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EUROWATERNET

Water quantity aspects

Technical guidelines for implementation

Draft

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Table of Contents

Preface

The European Environment Agency (EEA) according its regulation has a mandate to produce objective, reliable and comparable information to allow the Community Institutions and Member States to identify, quantify and monitor key environmental problems. EEA and the European Environment Information and Observation Network are created to be the main European system for supporting development and implementation of policy through the interactions of networking, connecting information from national monitoring to European reporting and the establishment of the EEA as the Reference Centre for environmental information.

The European Topic Centre on Water (ETC/W) has designed and tested an information and monitoring network, called EUROWATERNET. This network will provide the European Environment Agency with information that it needs to meet the requirements of its customers including the European Commission, other policy makers, national regulatory bodies and the general public. Information is required on:

- the status and trends assessments of Europe’s inland water resources, quality and quantity; and

- how that relates and responds to pressures on the environment (cause effect relationships).

Executive summary

This report has been split into three main parts. The first one describes the targets that EUROWATERNET aims to achieve with respect to the quantitative aspects of water, and outlines the main problems that have to be tackled. This chapter also proposes how to integrate data monitored by networks that are administered by different organisations in order to form different layers of information.

The second part of this report contains the guidelines themselves. The different variables to be measured and the relationships between them are defined there. It provides a description of three specific networks, each one of which is designed to obtain one particular hydrological variable: precipitation, natural internal outflow and actual outflow, together with the methodologies to be used for selecting the stations of these networks and for obtaining the variables.

Finally, the third part of this report, which is presented in the form of an Annex, describes a pilot design scheme for these three networks in Spain. It provides an assessment of the suitability of the methodology described, in which a check is made to ensure that the simplifications have not adversely affected the reliability of the data. The aim of this is also to provide a practical example that makes it easy to apply the proposed guidelines in the different EEA member countries.

The pilot project was first fulfiled for Spain and then it has been extended up to other ten countries, such as Denmark, Estonia, France, Germany, Greece, Hungary, Latvia, Lithuania, Slovenia, and United Kingdom. For all of them, the same methodology has been applied in order to better assess water resources at national level. In some cases, two different source data have been compared with the results from the proposed selection, particularly for the precipitation network, for which the comparison has also been made with the Eurostat data in the New Cronos database. Table 1 summarises the results obtained for the current status of the pilot project.

Table 1 Summary of results in the countries for which the pilot study has been implemented.

COUNTRY	DATA	AGGREGATE VALUE FROM AN OFFICIAL SOURCE	OFFICIAL SOURCE	AGGREGATE VALUE FROM THE SELECTION
DENMARK	Precipitation	740 mm	NewCronos	716 mm
		709 mm	Country	
	Internal Inflow	300 mm	Country	284mm
	Actual Outflow	$6000*10^6$ m^3	NewCronos	$3600*10^6$ m^3
ESTONIA	Precipitation	665 mm	Country	675 mm
	Internal Inflow			
	Actual Outflow			
FRANCE	Precipitation			
	Internal Inflow	328 mm	NewCronos	436 mm
	Actual Outflow	$168000*10^6$ m^3	NewCronos	$4690*10^6$ m^3
GERMANY	Precipitation			
	Internal Inflow	311 mm	NewCronos	244 mm
	Actual Outflow	$178000*10^6$ m^3	NewCronos	$104581*10^6$ m^3
GREECE	Precipitation	806 mm	Country	841 mm
		870 mm	NewCronos	
	Internal Inflow			
	Actual Outflow			
HUNGARY	Precipitation	623 mm	NewCronos	623mm
	Internal Inflow	64 mm	NewCronos	65 mm
	Actual Outflow	$120400*10^6$ m^3	NewCronos	$98568*10^6$ m^3
LATVIA	Precipitation	684 mm	Country	682 mm
		678 mm	NewCronos	
	Internal Inflow	263 mm	NewCronos	270 mm
	Actual Outflow	$34224*10^6$ m^3	NewCronos	$33211*10^6$ m^3
LITHUANIA	Precipitation	671 mm	Country	671 mm
		561 mm	NewCronos	
	Internal Inflow	198 mm	NewCronos	201 mm
	Actual Outflow	$25897*10^6$ m^3	NewCronos	$8703*10^6$ m^3
SLOVENIA	Precipitation	1323 mm	Country	1363 mm
		1095 mm	NewCronos	
	Internal Inflow	364 mm	NewCronos	800 mm
	Actual Outflow	$29855*10^6$ m^3	NewCronos	$14760*10^6$ m^3
SPAIN	Precipitation	691 mm	Country	675 mm
	Internal Inflow	223 mm	Country	211 mm
	Actual Outflow	$85000*10^6$ m^3	Country	$77894*10^6$ m^3
UNITED KINGDOM	Precipitation	1079 mm	Country	1123 mm
	Internal Inflow	646 mm	Country	773 mm

1. Introduction

The development and implementation of EUROWATERNET includes a specific task oriented to obtain comparable information on the water resources status of inland waters. Although in the implementation of EUROWATERNET water resources monitoring have to be based on existing national networks, experience shows that data of the totality of rain gage and gauging stations in each country is not available.

Moreover, as will be noted in this report, in some cases it is not possible to measure directly the determinand under consideration, thus it has to be estimated with the aid of different tools. This is the case when estimating internal renewable resources, which have to be calculated assuming that a non-altered regime is being dealt with, i.e. reconstructing the hydrological regime that would exist in the absence of hydraulic works and water abstraction or using mathematical modeling.

The main aim of this report is to describe station selection procedures and a methodology for water resources assessment using only data from the stations selected. The pilot study has been extended up to a total of eleven countries, such as Denmark, Estonia, France, Germany, Greece, Hungary, Latvia, Lithuania, Slovenia, Spain and United Kingdom. Table 1 of the Exceutive Summary of this report summarizes the results obtained from the guidelines implementation. The results show that there are slight differences between the official data and the value obtained with this methodology, which means that an assessment of water resources at national level can be made from data of a reduced number of stations in each country.

2. Aims of EUROWATERNET where water quantity aspects are concerned

The main aim of Eurowaternet, whose design guidelines are described in this report, is to furnish timely and comparable information on the status of the quantity of inland waters from all EEA member countries so that the associated key environmental problems can be identified, quantified and monitored. One clear understanding is that the monitoring network will be based when possible on existing national networks, using existing sources of monitoring information.

For inland water quantity monitoring, two broad categories of station may be recognised in philosophical terms; in practice, there may be considerable overlap between the categories at individual measurement sites:

- Statutory and operational monitoring arising from national or international obligations or to provide information to the business and operational needs of the regulators, suppliers and users of water;

- Surveillance monitoring to characterise and allow appraisal to be carried out of the state of water resources and, in conjunction with water quality measures and biodiversity, the state of the water environment.

The separation is based on measurements taken to ensure legal compliance or efficient utilisation of the water resource and what is beneficial in allowing the longer or broader view to inform policy making, assisting planning decisions and increasing basic knowledge.

EEA requires access to information from a sound surveillance network although, actually the information provided should extend beyond the monitoring and characterising of the state of the environment. In turn, this requires that the network should be capable of quantifying effects and providing insights to processes sufficient to frame scientifically based management or mitigation procedures.

The fact that there are approximately 19 000 flow measurement stations in Europe, would initially appear to suggest that it would be a relatively simple task to select a group of such stations that fulfil the aims described in this report. However, there are a series of factors that serve to complicate this apparently easy selection process. The following factors are among those involved:

- Lack of one single definition for water quantity aspects;
- Different ways of taking measurements;
- Different methodologies for assessment;
- Different spatial and time scales for integration;
- Use of information that has not been validated.

In spite of the different initiatives taken by a variety of institutions with a view to standardise different hydrological concepts used in different areas, a lack of a single and distinct definition for indicators concerning both resources and water demand, is a problem that still has to be overcome.

The European Environment Agency has undertaken a major task involving the definition of water-related indicators, basically with a view to creating the EUROWATERNET network. Several of these definitions appear in the `EEA State of the Environment and outlook report´, and are being used in this study.

Even when different countries use the same indicator definition, the different measurement procedures used mean that it is not possible to compare the available evaluations. This problem often crops up with water quality indicators, because it is often necessary to establish the measurement method as well as the indicator definition, but also affects some quantity indicators, i.e. actual evapotranspiration.

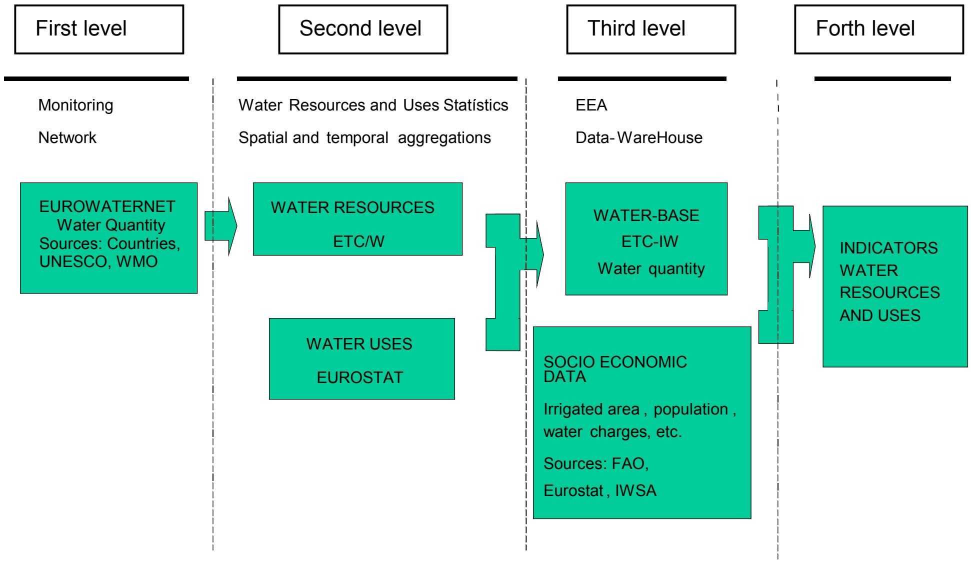
In some cases, it is not possible to measure directly the determinand under consideration, and it has to be estimated with the aid of mathematical models. This is the case when estimating internal renewable resources, which have to be calculated assuming that a non-altered regime is being dealt with, i.e. reconstructing the hydrological regime that would exist in the absence of hydraulic works and water abstraction.

An added difficulty, is the different space and time scales used for aggregating hydrological data. For example, concerning spatial distribution, socio-economic data are normally available at different administrative scales, but it is unusual for such information to exist on a river basin scale. In some cases, extrapolating to a different scale, the data measured in a particular river clearly gives rise to errors. The temporal aggregation level for the data also causes a degree of uncertainty.

Many of the aforementioned problems could be overcome by a suitable technical evaluation of the data supplied. However, in spite of the different initiatives taken by institutions as UNESCO (with the International Hydrological Program) or World Meteorological Organization (with the Operational Hydrological Program), no organisation yet exists to carry out this function on a European scale. It is customary to use the data provided by a particular country and this information is rarely questioned.

The figure below shows a proposal for water resources and uses information levels. It describes four different levels of information that go from a first level, which contains the basic hydrometeorological data, to a final level consisting of the indicators on water resources and uses.

Figure 2.1 Proposal for water resources and uses information levels.



As can been seen from the figure, after the data obtained by EUROWATERNET from different sources has been processed spatially and temporally, it forms part of a `Water Resources Data Base´ managed by the ETC Water. The information contained therein, together with the data concerning `Water Uses´ by EUROSTAT, make up the `Water Quantity Data Base´ that is contained in the `European Environment Agency Data-Warehouse´. This information has to be incorporated with socio-economic data coming from a variety of sources to constitute the `Water Resources and Uses Indicators´, which is the highest information level.

These guidelines basically deal with the first two levels referred to above. On the one hand, they describe how to set up the monitoring network and the variables to be taken into account (according the previous figure: First Information Level) and, on the other hand, how to analyse and enter the data obtained (Second Information Level).

3. Basic network description

3.1 Definition of the variables to be measured and the relationships between them

3.1.1 Natural Basins

In its natural state, water moves in a sequence of physical processes that constitute the *hydrological cycle*. The term hydrological cycle is to be understood as meaning the overall transfer of water between the atmosphere, the sea and the land in its three states, solid, liquid and gas. The driving force behind these transfers is the Sun.
The set of water processes that have taken place or will do so in nature without any kind of human interference is the *natural hydrological cycle*.

The basic processes that are involved in the natural hydrological cycle are precipitation evapotranspiration, infiltration, percolation and runoff. *Evapotranspiration* is the overall effect of the *evaporation* of the water from soils, seas, rivers and lakes, and *transpiration* loss of water from living organisms (e.g. plants). This evapotranspiration gives rise to the formation of vapour in the atmosphere that, on condensing under certain conditions, partly returns to the surface in the form of liquid or solid *precipitation*. A proportion of this precipitation *infiltrates* into the soil, from which it evaporates again, or *percolates* into the subsoil and the rest runs off over land or in the drainage network. The percolated water into the subsoil, builds up in the pores, cracks and fissures below the ground surface which, because of its physical characteristics, has a greater or lesser capacity to store water. The geological formations that can store and transfer water are known as *aquifers*. The proportion of water that *recharges* the aquifers by percolation, and then reappears in the river network at some later date, is referred to as *groundwater flow*.

The term *natural internal flow* at a particular point on a river is used to define the volume of water that runs through that point in a given period of time. Thus includes the total *runoff* for the entire basin lying upstream from that point, plus the *groundwater flow* that runs into the riverbeds upstream from that same point.

3.1.2 Altered Basins

The *natural internal flow* does not necessarily have to be the same as river discharge that is measured at the gauging stations, because transfers might take place from adjacent basins and human activity can in other ways alter the natural flow conditions.

Water has always been an essential element for the development of civilisation, and mankind has severely modified the natural water flows and storage in the hydrological cycle. Growth of cities, food production using irrigation in agriculture or energy production, have made it necessary to divert water from its natural location - rivers, lakes or aquifers - and use it for these purposes, thereby modifying the flows that would have taken place without human intervention.

There have been major interventions in many regions of Europe, and these have often given rise to a hydrological cycle that is very different from the natural cycle. The result of such modifications to the natural flows and storage by human activities, is referred to as *the altered hydrological cycle*.

From a quantitative viewpoint, the most significant effect on the natural flow cycle is the reduction of natural internal flow due to *actual consumption by uses*. This water generally comes from groundwater and the resources stored in reservoirs, whose yield is also reduced by evaporation.

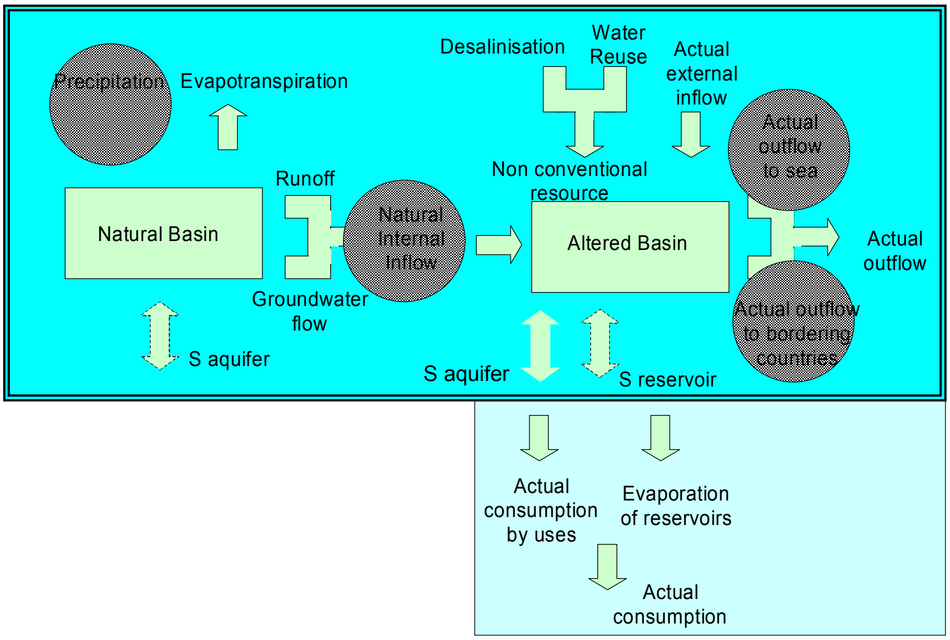
Apart from the natural internal flow, the *actual external inflow* coming from adjacent basins, must also be considered as coming to form part of the altered system, and the same applies to the *non conventional resources* if they happen to be used, the latter mainly consisting of resources that come from *desalinisation* and *water reuse*.

The outflows from the system would comprise the actual consumption and the *actual outflow*; with respect to the latter, a distinction can be made between the *actual outflow to sea* and the *actual outflow to bordering countries.*

3.1.3 Proposal for water quantity indicators

As a result of the description given in the preceding sections, the following figure shows the different elements in the natural and altered cycles, together with the main relationships that exist between them.

Figure 3.1 Components of the natural and altered cycles and the relationships between them



The above figure (Figure 3.1) shows in circles, the proposed set of water quantity indicators and upon which the current guidelines are focused:

- *Precipitation,*
- *Internal flow* and
- *Actual Outflow* (sum of the outflow to sea and the outflow to bordering countries).

If there was no variation in the aquifer storage in the natural hydrological cycle[1], the evapotranspiration could be obtained as the difference between the precipitation and the internal flow.

If one likewise assumes that there is no water storage variation in reservoirs in the altered cycle[2], the actual consumption (consumption plus evapotranspiration) will be obtained by calculating the difference between the actual outflow and the sum of the natural internal outflow, non-conventional resources and actual external inflow.

[1] The longer the chosen time scale the closer to reality the zero variation in aquifer storage hypothesis would be, and such a situation could be regarded as valid for periods greater than one year. If this hypothesis is not considered valid, it will be necessary to have an aquifer reserves indicator.

[2] Or, as has been stated in the case of aquifers, the data concerning their water reserves is known

3.2 Precipitation Stations Network

The basis of EUROWATERNET is the information derived from existing national and/or regional monitoring networks within each member country. Member countries are asked to select rain gage stations according to the criteria described in this section. These will form the *basic precipitation network* and are expected to be able to provide a general overview of the precipitation in each territory (country or river basin) at European level.

3.2.1 General characteristics

Only rain gauge stations that fulfil the following requirements are recommended:

- They must be in service;
- They must have at least 30 years of daily precipitation data.

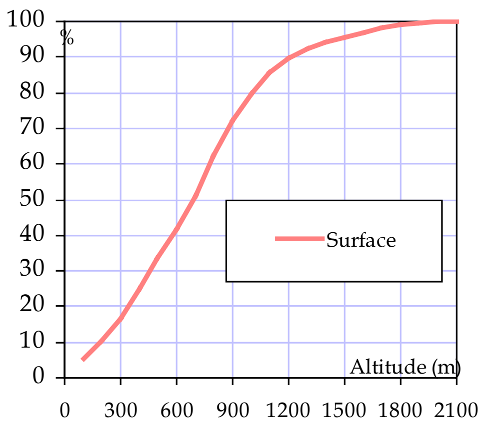
3.2.2 Geographical distribution

The required number of rain-gauge stations should be geographically spread across a member country with a density of one station per 5 000 km^2. The spatial distribution must be as even as possible.

3.2.3 Distribution of the stations by altitude

The percentage of rain gauge stations lying between two particular elevations should be approximately the same as for the surface areas distribution between them. If, for example, the contours (lines joining points of equal altitude) are as indicated below, the curve for the elevations of the selected rain gauge stations should have approximately the same shape.

Figure 3.2 Contours for a specific surface area



Hence, in this example, it can be deduced that the number of rain gauge stations with altitudes ranging from 600 to 900 m, should be approximately 30 % (70 - 40) of the total number of selected stations.

3.2.4 Obtaining the precipitation

Once the rain gauge stations have been selected, the distributed precipitation values for a specific area, will be obtained using the following procedure:

- *Specific value at each station to be estimated for the area:* Annual precipitation (mm) obtained by average value of the complete series
- *Methodology:* Squared inverse of the distance
- *Number of nearby points to be considered in the interpolation*: 3

3.3 Internal flow stations network

Member countries are asked to select gauging stations according to the criteria described in this section. These will form the internal flow stations network and are expected to be able to provide a general overview of the internal flow in each territory (country or river basin) at European level.

3.3.1 General characteristics

The stations should be selected according to the following criteria:

- The flow regime at the station must be as natural as possible, with little influence from human activities (e.g. abstraction or regulation)
- Stations should have a minimum record period of 25 years from 1960 to 1990.
- Stations must be in service.

3.3.2 Geographical distribution

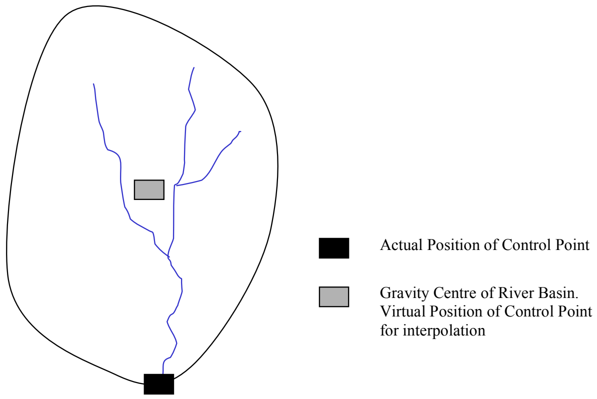
The natural regime condition expressed in Section 3.3.1, generally makes it necessary to select stations lying in sub-basins that are located in the upper reaches of rivers close to the headwaters. The geographical distribution of these sub-basins must be as even as possible in the area considered taking the aforementioned condition into account. The station density sought is approximately between one station per 20 000 km^2 to one per 5.000 km^2 depending on the covered area and its hydrological homogeneity.

3.3.3 Obtaining the internal flow

Once the gauging stations have been selected and their catchment areas have been defined, the distributed run-off values in a particular zone, will be obtained using the following procedure:

- *Specific value to be estimated for the area:* Run-off (mm) average value of the complete series for each station. This value is not allocated to the point at which the station is located, but either to the centre of gravity of the basin that drains into it or any other point that is considered representative for interpolation purposes. (See Figure 3.3).

Figure 3.3 Virtual position of control points for interpolation



- *Methodology:* Squared inverse of the distance
- *Number of nearby points to be considered in the interpolation*: 3

3.4 Actual outflow stations network

Member countries are asked to select gauging stations according to the criteria described in this section. These will form the actual outflow stations network and are expected to be able to provide a general overview of the actual outflow in each territory at European level.

3.4.1 General characteristics

The stations will be selected according to the following criteria:

The gauging stations must either be located at the points lying closest to the estuaries or at those where the river is administered by a different authority (example: the frontier between two countries).

- Stations are intended to have a minimum record period of 25 years from 1960 to 1990;
- Stations must be active.

3.4.2 Geographical distribution

Taking into account the conditions referred to in Section 3.4.1 the geographical distribution of these sub-basins must be as even as possible in the area concerned. Furthermore, all the main rivers must be considered.

3.4.3 Calculation of actual outflow

When the stations considered representative of a given territory have been selected, the outflow will be calculated supposing for the total area the same runoff value of the chosen station. Total outflow to sea will be calculated adding the different outflows of the territories. In a similar way, total outflow to bordering countries will be calculated by adding their respective outflows.

Annex

Pilot study: selection of precipitation, internal flow and actual outflow networks

A.1 Precipitation network

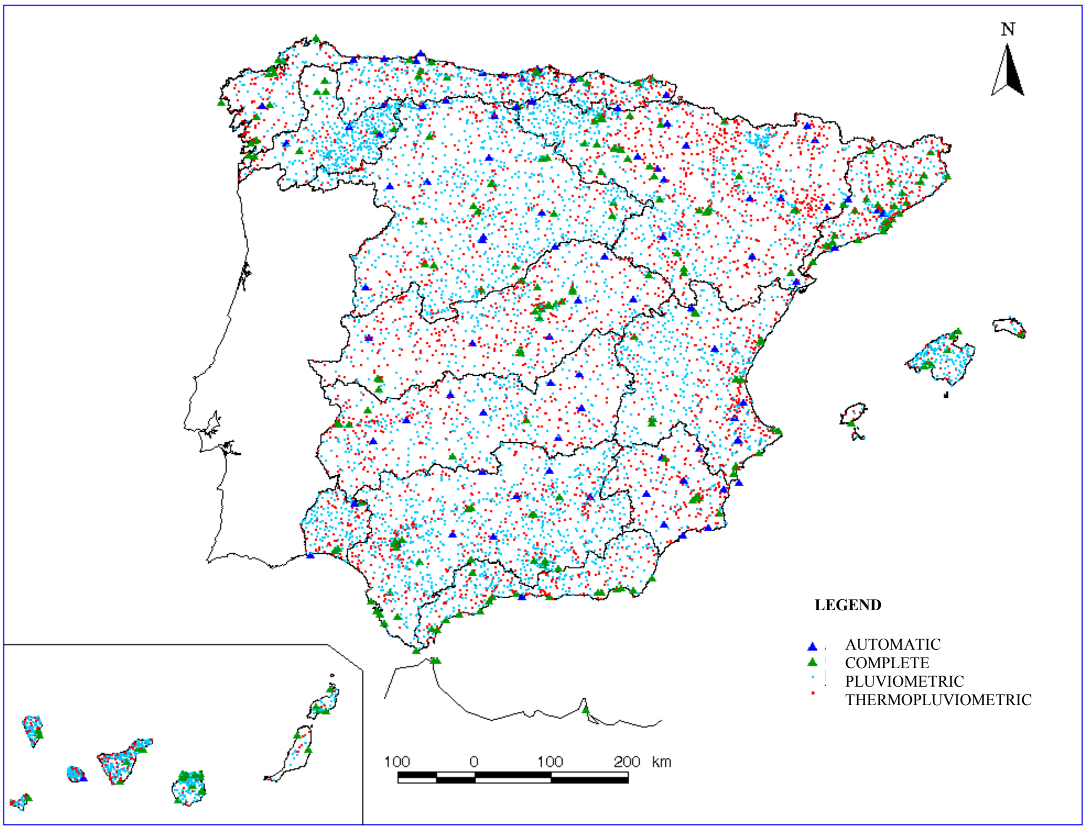
A description is given below of a pilot design study in Spain for the three networks proposed in these guidelines. The two basic aims are to confirm the suitability of the methodology described, in which a check is made to ensure that the simplifications have not adversely affected the reliability of the data and also to provide a practical example that makes it easy to apply the guidelines proposed in the different member countries of the EEA.

The network of Spanish meteorological data

The Spanish Department of the Environment is currently responsible for collecting, managing and publishing meteorological data via the National Meteorological Institute.

The national network, can be seen in the figure shown below, and consists of approximately 9 200 stations that contain historical records; 5 200 of these only measure precipitation (P); 3 700 measure both precipitation and temperature (TP); 200 are complete stations (C), which record precipitation, temperature, atmospheric moisture, insulation, wind , etc.; and 80 are automatic. The latter type of station is a recent development. They record the same types of data as the complete stations and their main characteristic is that they transfer the information automatically via the telephone network.

Figure A1 Spanish meteorological data network



Selection of stations

General Characteristics

An initial selection has been made of the stations that make up the network described in the preceding section; these stations all fulfil the following requirements:

- They must be in service;
- They must have at least 30 years of daily precipitation data

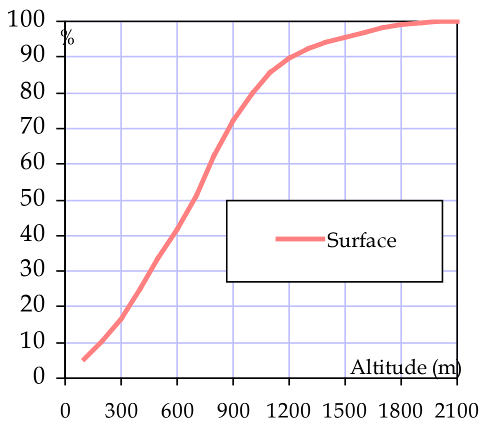
Applying these criteria 1 379 stations have been selected.

Geographical distribution by altitude

The Spanish mainland covers a surface area of 494 000 km^2. As a result, and considering control points with a density of one station per 5 000 km^2, it means that the precipitation network must be made up of about 100 stations.

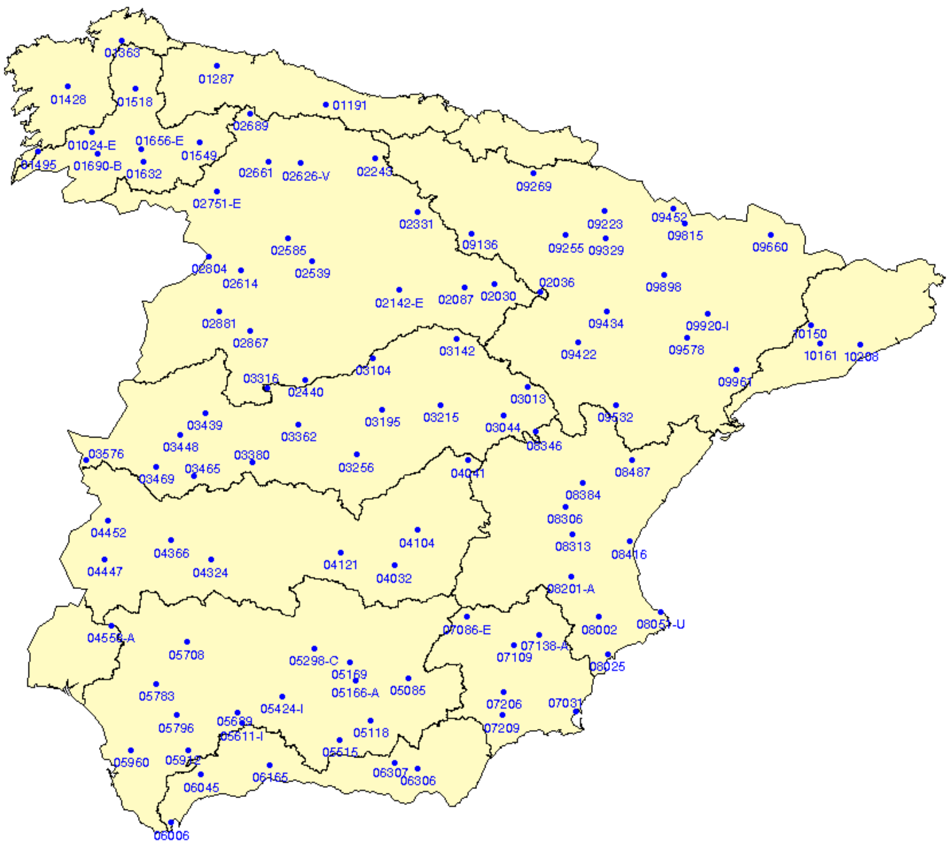
Furthermore, the curve that indicates the percentage of surface area in Spain that lies between the two elevations determined, can be seen in Figure A2.

Figure A2 Relationship between surface and altitude



In accordance with this distribution by elevations and endeavouring to obtain a geographical distribution that is as even as possible, 105 stations were selected. They can be seen in Figure A3.

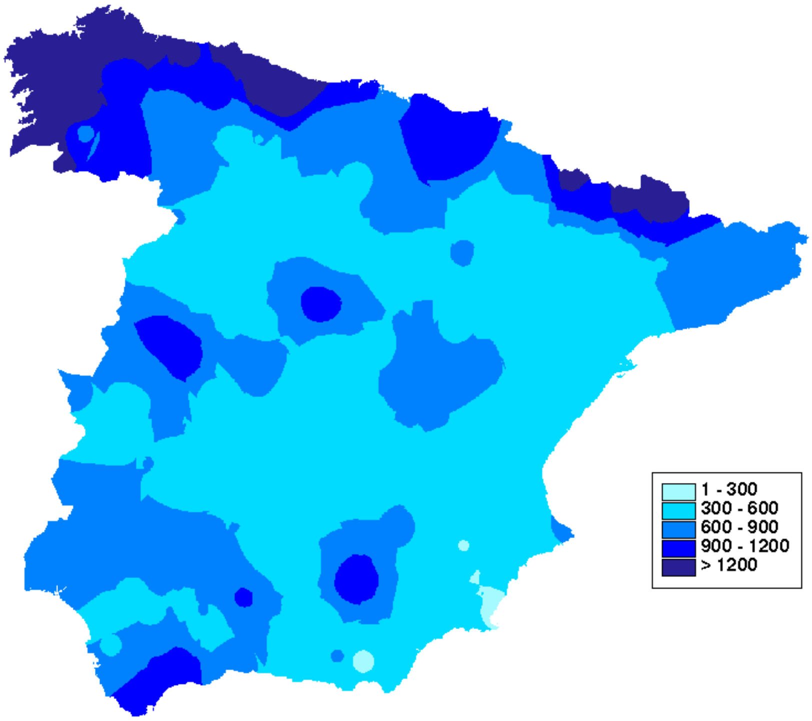
Figure A3 Stations selected for the Spanish precipitation network of EWN quantity



Obtaining the precipitation

Figure A4 shows the map obtained by interpolating the average precipitation values for the 100 points selected. As discussed earlier in the guidelines, the interpolation method used was the squared inverse of the distance, the value of the three nearest points being considered in the interpolation.

Figure A4 Precipitation map obtained from the selected stations (Series 1940-96)



Aggregate values in the main Spanish basins can be obtained from the above map. These values are as follows (Table A1).

Table A1 Aggregate precipitation value in the main Spanish basins, as obtained from the 105 stations selected (Series 1940-96)

River Basin	Surface (km^2)	Annual average precipitation (mm)
Norte I	17 600	1 072
Norte II	17 330	1 191
Norte III	5 720	1 002
Duero	78 960	601
Tajo	55 810	650
Guadiana I	53 180	523
Guadiana II	7 030	761
Guadalquivir	63 240	668
Sur	17 950	595
Segura	19 420	417
Júcar	42 900	502
Ebro	85 560	666
CI Cataluña	16 490	632
Galicia Costa	13 130	1 676
Peninsula	494 020	676

Estimation of the representativeness of the results

To check the suitability of the methodology used, the results shown above (Figure A4 and Table A1) were compared with those obtained for all the stations on the Spanish network and which were calculated with a view to preparing the Spanish White Paper on Water (See Figure A5 and Table A2).

Figure A5 Precipitation map obtained from the data for all the meteorological stations in Spain. Source: Spanish White Paper on Water (Series 1940-96)

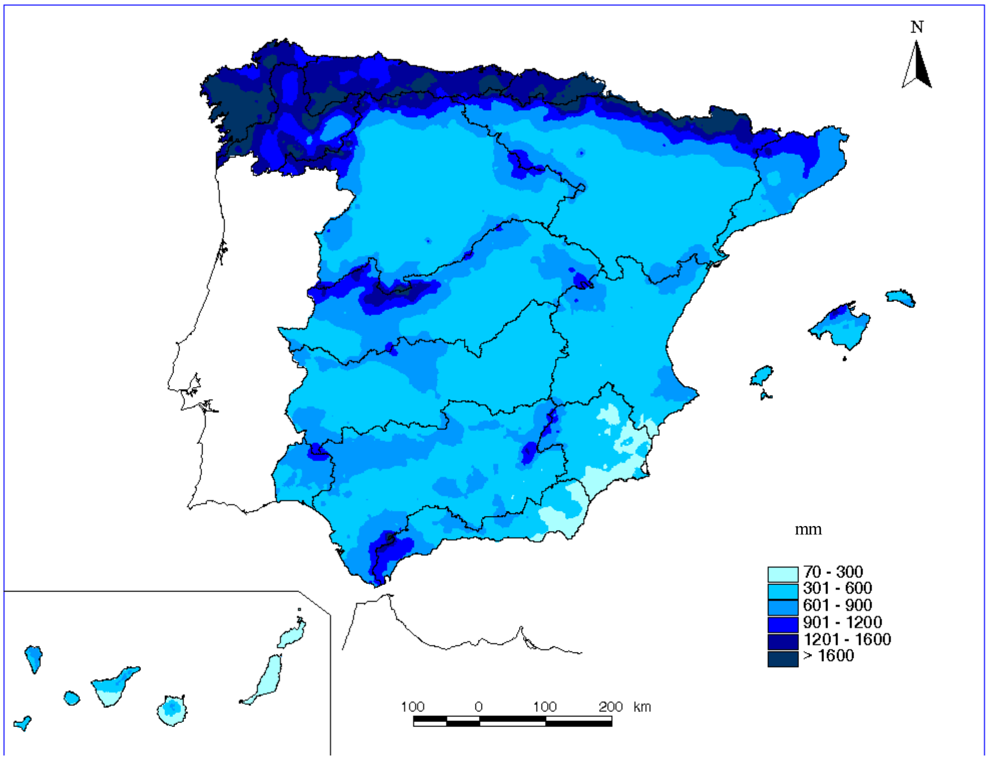


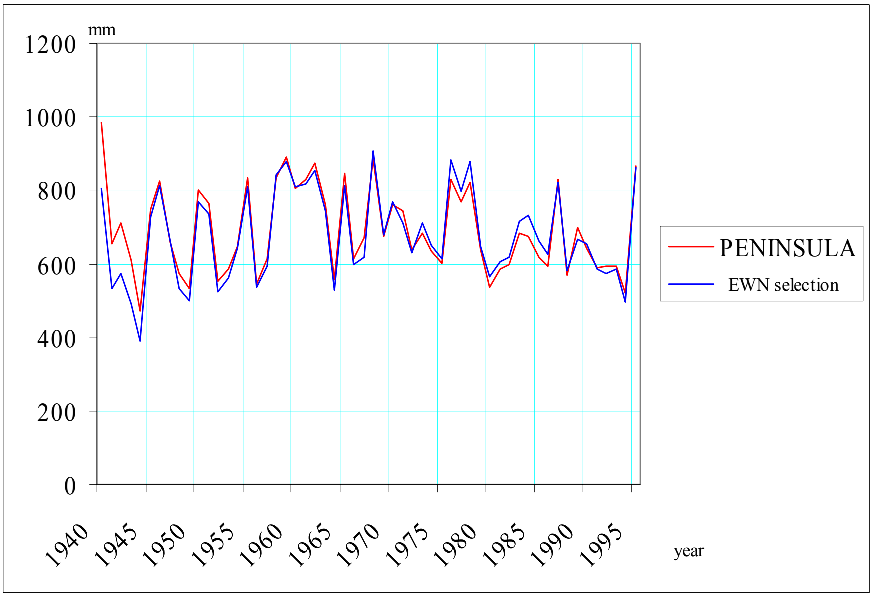
Table A2 Aggregate precipitation value for the main Spanish basins obtained for all the meteorological stations in Spain and comparison of the results. Source: Spanish White Paper on Water (Series 1940-96)

River Basin	Surface (km^2)	Precipitation (mm) All stations	Precipitation (mm) Selection EWN	Difference (%)
Norte I	17 600	1 284	1 072	16
Norte II	17 330	1 405	1 191	15
Norte III	5 720	1 606	1 002	38
Duero	78 960	625	601	1
Tajo	55 810	655	650	0
Guadiana I	53 180	521	523	0
Guadiana II	7 030	662	761	-15
Guadalquivir	63 240	591	668	-13
Sur	17 950	530	595	-12
Segura	19 420	383	417	-1
Júcar	42 900	504	502	0
Ebro	85 560	682	666	0
CI Cataluña	16 490	734	632	14
Galicia Costa	13 130	1 577	1 676	-1
Peninsula	494 020	691	676	1

It was revealed that the greatest differences are about 20 % in the smaller basins. The value for the whole of the Spanish mainland obtained from the EWN selection that was chosen, shows a difference of only 1 % with respect to the value obtained using all the meteorological stations in Spain.

Figure 6 shows the average annual precipitation in Spain from 1940 to 1996 estimated using all the meteorological stations (peninsula) as compared to an estimate obtained from the EWN selection.

Figure A6 Time series for the average annual precipitation in Spain, estimated from all the meteorological stations and from the 105 selected EWN sites.



An analysis of the graph shows that a suitable selection of stations has been made. The greatest discrepancies are found for the years 1940 to 1945. These differences can be explained by the fact that there are gaps in the data for some of the 105 stations considered, but these discrepancies are never greater than 20 %.

Along similar lines and using the same methodology, the following figures (Figures A7 and A8) show the annual precipitation values obtained for some of the largest river basins in Spain (Tajo and Guadiana), on the basis of both the selected stations in the respective basins and also for the total number of stations in those basins.

Figure A7 **Time series for the average annual precipitation in Tajo river basin estimated from all the meteorological stations and from the 105 selected EWN sites.**

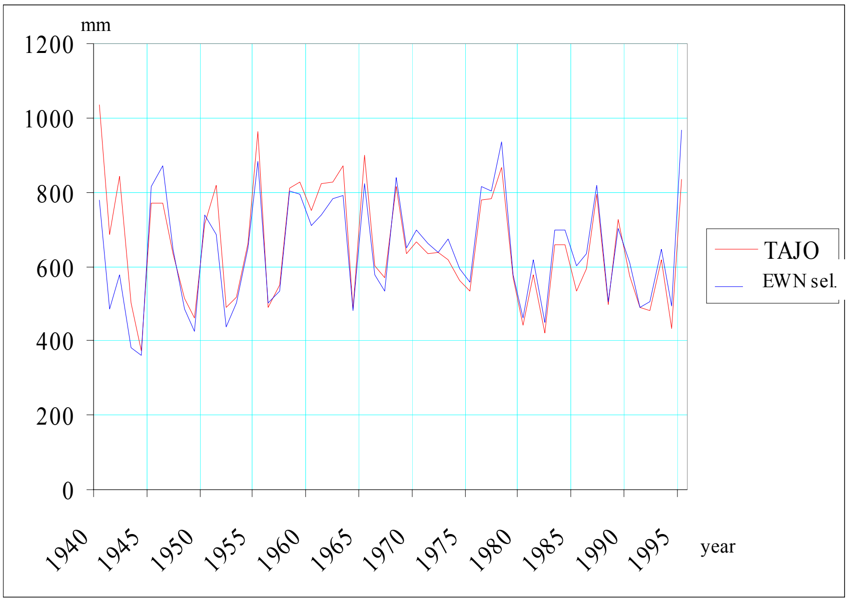
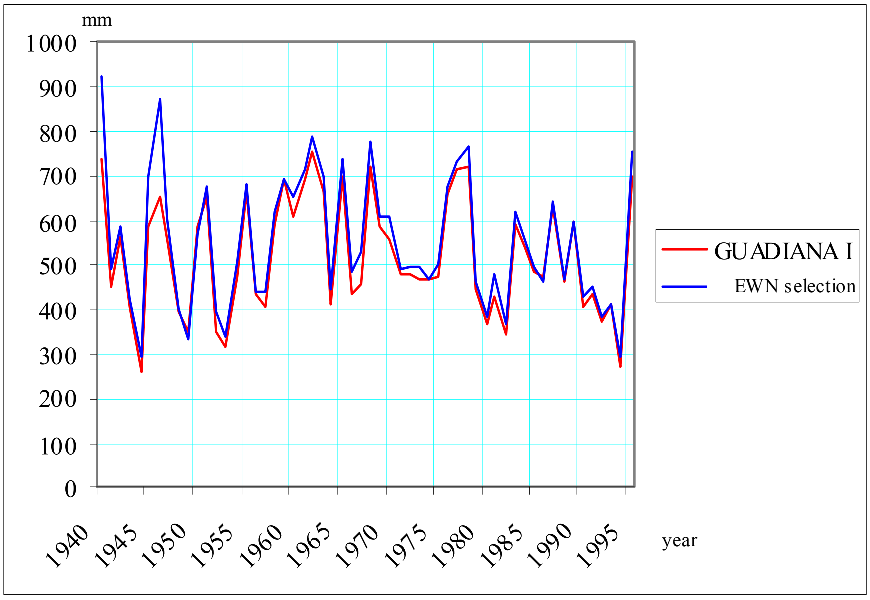


Figure A8 **Time series for the average annual precipitation in Guadiana river basin, estimated from all the meteorological stations and from the 105 selected EWN sites.**



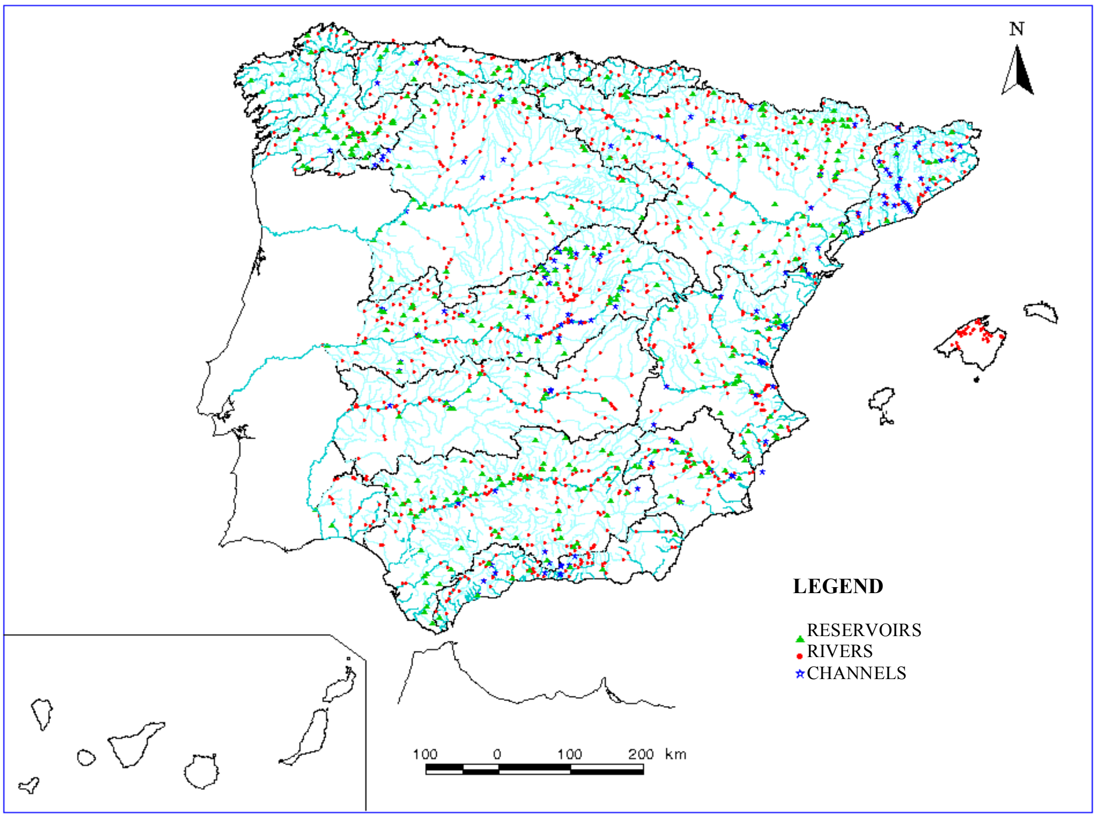
A2 Internal flow network

The Spanish gauging network

The River Basin Authorities are responsible for the operation and maintenance of these gauging networks, but it is the Department of the Environment that is responsible for the general filing and publishing of this information via the General Directorate of Hydraulic Works and Water Quality. In the case of the river basins that lie entirely within the boundaries of Catalonia, the Galician Coast, the Balearic and Canary Islands, the respective Autonomous Regional Governments are in charge of these activities.

The gauging network provides information on the water level and discharge at selected points on the rivers and the main reservoirs and channels. It consists of approximately 1 200 gauging stations on the rivers (of which about 730 are currently in service), approximately 300 control points for reservoirs with a storage capacity of more than 10 million m^3, and a further 180 control points on channels, as can be seen from the figure below.

Figure A9 Spanish gauging network



Selection of stations

General Characteristics

An initial selection of the stations that fulfil the following requirements, has been made from those described in preceding sections:

- The flow regime at the station should be as natural as possible, with minimum influence from human activities (e.g. abstraction or regulation) ;

- Stations should have a minimum record period of 25 years from 1960 to 1990;

- Stations must be in service.

Applying the criteria the 53 stations, whose basins are shown (Figure A10) have been obtained.

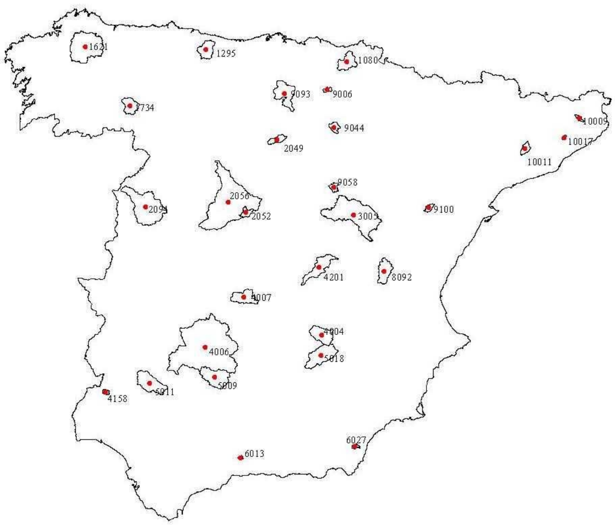
Figure A10 River basins of initial selection of gauging stations

Geographical distribution

The Spanish mainland covers a surface area of 494 000 km^2. As a result, and considering a control point density of one station per 20 000 km^2 (acceptable range between one per 5 000 to 20 000 km^2), it can be deduced that the internal flow network must consist of about 25 points.

Complying with the non-altered regime requirement and trying to obtain as even a geographical distribution as possible, the 28 stations that are shown in the following figure (Figure 11) were selected. As is indicated in these guidelines, the stations considered are located for interpolation in the centre of gravity of the catchment areas that drain into them, and that is how they are portrayed in the figure.

Figure A11 Gauging stations and basins in Spain applying EWN criteria

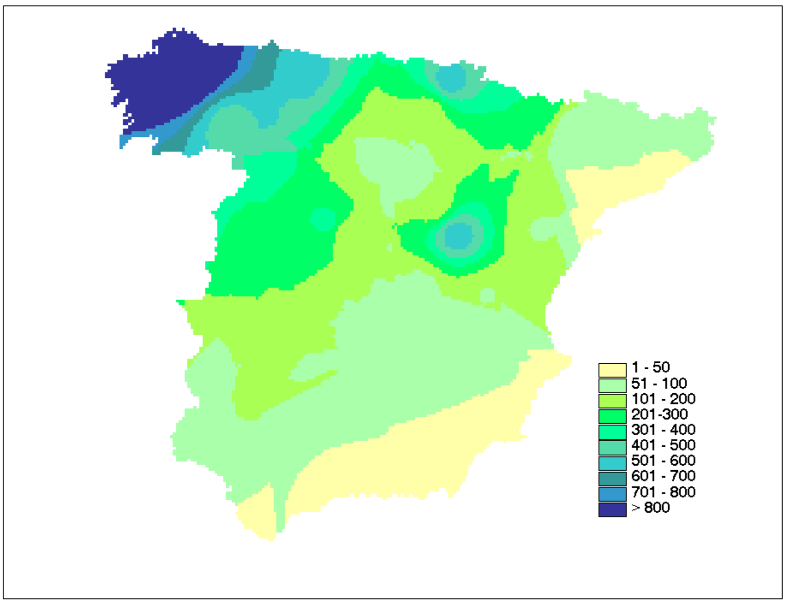


Note: The position of each gauging station is represented by the centre of gravity of its drainage basin

Obtaining the internal flow

The next figure (Figure A12) shows the map that is a result of interpolating the average runoff values for the 28 points selected. As is indicated in the guidelines, the interpolation method used was the squared inverse of the distance, the three nearest points being considered when interpolating the value.

Figure A12 Internal flow map (mm) obtained from the selected gauging stations (1940-96)



The aggregate value for the internal flow in the main basins, as deduced from the values in the map shown above (Figure A12), is as follows (See Table A3).

Table A3 **Aggregate internal flow value for the main Spanish basins obtained from the selected gauging stations.**

River Basin	Surface (km^2)	flow (mm) EWN Selection
Norte I	17 600	518
Norte II	17 330	1 083
Norte III	5 720	422
Duero	78 960	281
Tajo	55 810	200
Guadiana I	53 180	94
Guadiana II	7 030	65
Guadalquivir	63 240	66
Sur	17 950	23
Segura	19 420	44
Júcar	42 900	109
Ebro	85 560	167
CI Cataluña	16 490	53
Galicia Costa	13 130	1 052
Peninsula	494 020	211

Estimation of the representativeness of the results

To check the suitability of the methodology used, the results shown above (Table A3) were compared with those obtained for all the stations on the Spanish network and which were calculated with a view to preparing the Spanish White Paper on Water. This map was also obtained in non altered conditions.

Figure A13 **Internal flow map (mm) obtained by mathematical modelling. Source: Spanish White Paper on Water (Series 1940-96)**

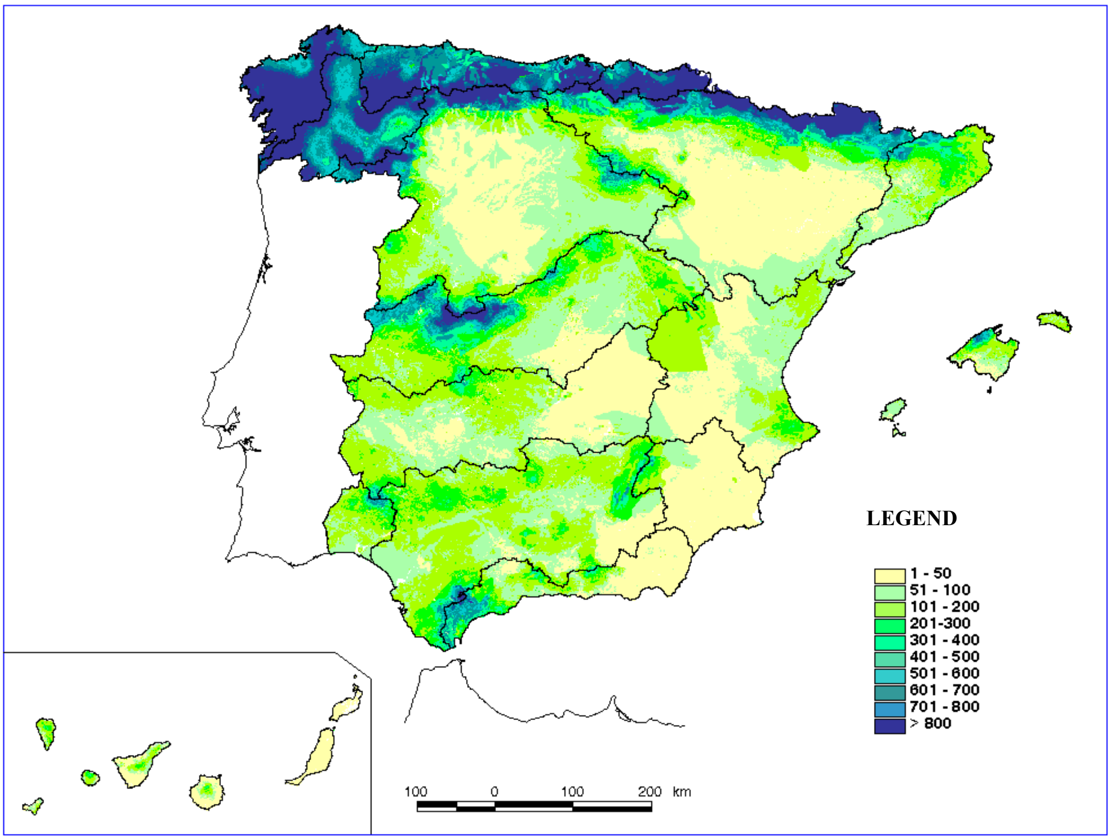


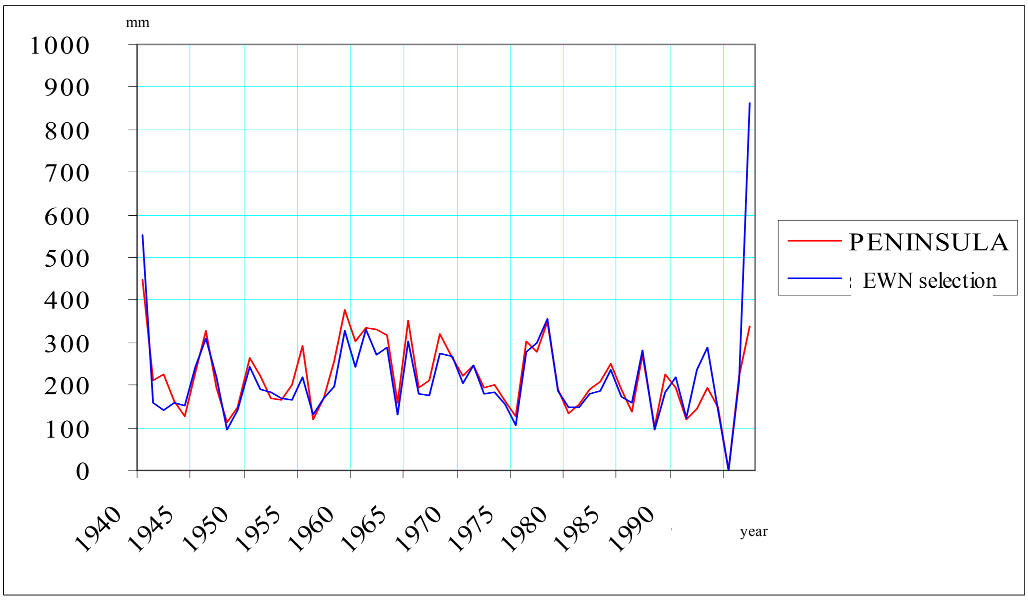
Table A4 **Aggregate runoff value in the main Spanish basins, obtained by mathematical modelling and comparing the results. Source: Spanish White Paper on Water (Series 1940-96)**

River Basin	Surface (km^2)	flow (mm) modelling	flow (mm) EWM Selection	Difference (%) with respect to modelling
Norte I	17 600	721	518	-39
Norte II	17 330	801	1 083	26
Norte III	5 720	933	422	-121
Duero	78 960	173	281	38
Tajo	55 810	195	200	3
Guadiana I	53 180	83	94	12
Guadiana II	7 030	151	65	-132
Guadalquivir	63 240	136	66	-106
Sur	17 950	131	23	-470
Segura	19 420	42	44	5
Júcar	42 900	80	109	27
Ebro	85 560	210	167	-26
CI Cataluña	16 490	169	53	-219
Galicia Costa	13 130	933	1 052	11
Peninsula	**494 020**	**223**	**211**	-6

It is clear that there are great differences in the smaller basins, so they do not influence too much the difference for all the country. There is a 6 % difference between the value for the whole of the Spanish mainland obtained from the EWN selection made and the value obtained with the mathematical model.

Figure A14 shows the annual values for the mean runoff in Spain, as obtained from the mathematical models, together with the results given by the selection made, in accordance with the methodology described here.

Figure A14 **Comparison of the development of the average annual internal flow in Spain, as obtained by mathematical modelling, and the results from the natural regime stations EWN selected**



Once again, it can be seen from the graph that the stations were suitably selected. Along similar lines and using the same methodology, the following figures (Figures A15 and A16) show the annual runoff values obtained for some of the largest river basins in Spain (Tajo and Guadiana), as obtained by mathematical modelling, together with the estimated runoff considering the stations that were selected.

Figure A15 Comparison of the development of the average annual internal flow in river Tajo basin, as obtained by mathematical modelling, and the results from the natural regime stations EWN selected

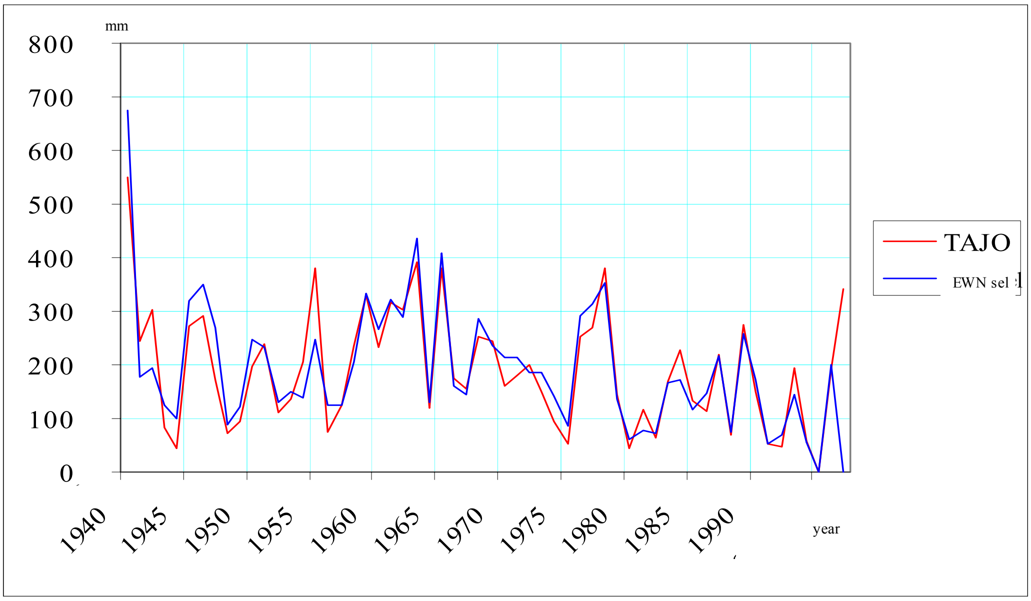
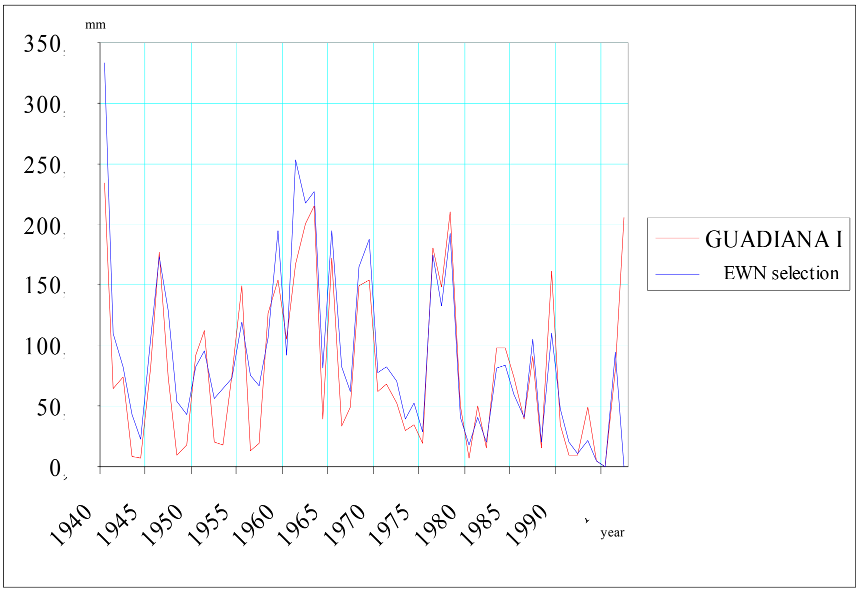


Figure A16 Comparison of the development of the average annual internal flow in river Guadiana basin, as obtained by mathematical modelling, and the results from the natural regime stations EWN selected



The difference between precipitation and the internal flow in Spain would give the evapotranspiration on a yearly average basis that is shown in the following table (Table A5).

Table A5 Average annual evapotranspiration in Spain as the difference between precipitation and internal flow as estimated from EWN selections

River Basin	Surface (km^2)	Precipitation (mm) EWN Selection	flow (mm) EWN Selection	Evapotranspiration (mm)
Norte I	17 600	1 196	518	678
Norte II	17 330	1 192	1 083	109
Norte III	5 720	1 293	422	871
Duero	78 960	633	281	352
Tajo	55 810	652	200	452
Guadiana I	53 180	530	94	436
Guadiana II	7 030	874	65	809
Guadalquivir	63 240	692	66	626
Sur	17 950	617	23	594
Segura	19 420	390	44	346
Júcar	42 900	511	109	402
Ebro	85 560	687	167	520
CI Cataluña	16 490	632	53	579
Galicia Costa	13 130	1 736	1 052	684
Peninsula	**494 020**	**701**	**211**	**490**

A.3 Actual outflow network

Selection of stations

A selection of the stations that fulfil the following requirements, has been made from those described in preceding chapters:

- The gauging stations must should be located at the points lying closest to the estuaries or at those where the river is administered by a different authority (example: the frontier between Spain and Portugal).

- Stations should have a minimum record period of 25 years from 1960 to 1990.

- Stations must be in service.

14 stations obtained; these are shown in the following figure (A17) .

Figure A17 Selected stations

Calculation of Actual Outflow

In the following table (Table A6), actual outflow is shown for the major river basins in Spain. For the whole area of the river basin, a run-off equal to the measured in the representative station has been adopted.

Table A6 Aggregate value of the actual outflow for the main basins (Series 1975-96)

River Basin	Surface (km^2)	Actual outflow (mm)[3]	Actual outflow (million m^3)[4]	Type
Norte I	17 600	534	9 398,40	Sea
Norte II	17 330	876	15 181,08	Sea
Norte III	5 720	922	5 273,84	Sea
Duero	78 960	109	8 606,64	Portugal
Tajo	55 810	138	7 701,78	Portugal
Guadiana I	53 180	27	1 435,86	Portugal
Guadiana II	7 030	219	1 539,57	Sea
Guadalquivir	63 240	44	2 782,56	Sea
Sur	17 950	61	1 094,95	Sea
Segura	19 120	2	38,84	Sea
Júcar	42 900	14	600,60	Sea
Ebro	85 560	127	10 866,12	Sea
CI Cataluña	16 490	96	1 583,04	Sea
Galicia Costa	13 130	898	11 790,74	Sea
Peninsula	**494 020**	**158**	**77 894,02**	**Sea+Portugal**
Peninsula	494 020	122	60 149,74	Sea
Peninsula	494 020	36	17 744,28	Portugal

Actual outflow to sea is, in consequence, about 60 000 million m^3 and actual outflow to Portugal is about 18 000 million m^3.

Evaluation of the representativeness of the results

In the Spanish White Paper on Water an average annual yield into the sea of about 64 000 million m^3 is considered, whereas the average annual yield into Portugal (Duero+Guadiana I+Tajo) is about 21 000 million m^3. Both figures were estimated using mathematical modelling. In view of the fact that the aforementioned figures have yielded errors of less than 10 % in estimating the actual outflow, it is considered that the methodology used is suitable enough.

An annual consumption demand of 26 000 million m^3 would be obtained for Spain by calculating the difference between the internal flow (211 mm that is equivalent to 104 238 million m^3) and the actual outflow (77 894 million m^3).

[3] Representative station value in each major basin
[4] Result of using representative station yield for the whole area of the basin