%</td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>Rhône Méditerranée Basin</td>
<td>9%</td>
<td>16%</td>
<td>6%</td>
<td>69%</td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>Loire Bretagne Basin</td>
<td>26%</td>
<td>18%</td>
<td>5%</td>
<td>51%</td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>Seine Normandie Basin</td>
<td>54%</td>
<td>5%</td>
<td>22%</td>
<td>18%</td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>5% groundwater body imbalances on average 2001-2004 in brown coal mining areas</td>
<td>No information</td>
<td>No information</td>
<td>No information</td>
<td>No information</td>
<td>No information</td>
</tr>
<tr>
<td>Hungary</td>
<td>Danube-Tisza interstice</td>
<td>25%</td>
<td>9%</td>
<td>18%</td>
<td>48%</td>
<td></td>
</tr>
<tr>
<td>Italy</td>
<td>Sicily</td>
<td>20%</td>
<td>No information</td>
<td>47%</td>
<td>20%</td>
<td>13%</td>
</tr>
<tr>
<td>Italy</td>
<td>Sardinia</td>
<td>20%</td>
<td>No information</td>
<td>47%</td>
<td>20%</td>
<td>13%</td>
</tr>
<tr>
<td>Italy</td>
<td>Central-Southern Italy</td>
<td>20%</td>
<td>No information</td>
<td>47%</td>
<td>20%</td>
<td>13%</td>
</tr>
<tr>
<td>Italy</td>
<td>Northern Italy</td>
<td>20%</td>
<td>No information</td>
<td>47%</td>
<td>20%</td>
<td>13%</td>
</tr>
<tr>
<td>Malta</td>
<td></td>
<td>33%</td>
<td>5%</td>
<td>35%</td>
<td>9%</td>
<td></td>
</tr>
<tr>
<td>Portugal</td>
<td>Lis</td>
<td>37%</td>
<td>62%</td>
<td>0%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Portugal</td>
<td>Mira</td>
<td>31%</td>
<td>69%</td>
<td>0%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Portugal</td>
<td>Mondego</td>
<td>4%</td>
<td>86%</td>
<td>10%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Portugal</td>
<td>Sado</td>
<td>2%</td>
<td>41%</td>
<td>4%</td>
<td>52%</td>
<td></td>
</tr>
<tr>
<td>Portugal</td>
<td>Tagus</td>
<td>1%</td>
<td>73%</td>
<td>6%</td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td>Portugal</td>
<td>Vouga</td>
<td>7%</td>
<td>86%</td>
<td>6%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Portugal</td>
<td>Western basins</td>
<td>14%</td>
<td>84%</td>
<td>2%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Slovenia</td>
<td></td>
<td>No information</td>
<td>No information</td>
<td>No information</td>
<td>No information</td>
<td>No information</td>
</tr>
<tr>
<td>Slovakia</td>
<td>Eastern part</td>
<td>52%</td>
<td>4%</td>
<td>45%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Spain</td>
<td>Alto Guadiana</td>
<td>6%</td>
<td>90%</td>
<td>3%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spain</td>
<td>Segura</td>
<td>19%</td>
<td>76%</td>
<td>4%</td>
<td>1%</td>
<td></td>
</tr>
<tr>
<td>Spain</td>
<td>Jucar</td>
<td>33%</td>
<td>65%</td>
<td>2%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Spain</td>
<td>Andalusian basins</td>
<td>67%</td>
<td>0%</td>
<td>3%</td>
<td>23%</td>
<td></td>
</tr>
<tr>
<td>UK (England)</td>
<td>South East</td>
<td>19%</td>
<td>0%</td>
<td>9%</td>
<td>54%</td>
<td></td>
</tr>
<tr>
<td>UK (England)</td>
<td>Thames</td>
<td>67%</td>
<td>0%</td>
<td>3%</td>
<td>23%</td>
<td></td>
</tr>
</tbody>
</table>
Table 4 – Information provided by MS on the use of 2000-2006 CAP rural development programmes

<table>
<thead>
<tr>
<th>Member State</th>
<th>Estimated funds dedicated to water scarcity and droughts</th>
<th>No funds dedicated to water scarcity and droughts</th>
<th>A certain amount of funds dedicated to water scarcity and droughts but no information on the amount specifically dedicated to these issues</th>
<th>No information provided</th>
<th>Main conclusions coming from evaluations of 2000-2006 programmes on Agro-Environmental Measures (AEM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>No measures targeting at water quantity, that is not considered a priority issue. According to the mid-term review, the existing irrigation systems do not cause problems because of the little areas under irrigation.</td>
</tr>
<tr>
<td>Belgium</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>No agro-environmental measures directly addressing quantitative issues</td>
</tr>
<tr>
<td>Cyprus</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>No agro-environmental measures directly addressing quantitative issues</td>
</tr>
<tr>
<td>Finland</td>
<td>~ 0.5 Mio € for the all programme period</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>No agro-environmental measures directly addressing quantitative issues</td>
</tr>
<tr>
<td></td>
<td>Projects including measures to improve insufficient or unsecured water supply due to droughts</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Country</td>
<td>Financial Contribution</td>
<td>Measures and Investment Supports</td>
<td>Agro-environmental Measures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------</td>
<td>------------------------</td>
<td>----------------------------------</td>
<td>----------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>5 to 10 Mio € per year</td>
<td>Two agro-environmental measures and investment supports</td>
<td>AEM with reduction in water supply applied on 13 200 ha (10% of the priority areas) AEM with reduction in irrigated areas applied on 10 400 ha (10% of the priority areas) AEM with drainage limitation or conversion of drained areas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>×</td>
<td>No agro-environmental measures directly addressing quantitative issues</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greece</td>
<td>Source DG AGRI: - Measures related to the development of water management plans, construction of water reservoirs and distribution systems with priority given to insular areas, groundwater recharge and broad range of water infrastructure projects - Measures for the protection of lakes and lakeside areas, linked with the protection and recharge of water tables. But these measures did not attract many beneficiaries. Limited results - Measures to reduce irrigation. Evaluation of these measures not available</td>
<td>One AEM with reduction in irrigated area (reduction of irrigation water consumption up to 30% through set aside and/or creation of standard fallow fringe and/or application of crop rotation) applied on 2 037 ha, corresponding to 0,024% of the regional area and 2% of the problem zone area.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hungary</td>
<td>×</td>
<td>No agro-environmental measures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Country</td>
<td>Measures Addressing Quantitative Issues</td>
<td>In Sicilia</td>
<td>At National Level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------</td>
<td>----------------------------------------</td>
<td>------------</td>
<td>-------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Italy</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sicilia</td>
<td>In Sicilia: reduction in irrigation amounts applied on 10 352 ha (0.52% of the total Sicilia agricultural area), reduction in irrigated area, applied on 31 236 ha (1.58% of the total area), limitation of drainage or conversion of drained zones on 10 352 ha (0.52% of the total area) At national level, no available definition of what could be priority areas for quantitative issues</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lithuania</td>
<td>×</td>
<td></td>
<td>×</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Malta</td>
<td>×</td>
<td></td>
<td>×</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Norway</td>
<td>×</td>
<td></td>
<td>×</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Portugal</td>
<td>×</td>
<td></td>
<td>×</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Measures that indirectly contribute to preventing scarcity and droughts: dams
<table>
<thead>
<tr>
<th>Country</th>
<th>×</th>
<th>Source: DG AGRI</th>
<th>No agro-environmental measures directly addressing quantitative issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slovak Republic</td>
<td>×</td>
<td>Source: DG AGRI</td>
<td>No agro-environmental measures directly addressing quantitative issues</td>
</tr>
<tr>
<td>Slovenia</td>
<td>×</td>
<td>Source: DG AGRI</td>
<td>Irrigation schemes including reservoirs No agro-environmental measures directly addressing quantitative issues</td>
</tr>
<tr>
<td>Spain</td>
<td>×</td>
<td>Source: DG AGRI</td>
<td>One AEM entitled &quot;irrigation water saving and promotion of production extensification&quot; Castile la Mancha is the only region eligible to this measure Around 85 000 ha where the measure has been applied (83% of the priority area) = 40,3% of the total spending of AEM contracted in the 1993-1998 period Some limits highlighted: contribution to overexploited aquifer restoration is difficult to assess.</td>
</tr>
<tr>
<td>United Kingdom, Denmark, Netherlands</td>
<td>×</td>
<td>Source: DG AGRI</td>
<td>Use of RD to support the development of winter storage reservoirs for farms (small amounts). Likely to continue at low levels in future No agro-environmental measures directly addressing quantitative issues</td>
</tr>
</tbody>
</table>
Table 5 – Information provided by MS on the use of 2000-2006 structural funds

<table>
<thead>
<tr>
<th>Member State</th>
<th>Estimated funds dedicated to water scarcity and droughts</th>
<th>No funds dedicated to water scarcity and droughts</th>
<th>A certain amount of funds dedicated to water scarcity and droughts but no information on the amount specifically dedicated to these issues</th>
<th>No information provided</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Belgium</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cyprus</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finland</td>
<td>~ 2 Mio € for the all programme period Improvement of water supplies</td>
<td>×</td>
<td>In most programmes, several types of measures are gathered in one and single measure. Water issues mentioned in all regional programmes</td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Greece       | ×                                                       |                                                  | - Late approval of the structural fund programmes (2001)  
- Delayed implementation of the interventions (end 2002)  
- No evaluation findings at this stage                                                                                                                     |                        |
| Hungary      | ×                                                       |                                                  |                                                                                                                                 |                        |
| Italy        | ×                                                       |                                                  | Cohesion funds in particular                                                                                                                                          |                        |

- Interreg II C 35,7 Mio €  
- Interreg III B 6,5 Mio €  
+ Funds (no amount specified) for metering of macro-consumption and monitoring of available of supply systems
<table>
<thead>
<tr>
<th>Country</th>
<th>Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lithuania</td>
<td>×</td>
</tr>
<tr>
<td>Malta</td>
<td>× Upgrading of desalination facilities for the improvement of public water supply</td>
</tr>
<tr>
<td>Norway</td>
<td>×</td>
</tr>
<tr>
<td>Portugal</td>
<td>New multipurpose storage reservoirs – urban water supply – new distribution networks and rehabilitation</td>
</tr>
<tr>
<td>Slovak Republic</td>
<td>× Interreg III B: In 2006, start of a new project HYDROCARE, that will notably address water balance issues. Estimation of water resources in the region CADSES – Central, Adriatic, Danubian and South-Eastern European Space</td>
</tr>
<tr>
<td>Slovenia</td>
<td>×</td>
</tr>
<tr>
<td>Spain</td>
<td>Structural funds Water supply to population and economic activities: 1 864 Mio € Improvement of existing infrastructures and water supply: 542 Mio € Agriculture water resources management: 510 Mio € Support infrastructures development and improvement: 477 Mio € National Society of Agricultural Infrastructures: 270 Mio € Cohesion funds</td>
</tr>
<tr>
<td>United Kingdom, Denmark, Netherlands</td>
<td>Water supply (dams, desalination plants, etc) : 1 727 Mio €</td>
</tr>
<tr>
<td>Country</td>
<td>Water pricing policy</td>
</tr>
<tr>
<td>-----------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Austria</td>
<td>- No answer</td>
</tr>
</tbody>
</table>
| Belgium   | - Incentives to ensure an efficient use of water resources included in the Flemish legislation: taxes on groundwater and legislation on drinking water  
- Groundwater: Taxation depends on the total amount pumped, the aquifer and the status of the groundwater in the region  
- Surface water: Taxation depends on the total amount abstracted and the sector of water use. The higher volumes abstracted are, the less important tariffs are.  
- Abstraction for agriculture uses is charged with fixed prices. |
| Cyprus    | - Fixed and maintenance charges with rising block tariffs for domestic water supply  
- For irrigation water provided through the government schemes, charges are established on a volumetric basis – uniform for all schemes – and cover a high proportion of all financial costs.  
- Assessment of the incentive properties of current pricing policies in progress; expected to be completed by end 2008. Pricing policies will be reviewed in the context of WFD provisions.  
- Currently, the bulk domestic rate for Nicosia, Larnaca, Famagusta and Lemesos areas is equal to 0,75 €/m³ (0,45 £/m³) while for the district of Pafos it is equal to 0,55 €/m³ (0,33 £/m³). The level of cost recovery of financial costs was expected to reach approximately 73% in 2005. |
| Denmark   | - A water pricing policy has been developed. The use of water pricing has generally had a positive effect on both water use and loss in distribution systems.  
- Average water price is around 5/m³. |
| Finland   | - No common pricing policy for irrigation (system operated by individual farmers)  
- Present pricing policy for water supplies is the full cost-recovery. |
| France    | - No specific water pricing for the dry season  
- Cost-recovery over 85% for household and industry – including environmental charges (15% of tariffs)  
- In some cities with great numbers of tourists: specific tariffs can be put into place.  
- Cost-recovery varying from 40% for collective systems to 100% for individual systems in agriculture  
- Incitation to water metering through tariffs |
| Germany   | - "In general, pricing systems for cost-effectiveness in all water related sectors" |
| Hungary   | - Prices depend on the ownership of the water works (local government or State) and on regions.  
- Water prices for industrial plants and institutions are larger than for households (encouragement to get their own wells).  
- A recent amendment of the Water Management Act has suppressed the tariff system for agriculture uses. |
<table>
<thead>
<tr>
<th>Country</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Italy</td>
<td>- No adequate incentives to ensure an efficient use of water resources.</td>
</tr>
<tr>
<td></td>
<td>- Water pricing policy not yet completed</td>
</tr>
<tr>
<td></td>
<td>- Different prices on the territory and depending on sectors</td>
</tr>
<tr>
<td>Lithuania</td>
<td>- Expenses for the consumed water comprise on average about 2-2.5% of family budget.</td>
</tr>
<tr>
<td></td>
<td>- The cost recovery for water services varied from 74% till 83% in different river basin districts in 2004.</td>
</tr>
<tr>
<td></td>
<td>- The national methodology obliges water suppliers to define their costs and revenues according to the approved utility development programmes and consider comparative indicators of activity.</td>
</tr>
<tr>
<td></td>
<td>- Environmental costs are also included in tariff by the mean of pollution charges. However, it is likely that the charges do not reflect real environmental costs, due to difficulty in assessing them.</td>
</tr>
<tr>
<td></td>
<td>- The resource costs are not included because no methodology has been developed so far to measure them.</td>
</tr>
<tr>
<td></td>
<td>- A process is in progress to eliminate customer discrimination and the phenomenon of cross-subsidies, equalizing water prices for all water users. Some factors show that the pricing policy has incentive elements but it is also clear that there is still room for improvement.</td>
</tr>
<tr>
<td>Malta</td>
<td>- Pricing policies not yet developed</td>
</tr>
<tr>
<td>Netherlands</td>
<td>- Dutch provinces charge for groundwater abstractions in order to cover the costs for groundwater management.</td>
</tr>
<tr>
<td></td>
<td>- On a national basis, there is an environmental levy for groundwater abstractions.</td>
</tr>
<tr>
<td>Norway</td>
<td>No water pricing policy has been developed so far to provide adequate incentives for users to use water resources efficiently.</td>
</tr>
<tr>
<td>Portugal</td>
<td>- Taxes and tariffs do not cover all costs.</td>
</tr>
<tr>
<td></td>
<td>- Reference model applying cost-recovery principles under construction</td>
</tr>
<tr>
<td></td>
<td>- Lack of data in some sectors: industry, private farm abstractions</td>
</tr>
<tr>
<td>Slovak Republic</td>
<td>- Water for irrigation free of charge</td>
</tr>
<tr>
<td>Slovenia</td>
<td>- No water pricing policy developed</td>
</tr>
<tr>
<td>Spain</td>
<td>- Water pricing system includes charges for services provided by river basin authorities to irrigation associations, municipal services and industrial users.</td>
</tr>
<tr>
<td></td>
<td>- Urban tariffs to domestic and industrial users include three block tariffs to penalise excessive usages.</td>
</tr>
<tr>
<td></td>
<td>- Industrial tariffs discriminate for bigger users in the fixed and variable charges.</td>
</tr>
<tr>
<td></td>
<td>- An increasing number of irrigation associations are establishing charges by volume and penalisation for excessive use when scarcity occurs.</td>
</tr>
<tr>
<td>UK (England)</td>
<td>- Abstraction charges are levied on all licensed abstractors.</td>
</tr>
<tr>
<td></td>
<td>- Charges reflect environmental impacts: use, location, seasonal impacts</td>
</tr>
<tr>
<td></td>
<td>- Tariffs vary from 1.4 € to 140 €/Mio litres.</td>
</tr>
</tbody>
</table>
Annex 2

SPANISH DROUGHT MANAGEMENT PLANS

Spain presents great spatial and temporal water resources variability and suffers from the effects of both water scarcity and severe droughts. This situation has led to a complex water management and policy development, and high investments in hydraulic works and infrastructures while coping with national and European social and environmental standards.

Spanish policies, in accordance to European legislation, establish a double-way action:
- Emergency actions against drought situations with a focus on crisis situation.
- A planning approach, indicating the necessity of designing a global system of hydrological indicators that allows foreseeing these situations, as well as the requirement for elaborating Drought Management Plans.

The development of Drought Management Plans (DMPs) in Spain started in 2002 to enforce article 27 of the 2001 National Hydrological Plan law, which indicated that River Basin Authorities had to elaborate Special Action Plans for Alert Situations and Eventual Droughts. Works finalised through 2006, and the resulting DMPs were launched on March 2007 for all the river basins coordinated through the Ministry of Environment.

The main objectives of these Plans are to anticipate droughts, foresee solutions to satisfy priority demands and reduce socio-economic and environmental impacts.

The bases for the DMPs are:

- Present indicators that will provide a quick drought status early enough to act according to the forecasts of the Plan
- Provide knowledge of the resources system and its elements’ capability to be strained during scarcity situations
- Provide knowledge of the demand system and its vulnerability towards droughts, organised by priority degrees
- Present structural and non-structural alternatives to reduce drought impacts, and adaptation according to the status indicator
- Measure the cost of implementing measures
- Adapt the administrative structure for its follow-up and coordination among the different Administrations involved (Ministry, regional governments, municipalities)
- Discuss Plans, results and follow-ups with all interested parties, ensuring full public participation to avoid social conflicts.

Map of drought indicators to establish each basin’s status
Example of simulation model (demands and uses in the Júcar basin
Annex 3
EXAMPLE: GREEK NATIONAL ACTION PLAN FOR COMBATING DESERTIFICATION
(Extract from the Extended Summary, 2001)

I. MEASURES CONCERNING THE WATER RESOURCES SECTOR

II. CURRENT SITUATION

1a. General quantitative assessment of Water Resources
Significant surface and sub-surface water resources exist all over Greece. Various factors, such as the uneven spatial distribution of supply and demand complicate their use, resulting in significant reduction in water availability.

International agreements are going to regulate the usage of transboundary waters, according to U.N.O.’s principles.

1b. Overall qualitative assessment of Water Resources.
The quality of water resources has shown recently, in some locations, signs of deterioration. Agricultural activities, urban effluents and industrial discharges act as sources of pollution.

The administrative organization of water resources presents some problems. The legislative framework covering water management needs better codification and more efficient enactment. There is some delay in the completion and implementation of the institutional framework.

1d. Irrigation
In Greece, more than 80% of the water resources are used for irrigation. There is need for more efficient infrastructure (dams, reservoirs, land reclamation projects), while maintenance of the existing irrigation networks needs improvement. There are significant water losses from the irrigation networks.

1e. Drilling
In many locations, water over-pumping has resulted in lowering the ground table of aquifers. In many coastal regions, brackish water has been observed in aquifers.

1f. Sufficiency of Irrigation Water
For the time being, there are possibilities for saving irrigation water. Demand though, for irrigation water, is highly increasing. Greenhouse effect will alter the water balance, through decreasing water stocks and increasing demands.

II. INSTITUTIONAL MEASURES
Because of the significant difference between water supply and demand, regional policies concerning water (per water district or group of water districts) should be established. The relevant legislation will be applied following points and priorities:
- Immediate planning of water resources development at all levels.
- Completion and functioning of regional water management services.
- Issuing regulations to protect water resources for each water basin, by the Prefectures.
- Effective checking for any law infringement and infliction of the respective penalties.
- Issue and implementation of all envisaged legislative regulations.

III. MEASURES FOR IRRIGATION
The measures to be taken are:
- Repairing the irrigation networks
- Renewal of the various components of the networks and use of new technologies
- Integrated management of irrigation water
- Water recycling and re-usage

It is estimated that by applying the above-mentioned measures, water saving will range from 10 - 50%.

IV. MEASURES FOR URBAN AND INDUSTRIAL WATER USE
- Adjustment of prices during summer and prolonged periods of drought.
- Changes in hydraulic installations to decrease water consumption
- Reduction of the water leakage
- Incentives for constructing private tanks and rain-water reservoirs
- Restrictions on use of water-demanding plants in gardens and flower beds
- Public information on water saving needs and methods

### 15. MEASURES FOR INCREASING AVAILABLE WATER
- Studies on water insufficiency in vulnerable regions
- Evaluation and improvement of management applied on the reservoirs
- Retention and storage of running and surface water
- Financing of projects dealing with water recycling and water re-usage
- Enrichment of underground water
- Ensuring the readily available ground water
- Transport of surface water to regions threatened by desertification. A well documented feasibility study is needed for the implementation of this measure.
- Water supply increasing management of forest lands.

### 16. RESEARCH
Regarding accurate knowledge of water availability, a research program on water resources will be prepared aiming at completing and processing hydrologic information about water quality.
Annex 4

Droughts and climate change

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3. Projected droughts (future climate)
4. Role of EC Integrated Project WATCH
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1. Introduction
Drought is a sustained and regionally extensive occurrence of below average natural water availability. It is mainly caused by low precipitation and high evaporation rates, but in regions with a cold climate, temperatures below zero can also give rise to a winter drought. Drought can be characterized as a deviation from normal conditions in the physical system (climate and hydrology), which is reflected in variables such as precipitation, soil water, groundwater and streamflow. Drought is a recurring and worldwide phenomenon having spatial and temporal characteristics that vary significantly from one region to another (Tallaksen & van Lanen, 2004). Drought should not be confused with aridity, which is a long-term average feature of a dry climate, or with water scarcity, which reflects conditions of long-term imbalances between available water resources and demands (Tallaksen & van Lanen, 2004; Working Group on Water Scarcity and Drought, 2006). It is important, however, to note that the most severe human consequences of drought are often found in arid or semi-arid regions where water availability is already low under normal conditions (aridity), demand is close to, or exceeds, natural availability and society seldom lacks the capacity to mitigate or adapt to drought.

Climate change is expected to primarily affect precipitation, temperature and potential evapotranspiration, and, thus, is likely to effect the occurrence and severity of meteorological droughts. An important question for the assessment of future impacts (i.e. socio-economic and environmental) is how changes in meteorological drought will affect soil water, drought and hydrological drought, i.e. groundwater and streamflow droughts. Soil water drought is, for example, relevant for agriculture, terrestrial ecosystems, and health through the occurrence of heat waves, whereas hydrological drought has significance for among others water resources (agriculture, domestic and industrial water use), aquatic ecosystems, power generation, and navigation.

Sections 2 and 3 describe changes in the physical system (climate and hydrology) with emphasis on hydrological changes for past and future conditions, respectively. Elaboration of possible changes of environmental and socio-economic impacts due to altered drought development is beyond the scope of this annex. The annex concludes with thoughts on how
to move forward, in particular about the role the EC Integrated Project WATCH (WATer and global CChange) can play.

2. Droughts and climate change (past climate)
Over the last decade, numerous studies have been published about climate change and drought-related issues, although it is hard to discriminate from other human influences. Moreover it is difficult to distinguish between effects of climate change and multi-decadal climate variability (e.g. Berdowski et al., 2001). Different approaches can be followed to assess the possible change of the past climate and its impact on drought. Commonly, physically-based, process-oriented models are applied to simulate time series of hydrometeorological data. Following types of models have been used:
1. GCMs and RCMs (e.g. Gedney & Cox, 2003; Huntingford et al., 2003; Kabat et al., 2004) that simulate the atmosphere including a more or less simple land surface scheme. These models generate gridded time-series of hydrometeorological variables at a large scale (10-50 km);
2. Land Surface Hydrological models (LSHMs) (e.g. Hagemann & Dümenil Gates, 2003), which are off-line modules of GCMs and RCMs, and Global Hydrological Models (GHMs) (e.g. WBM, Vorosmarty et al., 1998; LaDWorld, Milly et al., 2002; WaterGap, Alcamo et al., 2003 and Döll et al., 2003; GUAVA, Meigh et al., 2005). The GHMs have a more detailed representation of the hydrology than the GCMs, RCMs or LSHMs. The LSHMs and GHMs use climate forcing data as boundary condition and also produce gridded time-series of hydrological variables at a large scale (10-50 km);
3. River Basin Hydrological Models (RBHMs) (e.g. Göttschalk et al., 2001; van Lanen et al., 2004b; Bell et al., 2006). These models also use climate forcing data (preferably RCM output) as boundary condition and generate time series of hydrological data at a detailed scale (~1 km).

The models are calibrated and validated with rather short time series of observed data, as far as possible. The modelling is supported by analysis of preferably long time series of observed hydrometeorological data to detect trends$^2$ (e.g. Hidral et al., 2001; Pekarova et al., 2006).

The 4th Assessment Reports of the IPCC (Alley et al., 2007; Adger et al., 2007) provide a recent summary of observed changes in hydroclimatological variables. Records of global surface temperature show that the eleven years from the period 1995–2006 rank among the 12 warmest years in the record of the last 150 years. The total temperature increase from 1850-99 to 2001-05 is 0.76°C [range 0.57°C to 0.95°C]. Widespread changes in extreme temperatures have been observed over the last 50 years. Colder conditions have become less frequent, while hot days and heat waves have happened to be more frequent. Furthermore the IPCC report states that mountain glaciers and snow cover have declined on average both in the Northern and Southern hemispheres. The number of glacial lakes has been increased and their areas have been grown. The IPCC authors report increased run-off and earlier spring peak discharge in many glacier- and snow-fed rivers, indicating a regime shift for some rivers. Although not consistent for all assessed regions due to the highly spatial and temporal nature of precipitation, a long-term trend (1900-2005) could be observed, showing a significant precipitation increase for Northern Europe and a decrease for the Mediterranean region. More intense and longer droughts have been observed over wider

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$^2$ In addition paleoclimatic studies are carried out (for more information see, e.g. Stahl & Hidral, 2004; Alley et al., 2007).
areas since the 1970s, in particular in the tropics and subtropics. Such droughts have been linked to higher temperatures and decreased precipitation, which are considered to be the result of large scale changes in atmospheric circulation in response to changing sea surface temperatures, wind patterns and decreased snow pack and cover.

Alley et al. (2007) state that the observed widespread warming, together with ice mass loss, supports the conclusion that it is extremely unlikely that global climate change of the past 50 years can be explained by known natural causes alone. Difficulties remain in reliably attributing observed temperature changes at smaller scales because natural variability is relatively large. It is likely that the area affected by droughts has increased in many regions and it is more likely that it has a human cause. This also holds for the frequency of heat waves. The increased demand for water has worsened the consequences of drought in many cases.

Many IPCC conclusions are based on regional-scale studies. For example, Klein Tank et al. (2002) report that the observed annual precipitation (1946-99) in 34 European countries show a positive trend mainly for northern stations, whereas negative trends concentrate in the south. At 45% of the stations a significant decrease in frost days occurred. The Europe-averaged increase in number of warm days is similar to the decrease in cold days.

Becker et al. (2004), van Lanen et al. (2004a) and Schulze (2004) give a detailed description of the response of hydrological processes to among others climate variability and change at scales from the small catchment to the river basin. Van Lanen et al. (2004b) and Demuth et al., (2006) provide a comprehensive overview of the possible observed effects of climate change on hydrological droughts, even though detection of trends is cumbersome because long time series are needed (e.g. Stahl & Hidal, 2004; Knudziewicz & Robson, 2004, Dixon et al., 2006) and differences in catchment response might influence the regional patterns. Measurements for several decades to over a century are required to detect climate change with high confidence (Ziegler et al., 2002). Pekarova et al. (2006) have analyzed annual river flow from 18 major European rivers over the period 1850-1997. The investigation shows neither significant long-term increase nor decrease. Lang et al. (2006) report on an ongoing comprehensive study that uses time series of river flow from about 200 French gauging stations. The first results show that there is no conclusive proof that climate change has a significant effect on drought regimes. Majerčáková et al. (1997) show a remarkable decrease in the annual streamflow since 1980 for 64 Slovak rivers covering a range of hydrological regimes. The decrease is most prominent in autumn and winter months. The highest decrease in streamflow is in the southeast (30 – 40%) and the lowest in the west, northwest and northeast (5-10%) of Slovakia. Analysis of spring yields gives similar results, although the decreasing trend strongly varies over the country. The decrease seems to be related to a change in precipitation and temperature. In the United States streamflow from catchments without evident anthropogenic influence shows an increasing trend in 16 out of 20 water regions over the period 1929–1988 (Hubbard et al., 1997). It is likely that external climatic forcing causes the increase.

Global warming may also result in a regime shift particular in regions with snow and ice, where higher temperatures lead to earlier snowmelt and longer growing season. This trend is confirmed by observations showing that the beginning of the growing season in mid-latitudes has clearly advanced since 1989 (Chmielewski & Rötzer, 2002). Subsequently, this might lead to an increase in the frequency and severity of summer drought in these regions. The higher temperatures also cause more intensive melting and retreat of glaciers (e.g. Berdowski et al., 2001). For example, Chalise et al. (2006) report on an increasing
number of glacier lakes, glacier lake outburst, and higher discharge at high elevation in the Himalayas. The increase can be related to a temperature rise. A study for the Nordic countries (Hisdal et al., 2006) reports that the increased temperature has caused both an earlier snowmelt and a higher evaportranspiration. In Southeast Norway this has led to longer summer droughts in about 60% of the river basins.

There are, however, large regional variations in trends due to the high natural variability in climate as well as catchment properties as demonstrated by Hisdal et al. (2001) for hydrological drought conditions in Europe. The study showed that there were no significant changes for most stations in the period 1962-90, however, distinct regional differences were found. Trends towards more severe droughts in Spain, the western part of Eastern Europe and in large parts of the UK, whereas trends towards less severe droughts occurred in large parts of Central Europe. (Fig 1). The study further illustrates that the use of time-series with a length of 30 years (e.g. the WMO standard periods are 1931-60 and 61-90) can lead to erroneous conclusions about long-term trends. Periods of 30 consecutive years were selected from a 100 year dataset with daily streamflow. Depending on the selected subperiod, trends towards both more or less severe hydrological droughts were found over the period 1901-2000 with no clear development over the century.

Drought severity and frequency studies have to consider the full range of climate variability. Several studies, that have used long records, point to the large temporal variability, which makes it difficult to draw firm conclusions on the influence of climate change on hydrological drought. Based on an analysis of the discharge of the River Meuse over the period 1911-1998, it is impossible to conclude that drought has become more severe or frequent (Uijlenhoet et al., 2001; De Wit et al., 2001). No trend can be identified, although the River Meuse regularly suffers from drought (10 out of 100 years the river cannot meet the minimum supply criteria for some time of the year). Cole & Marsh (2006) and Marsh et al. (2007) have analyzed hydrometeorological data and other documents for England and Wales.

![Trend in number of droughts over the period 1962-1990, red - significant positive trend (towards drier conditions) and blue - significant negative trend (towards wetter conditions)](source: Hisdal et al., 2001).

Figure 1.
from the period 1800-2006. They report that the historical period contains many multi-year droughts, in particular the 1940s experienced repeated periods of significant rainfall deficiencies. Extreme droughts occurred in 1798-1808 and 1890-1910 (so-called ‘long-drought’). The authors show that the annual rainfall totals for England and Wales do not exhibit a clear change over time, as derived from the frequency of drought episodes, indexed by exceptional 12-month (non-overlapping) rainfall deficiencies. However, they illustrate that since the latter stages of the Little Ice Age in the early 19th century, the hydroclimatic time series exhibit a number of changes which have important implications for droughts. There has been an increasing tendency, notwithstanding some recent droughts in the 1990s and 2000s, towards a more distinct seasonal partitioning of annual rainfall totals resulting in wetter winters and drier summer, which commensurate with most climate change scenarios. This means a modest increase in winter run-off in flashy catchments, which is beneficial for reservoir refilling, and an increased recharge in groundwater catchments leading to a higher storage and increased groundwater discharge that sustains summer streamflow.

In summary, it is still hard to detect changes in hydrological drought (streamflow and groundwater) in the 20th century and, if occurring, to attribute to climate change. Most studies do not show clear trends in time and over extended areas.

3. Projected droughts (future climate)
Clearly, projections of future changes in climate and associated drought development can only be simulated with a suite of models as mentioned in the previous section. On the basis of these modelling experiences the 4th Assessment Reports of the IPCC (Alley et al., 2007; Adger et al., 2007) provide the following key findings that are relevant for changes in drought. Until 2020 a warming of about 0.2°C per decade is projected for a range of SRES scenarios. The projected globally average surface air warming (2000-99 relative to 1980-99) for SRES scenarios ranges from a best estimate for the low scenario (B1) of 1.8°C (likely range: 1.1-2.9°C) and for the best estimate for the high scenario (A1FI) of 4.0°C (likely range: 2.4-6.4°C). Schip et al. (2004) and Senewicke et al. (2006) also point at a regime with an increased variability of summer temperatures (in addition to increases in mean temperature).

In 2050, IPCC expects that the annual average river flow will have increased by 10-40% at high latitudes, and decreased by 10-30% over some dry regions at mid-latitudes and semi-arid low latitudes, some of which are presently already water-stressed areas. Drought-prone areas and regions affected by heat waves are considered likely to increase in extent. Water stored in glaciers and snow cover is projected to continue to decline, initially increasing, but eventually reducing streamflow during summer in downstream regions supplied by melt water from major mountain ranges. In Southern Europe especially climate change is projected to worsen conditions (high temperatures and drought) in a region that already faces water scarcity and heat waves in a substantial number of areas. In Central and Eastern Europe, summer precipitation is projected to decrease, causing higher water stress.

GHMs and RBHMs with climate forcing data as boundary condition (Section 2) have been applied to explore the effect of climate change in the 21st century on hydrological drought. In a global-scale assessment Arnell (1999) uses a GHM to simulate streamflow across the world. The results show that the patterns in change of annual river flows are generally similar to the change in annual precipitation. According to his study, the annual

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1 Please note that the partitioning over winter and summer seasons is also relevant. In some river basins a higher annual precipitation still will lead to more severe summer drought (see below).
flow is expected to increase in high latitudes and many equatorial regions, but it is anticipated to decrease in mid-latitudes and some subtropical regions. He illustrates that the change in the minimum annual flow with a return period of 10 years (indicator for hydrological drought) alters in a similar way to the average annual streamflow. However, the proportional change tends to be larger. This conclusion is also supported by assessments at the catchment scale, e.g. Dvorak et al. (1997) show that changes in low flow characteristics tend to be proportionately larger than changes in annual, seasonal or monthly flows. The RBHM study in a Dutch catchment (van Lanen et al., 2004b) confirms Arnell’s conclusion for the high latitudes, meaning that droughts become less severe.

![Simulated effects of climate change for the HadAM3H/A2 scenario in the Nordic countries (2071–2100 relative to 1961–90); left: percentage change in mean winter (DJF) run-off, middle: percentage change in mean summer winter (JJA) run-off, and right: change in mean annual number of days per year with snow covered ground (source: Beldring et al., 2006).](image)

However, in some high-latitude regions the annual streamflow will reduce because of a general increase in evaporation that counteracts the increase in precipitation. For example, catchments on the Belgium-Dutch border show this trend in simulated series (Quetsner et al., 1997; Peters & van Lanen, 2001).

At the mid-latitudes, e.g. in many areas in the Mediterranean, the effects of climate change will be often overwhelmed by the effects of land use. Creses et al. (2000) illustrate this for the Upper-Guadiana catchment (Spain), where more water-demanding agriculture has been implemented under semi-arid conditions and groundwater is heavily exploited since the 1960-70s.

In snow-affected climates the temperature increase can lead to a high portion of quick shallow subsurface flow which does not feed the aquifer or to a shift in the timing of the snowmelt from spring to winter implying a reduction in the summer low flow and higher drought risk (e.g. van Lanen et al., 2004b). This is confirmed by modelling results from Eckhardt & Ulbrich (2003), who found a reduction of mean monthly groundwater recharge and streamflow of up to 50% for a catchment located in the central European low mountain range. In the Nordic countries a comprehensive study has been carried out to investigate the influence of climate change on hydrology with the main objective to provide information for hydropower generation (Beldring et al., 2006). In Figure 2 the difference in winter and summer run-off and number of snow days for a particular scenario are shown. Climate
change leads to substantial effects. The study shows that in general, the available water resources for hydropower increase, but in some areas dryer conditions are projected. In the summer season water shortage may occur at some locations. Hence, despite the projected increase in annual discharges at high latitudes, the RBHMs still predict more severe summer drought in some regions when account is taken for the change in precipitation distribution over the seasons, the earlier snowmelt and the higher evapotranspiration and longer growing season (Hisdal et al., 2006). This holds in particular for catchments with low storages.

Several studies illustrate that the effect of climate change on low flow is significantly affected by the stores in the catchment, e.g. soils, aquifers, lakes, bogs, snow pack, glaciers (van Lanen et al., 2004b). Results, for example, of low flow changes simulated for several Belgian catchments by using GCM scenarios show how the same scenario could produce rather different changes in different catchments, depending largely on the catchment geological conditions (Gellens & Roulin, 1998). Catchments with greater groundwater storage capacity tend to have higher summer flows under the climate change scenarios considered because additional winter rainfall tends to lead to larger groundwater replenishment. Low flows in catchments with low storage capacity tend to be reduced because these catchments cannot take advantage of increased winter recharge.

In summary, the mid-latitudes, e.g. the water-scarce regions around the Mediterranean, are projected to be worse off in the future (higher number and more severe droughts). In addition, more heat waves are expected in South and Central Europe, which is a major health concern. For North and West Europe, the IPCC projects higher temperatures and associated evapotranspiration and an increase of annual river flow. Generally, this will lead fewer and less severe droughts, especially winter droughts. However, the physical structure of the river basin, in particular the stores, the seasonal distribution of precipitation and increased evapotranspiration will determine if more and more severe summer droughts will occur. Rivers draining snow-covered mountains may suffer more summer droughts from a reduced snow cover at the long run as these mountains provides important meltwater. Initially river flow will be higher (e.g. Chalise et al., 2006). The larger summer temperature variability that has been expected by Schär et al. (2004) and Seneviratne et al. (2006) will likely lead to more droughts in many European regions.

Regions located in the transition zone between major climate zones, e.g. from the temperate to the dry climates, are particular susceptible to drought and thus to potential changes in climate (Stahle & Hisdal, 2004). A shift in climate may create a new transitional climate zone with unknown feedback mechanisms. In Europe a northward shift is observed influencing summer climate variability in Central and East Europe due to strong land-atmosphere coupling. This may potentially cause more droughts and heat waves in this and other mid-latitude regions (Seneviratne et al., 2006).

There are many uncertainties in our understanding of the current water cycle (oceans, atmosphere and land) and how it will develop in the future (e.g. Prudhomme, 2006; Prudhomme & Davies, 2006).

4. Role of EC Integrated Project WATCH
The Integrated Project (WATCH: WA TER and climate CHange) will advance our knowledge and skills to predict the effect of climate change on drought. It analyses and describes the current global water cycle (20th century), especially causal chains in the physical system (climate-hydrology) leading to observable changes in extremes (e.g. droughts). It will evaluate how the global water cycle and in particular droughts (21st century) respond to future drivers.
of global change (including greenhouse gas release and land cover change) and will contribute to a clarification of the overall vulnerability of global water resources. WATCH will assess the uncertainties in the predictions of climate-hydrological-water resources model chains using a combination of model ensembles and observations.

WATCH brings together hydrologists, water cycle experts and climate modelers. There has been a historical, disciplinary "disconnect" between communities: (1) developing integrated water cycle and water resources assessment and modeling frameworks, (2) estimating hydrological extremes, and (3) developing climate modeling frameworks. This has resulted in many conceptual and data-related inconsistencies in the studies and in projections of the state of future water cycle, including its extremes — both globally and in the regions. The different approaches are, however, gradually converging. Process representation in the models is becoming more comprehensive, the grid size of climate models is approaching that needed to resolve large basins and methods to use statistical information from climate models are being developed.

Our understanding of the global water cycle, including the characteristics of past droughts (Section 2) and how they might change in future (Section 3), is very fragmented and highly uncertain. There are many sources of information, which have a wide range of space and time scales and also come from different scientific communities. There has been no systematic collection and analysis of the observations globally. Hence, WATCH will develop a new consolidated dataset.

The current generation of global and regional climate models (GCMs and RCMs) is expected to unsatisfactorily reproduce historical hydrological extremes, with considerable variability in the prediction of rainfall patterns, with differences between climate models and between different ensemble members of the same climate model. The issue of the inaccuracies in climate model output (in particular the rainfall, high temperatures and persistent dry periods) will be addressed by investigating the best method of transferring and validating information about extreme events between climate and hydrological models at different scales. WATCH will develop a new, highly consistent modeling framework for water resources, hydrology (incl. extremes) and climate studies. This framework, however, will not be attempting to fully link individual model segments into a fully coupled modeling system. Instead, WATCH analyses, data consolidation and modeling efforts will focus on building a new generation of interfaces between water resources, hydrological and climate models, attempting a maximum possible consistency in spatial and time scales involved, and in related process descriptions.

It is essential to know the uncertainty in any assessment of possible future changes in hydrological extremes and water availability. Uncertainty can come from a large range of sources: errors in our current "baseline" assessment, uncertainty in future development scenarios, the spread in climate model predictions, uncertainties in our hydrological models etc. It is essential to combine these uncertainties to produce a realistic assessment of the total uncertainty. The outputs from this merging of climate and hydrological models will be a full uncertainty analysis of the spatial and temporal scaling techniques available and recommended methodologies to transfer guided climate model output to the basin scale.

Another crucial issue is the attribution of changes in the hydrological cycle (incl. the extremes), discriminating between external drivers, both natural and anthropogenic, and internal variability. There is considerable public and political interest in issues of attribution and it has significant practical implications as well. Attribution studies to date have focused overwhelmingly on large-scale temperature changes. Attribution of changes in hydrological
variables and extreme weather events received much less attention, but is more relevant to many practical water management and policy decisions.

The WATCH project has identified one Work Block that investigates the frequency, severity and scale of the extremes, with emphasis on drought for past and future conditions. The overall objective of the work block is to advance knowledge on the impact of global change on hydrological extremes, i.e. spatial and temporal scale of droughts and large-scale floods.

The following specific objectives have been defined:
- to estimate the likely frequency, severity and scale of hydrological extremes (droughts and large-scale floods) globally in the 20th century;
- to advance our understanding of drought and large-scale flood generating processes and spatial and temporal development (scale) at the global, regional and river basin scale;
- to identify possible links between large-scale climate drivers and the temporal and spatial dynamics of hydrological extremes, including teleconnections and synchronicity of extremes at the regional and global level;
- to identify and develop physical indicators for various types of droughts and large-scale floods considering different spatial scales and hydrological regimes;
- to develop statistical methods to detect hydrological extremes at different scales, including the coarse-gridded scale typical of global models;
- to attribute the impact of climate and anthropogenic changes to hydrological extremes by comparing trends in observed time series and simulated time series obtained from climate forcing models combined with land surface hydrological and river basin models;
- to predict the likely frequency, severity and scale of future hydrological extremes (21st century) considering the sensitivity in hydrological extremes to changes in predicted climate and anthropogenic influences, and
- to analyse the uncertainty in predicted hydrological extremes at different scales including the propagation of uncertainties within linked modeling studies.

Figure 3 Flow chart showing how droughts are derived by using different models.
Different climatological and hydrological models and combinations are used to detect droughts (Fig. 3). Droughts are directly derived from the guided outcome simulated by Land Surface Hydrological Models (LHSMs) linked to a GCM (1) or RCM (4). Droughts are also obtained from the guided output generated by Global Hydrological Models (GHMs) that use climate forcing data from GCMs (2) or RCMs (4). For a few river basins (e.g. Gomma, Elbe, Upper-Guadiana), River Basin Hydrological Models (RBHMs) will be applied to detect droughts. These models are driven by climate forcing data from GCMs (3) and RCMs (6).

The main outcomes of the work block are:
- frequency, severity and scale of historical extremes (droughts and large-scale floods in the 20th century), including possible causes for observed trends/changes in the extremes (detection and attribution); and
- frequency, severity and scale of future extremes (droughts and large-scale floods in the 21st century), including an assessment of the sensitivity in the extremes due to climate change and anthropogenic influences.

The WATCH project has started in February 2007 and will last 4 years and the outcome will gradually become available in the coming years. It will make a significant contribution to climate change impact research, including assessing droughts, by bringing together different research communities, thus emphasizing the need to corporate between disciplines to move forward in this field.

Clearly, WATCH will not address all aspects relevant for droughts and climate change. For example, knowledge on the physical system (climate and hydrology) still need to be enhanced, especially on the propagation (space-time) of meteorological drought in soil water and hydrological drought, to be used as basic elements for early warning systems, forecasting of drought conditions that also considers climate change. Additionally, assessing impacts (environmental, socio-economic) of drought need more research. It is expected that these aspects will be covered by studies in the framework of the 7th Framework Programme.

References


