Chapter 13
Development of Drought Management Plans in Spain

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Abstract This chapter presents the process of development of drought management plans in Spain. The Law of the National Hydrologic Plan, in 2001, included the obligation for all Basin Authorities to develop Special Drought Management Plans. The process was finished in 2007, with the approval of the Plans for Basin Authorities depending on the central government. The methodology applied for the technical analyses carried out is presented, together with a description of the drought management actions included in the Plans.

The Planning Framework

Drought, Water Scarcity and Aridity are Overlapping Issues in Spain

Water resources in Spain are limited, scarce, and highly irregular in space and time. The potential use of surface water under the natural regime is only 7% of total natural resources. The availability has increased to 40% due to the intensive development of hydraulic infrastructures during the last century. Groundwater use is also intensive in many areas of the country, and it contributes to an additional 10% of the total available resources. Water use in Spain is mainly for agriculture (over 68% of water demand), but other economic and social water demands are rapidly increasing, such as tourism (current urban demand is 13%) and ecosystem services. With limited and scarce water resources and demand rising due to demographic shifts, economic development and lifestyle changes, water management problems are significant even without drought events (Table 13.1)

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A. Iglesias et al. (eds.), *Coping with Drought Risk in Agriculture and Water Supply Systems*, Advances in Natural and Technological Hazards Research 26,
DOI 10.1007/978-1-4020-9045-5_13,

Table 13.1 Total freshwater resources, available resources, demands, and water reliability in the hydrological basins of Spain

	Total Freshwater Resources (km^3)	Available resources (km^3) (a)	Reservoir capacity (km^3)	Regulated water (%) (b)	Demand (% of available resources)	Irrigation demand (% of total demand)	Pop. (millions)	Total resources per capita (m^3/person)
Norte	44.2	6.8	4.4	15	37	42	6.7	6,542
Duero	13.7	8.1	7.7	60	47	93	2.2	6,071
Tajo	10.9	7.1	11.1	65	57	46	6.1	1,784
Guadiana	5.5	3.0	9.6	54	85	90	1.7	3,298
Guadalquivir	8.6	3.6	8.9	42	104	84	4.9	1,755
Sur	2.4	0.54	1.3	21	268	79	2.1	1,135
Segura	0.8	0.7	1.2	90	253	89	1.4	590
Júcar	3.4	2.0	3.3	58	149	77	4.2	819
Ebro	18.0	13.0	7.7	72	80	61	2.8	6,509
Catalonia	2.8	1.1	0.8	40	122	27	6.2	451
Balearic Is.	0.7	0.3		45	96	66	0.8	785
Canary Is	0.4	0.4		102	102	62	1.7	241
SPAIN	111.2	46.6	56.1	42	76	68	40.1	2,728

(a) Surface and groundwater.

(b) Regulated water: rate of available resources from total natural resources.

Drought can have serious effects on the economy and the environment of Spain and on the population's well being. The major drought of the mid 1990s affected over 6 million people, almost ten times more than the number of people affected by floods in Spain during the last fifty years. The economic damage caused by drought in Spain during the last twenty years is about five times more than in the entire United States (EM-DAT, 2007). Drought events affect water supplies for irrigation, urban, and industrial use, ecosystem health, and give rise to conflicts among users that limit coherent integrated water resource management. The reduction of wetland area (from over 1200 km^2 in the 1970s to less than 800 km^2 in 2000, excluding the Guadalquivir marshlands) has been in part related to recurrent drought episodes and surface water scarcity, and amplified by the excessive groundwater pumping to compensate for these problems. In addition to water scarcity, droughts also cause water quality problems, since water quality parameters deteriorate during drought due to lack of dilution and water may not be acceptable for human consumption.

Legal and Institutional Framework

There are two main legal sources of the Spanish water codes and statutes: the Spanish Constitution (1978) and the European Union Water Framework Directive (2000). These two legal bodies are at the top of the hierarchy of laws and statutes pertaining to water and droughts (Iglesias, Moneo, 2005). Three instrumental laws are identified as the context for drought preparedness and planning: The Water Law (2001), the Law of the National Hydrological Plan (2001) and the Agricultural Insurance Law (1978). The Law of the National Hydrological Plan explicitly ordered the development of Special Drought Management Plans for all basins and Drought Emergency Plans for all urban water supply systems serving more than 20,000 inhabitants.

The administrative body that is responsible for providing public service regarding water management in the basin is the Basin Authority, with competence on inland water and groundwater. The Basin Authority is an autonomous public organization subordinate to the Ministry of the Environment. The Ministry of the Environment also hosts the National Drought Observatory that provides updated general information. Table 13.2 summarizes the stakeholder groups that may compete for water during periods of drought and water scarcity.

The implementation of the new European WFD gives Spain the opportunity to develop integrated drought management plans that incorporate the extensive national experience in hydrological management with the new environmental challenges. Regarding exceptions, "prolonged droughts" are introduced in the WFD as "force majeure" events. The conditions under which exceptional circumstances are or could be considered have to be stated through the adoption of the appropriate indicators. Contingency drought plans must face these issues. Historically, the urban, cultural, and agricultural development in Spain has demonstrated a profound

Table 13.2 Stakeholders in the Spanish basins

Stakeholder	Variable of interest	Preference and compromise
Farmers	Water to irrigation	More water May be willing to accept lower abstraction permits in exchange for lower prices (or vice versa, may be ready to pay higher prices to obtain more water)
	Price of water for irrigation	Lower price Subsidies for switching to less water-demanding crops
	Dam and reservoir capacity	More capacity (decrease vulnerability to drought)
Environmentalists	Residual water	Well above minimum flow requirement
	Dams and reservoirs	No additional investment to protect biodiversity Sustain ecological flow
Urban and Rural dwellers	Secure access to safe water	Closer safe water sources Guaranteed minimum water quantity Participatory water planning
Urban water supply companies	Dams and reservoirs	Increase storage capacity Infrastructure
Basin Authority	Dams and reservoirs	Integrated resource management Evaluate storage capacity First priority is urban water supply Other uses and services of water may be negotiated
	Ecological water	Guarantee ecological services and flow requirements

knowledge of adaptation strategies to drought, water scarcity, and precipitation variability.

Legal Instruments for Drought Management in Spain

Institutional responses to hydrological drought or water scarcity in Spain are classified in two categories: proactive and reactive. Proactive measures are defined in River Basin Management Plans, and are in permanent progress. The set of structural and non-structural measures contemplated in RBMPs is designed to improve the reliability of water resource systems, reducing their vulnerability to drought. However, these measures may not eliminate completely the risks associated to droughts. Reactive measures were usually adopted under this contingency to compensate for water scarcity within the existing framework of water resources, demands and infrastructure in the basin.

Under the traditional approach, specific measures to react to the drought situation were adopted by the Government under the guidance of Basin Authorities and implemented through Royal Decrees. The Reservoir Release Commission of Basin Authorities can also agree with users on the activation of emergency drought management measures. For instance, special operating strategies have been defined

to limit consumption (programs for public awareness, restrictions of nonessential uses, intensification of control of water consumption and implementation of penalties for violators) and to increase supply (implementation of planned structural and non structural measures: the use of dead reservoir storage or water of lower quality, transient overexploitation of the aquifers, modification of usage priorities and resort to high-cost sources of supply). In general, these reactive responses are specific of drought periods, and are discontinued when the drought is over.

This approach based on reactive measures will probably have to be used in the future. However, the Law of the National Hydrologic Plan, approved in 2001, established new legal instruments for drought management in Spain. The action is based on three main instruments (Estrela, 2006)

- A drought monitoring system based on drought indicators for each Basin Authority and for the entire country
- Special Drought Management Plans for Basin Authorities
- Emergency Drought Plans for urban water supply systems serving more than 20,000 inhabitants

The National System of Drought Indicators was developed during 2006 by the Spanish Ministry of the Environment. It is currently operational, and may be accessed on the web page of the Ministry of the Environment, in the National Drought Observatory. The system of indicators is a general reference for Basin Authorities for formal declaration of drought situations, which can activate drought emergency measures with legal constraints or specific budget application.

Spain has recently completed the process of drafting Drought Management Plans for all Basin Authorities. Special Drought Management Plans (SDMP) at river basin level are complementary to River Basin Management Plans (RBMP) for drought conditions. SDMPs are mainly targeted to identify the conditions and schedule the activation of tactical measures to prevent or mitigate drought effects. Therefore, measures involved are mainly water demand management or water conservation measures and, with the progressive application of WFD schedule, measures to achieve and comply with good environmental status.

At local level, specific emergency plans for all public water supply systems serving more than 20,000 inhabitants will have to be developed. The objective of these plans is to ensure that a proactive approach is adopted for drought management in urban water supply, avoiding the need to implement improvised emergency measures under the pressure of imminent water shortages.

Drought Indicators System

The basis of any drought management plan is a robust system of drought indicators that can identify and diagnose anomalies in water availability and can provide the basis for early detection of drought episodes. Drought characterization in highly regulated systems is complex and calls for multiple indicators. For instance, SPI and

other rainfall-based indices have been used with important limitations when applied in isolation, especially over short time periods. These indices show little correlation with water shortage situations, since water storage plays an important role in water resources management. Therefore, a more complex system of indicators is required in order to identify situations when there is risk of water shortages.

A comprehensive study of hydro-meteorological time series and drought indices in the basin is required for the definition of a drought indicators system. The methodology adopted is based on the analysis of water demand units. For each of them, a list of variables is selected to characterize the evolution of available water resources, such as water stored in reservoirs, piezometric levels in aquifers, river flow in stream gauges, rainfall in precipitation gauges, etc. Historic time series compiled for each variable are normalized on a scale from 0 to 1, with 0 corresponding to the minimum historic value, 1 to the maximum and 0.5 to normal conditions. The functions to relate variables and indicators are chosen to characterize the risk of water shortages and are validated through the analysis of historic values and drought episodes. Individual demands are grouped in water resources systems, obtaining average values of the indicators that are representative of the global situation of each system. Usually a weighted average is selected as the averaging procedure, with weights proportional to the relative importance of each demand unit. The system of indicators is in continuous revision, taking into consideration the availability of new information and the progress in knowledge of the hydrologic behavior of the basins.

The hydrologic state of every system as measured by the indicators is classified into four categories: Normal, Pre-alert, Alert and Emergency conditions, with the following meanings:

- Normal: The normal condition corresponds to situations in which there are no risks of water shortages in the near future
- Pre-alert: The pre-alert condition is declared when monitoring shows the initial stage of drought development, which corresponds to moderate risk (i.e. greater than 10%) of consuming all water stored in the system and not being able to meet water demands
- Alert scenario: The alert condition is declared when monitoring shows that drought is occurring and will probably have impacts in the future if measures are not taken immediately. There is a significant probability (i.e. greater than 30%) of having water deficits in some time horizon.
- Emergency scenario: The emergency condition is declared when drought indicators show that impacts have occurred and supply is not guaranteed if drought persists.

The current values of the system of indicators are published quarterly by the National Drought Observatory, and can be accessed in the web page of the Ministry of the Environment. As an example, the situation in September 2007 is shown in Fig. 13.1.

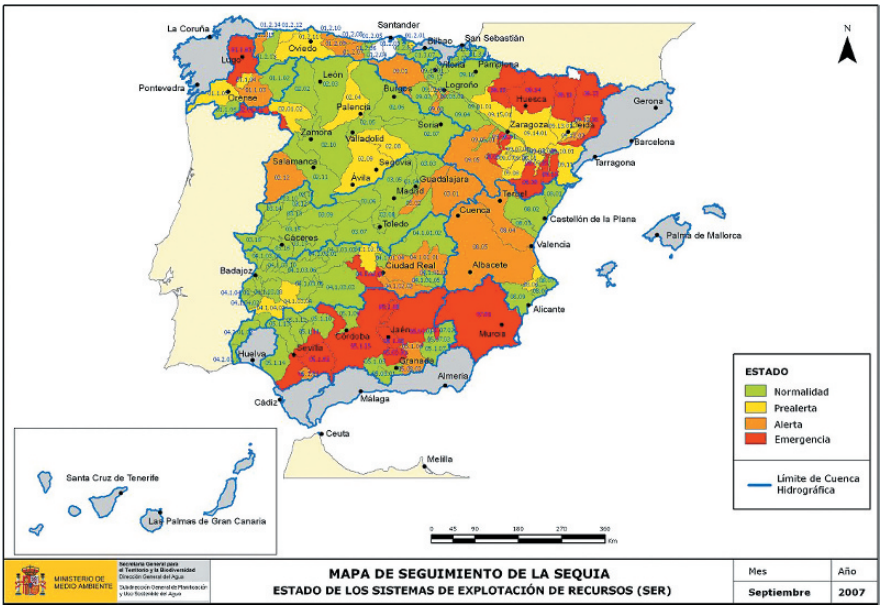

Fig. 13.1 Drought condition of main water resources systems in Spain in September 2007

Special Drought Management Plans

The objective of Special Drought Management Plans is to anticipate drought situations and to plan solutions to satisfy water demands and to comply with environmental requirements (Iglesias et al., 2007). They are based on:

- A deep knowledge of water resources and their capacity to be stressed under water scarcity situations
- A deep knowledge of water demands and their vulnerability to water scarcity situations
- A system of drought indicators for early warning, to allow for the adoption of management actions contemplated in the plan.
- A catalogue of measures to reduce drought impacts for each drought condition
- An adequate administrative framework for the implementation of measures, allowing for the coordination of the administrative units involved.
- A plan for public participation to guarantee cooperation of all users involved and to disseminate important information

The elaboration of the SDMPs is the result of a complex process in which user participation is encouraged and stimulated. Once the Plan is drafted, it is submitted to public scrutiny, and concerned individuals and social or political groups can make allegations that are discussed and negotiated in the Water Council, where a majority vote is required for acceptance. If the drafted plan obtains a favorable vote, it is formally approved and is legally binding to all stakeholders.

Management Actions

The basin drought policy is summarized as a list of possible actions to be taken in case of drought. The catalogue of possible actions is restricted by the legal competences that are attributed to Basin Authorities, but the resulting list includes a great number of actions of very diverse nature, like the examples presented in the following categories:

- Internal operation. Within the Basin Authority, most frequent measures include intensification of monitoring, prevention of leaks, or revision of rules for the operation of infrastructure.
- Water uses. Demand management measures include: information dissemination and user involvement, promotion or enforcement of water savings, prohibition of certain uses, temporary exemption of environmental obligations, etc.
- Water resources. Drought measures focus on conservation and protection of stored resources, activation of additional resources or monitorization of indicators of water quality.
- Institutional. The President of the Basin Authority may appoint committees or task forces to address specific issues, usually in conjunction with affected users, or enhance cooperation with other organizations or stakeholders.
- Legal. There are a number of legislative measures that can be adopted, ranging from the official declaration of emergency due to drought, to a long list of possible palliative measures with different objectives: subsidy, restrictions, emergency works, etc.

The operational effectiveness of SDMPs plan is greatly enhanced if the selected measures for every system are associated to each of the three drought states corresponding to increasing levels of severity: Pre-alert, alert, and emergency scenarios. The management actions associated to these scenarios are described in the following paragraphs.

The management objective in the pre-alert scenario is to prepare for the possibility of a drought. This means to ensure public acceptance of measures to be taken if drought intensity increases by raising awareness of the possibility of societal impacts due to drought. The kind of measures that are taken in the pre-alert situation are generally of indirect nature, are implemented voluntarily by stakeholders and are usually of low cost. The goal is to prepare the organism and the stakeholders for future actions. Regarding the Basin Authority, main actions are intensification of monitoring, usually through the creation or activation of drought committees, and evaluation of future scenarios, with special attention to worst case scenarios. Regarding the stakeholders, the focus is communication and awareness. Generally, non-structural measures are taken, aimed to reduce water demand with the purpose of avoiding alert or emergency situations.

The management objective in the alert situation is to overcome the drought avoiding the emergency situation by enacting water conservation policies and mobilizing additional water supplies. These measures should guarantee water supply at least during the time span necessary to activate and implement emergency measures. The

kind of measures that are taken in the alert situation are generally of direct nature, are coercive to stakeholders and are generally of low to medium implementation cost, although they may have significant impacts on stakeholders' economies. Most measures are non-structural, and are directed to specific water use groups. Demand management measures include partial restrictions for water uses that do not affect drinking water, or water exchange between uses. This may be a potential source of conflict because user rights and priorities under normal conditions are overruled, since water has to be allocated to higher priority uses. For example, irrigation can be supplied using waters from an alternative source, although farmers usually disagree with this option, since it may imply lower water quality or an increase in pumping costs.

The management objective in the emergency scenario is to mitigate impacts and minimize damage. The priority is satisfying the minimum requirements for drinking water and crops. Measures adopted in emergency conditions are of high economic and social cost, and they should be direct and restrictive. Usually there has to be some special legal coverage for exceptional measures, which are approved as general interest actions under drought emergency conditions. The nature of the exceptional measures could be non-structural, such as water restrictions for all users (including urban demand), subsidies and low-interest loans, or structural, like new infrastructure, permission for new groundwater abstraction points and water transfers.

Risk Analysis

The operational implementation of the plan requires a connection between the system of drought indicators and selected measures. To avoid untimely negotiations, the drought plan contemplates the activation of the set of measures associated to a drought scenario when the system of drought indicators reaches a predefined level. The final goal is to achieve a balance between the frequency of declaration of drought scenarios and the effectiveness of the application of the measures. If drought scenarios are declared too early, users are frequently exposed to unnecessary restrictions. If the declaration of drought scenarios is delayed, it may be too late for the measures to be effective.

The process of plan discussion and negotiation is very important, since consensus is a major goal to achieve before the plan is operational. In discussions, all users generally agree on the importance of drought indicators and on the rationale of the proposed measures. The disagreements usually concern the timing of measures. Users that are going to be benefited by measures, because their demands will be protected due to the high priority of urban supply, tend to encourage early action, even at the risk of incurring frequently in false alarms and unnecessary restrictions. Users whose demands are going to be restricted, because of lower priorities of irrigation or power production, tend to support the delay of the application of exceptional measures, even at the price of depleting the reserves completely.

Risk analysis is an essential tool to analyze the problem and to find a consensus among users by testing different options. It is important that the rationale behind the measures proposed in the plan can be understood by all stakeholders that might be affected by them, and therefore, special emphasis has to be placed on developing a methodology to establish an objective link between quantitative drought indicators and concrete measures.

The methodologies applied in Spanish basins involve comprehensive analyses of alternative policies and objective procedures to plan the ordered implementation of management actions based on quantitative drought indicators. The details of the analysis differ from one basin to another, depending on local conditions. In most of them, water resources simulations models are applied to analyze the risk of water shortages and to test the effectiveness of management actions. As an example, a brief summary of the methodology applied in the Tagus basin is presented below. A detailed description can be found in Garrote et al. (2007) and Iglesias et al. (2007).

The objective of the analysis is to define the thresholds of drought indicator values for the declaration of the pre-alert, alert and emergency scenarios. Since future reservoir inflows are uncertain, these thresholds should be formulated in probabilistic terms. In the Tagus basin, thresholds are defined as the available storage in the system, S, that is required to satisfy a fraction, f, of the demand in a time horizon, h, with a given probability, p. Values of f, h and p are model parameters that are analyzed with the help of a water resources simulation model and are fixed through discussion with stakeholders. They depend on several factors: the type of the demand in the system (urban, irrigation, hydropower, etc.), the reliability of the current water supply system, the alternative management strategies that can be applied during droughts, the vulnerability of the demand to deficits of a certain magnitude, etc.

The characteristics of demands in every system are the first factor to assign values to model parameters. Demands having only one single source of supply are more vulnerable and require stricter parameter values than those having alternative sources. In this group, demands having such sources available exclusively to themselves are less vulnerable than those sharing them with other demands. The expected effects of drought declaration should also be balanced versus drought risk. In systems where demands are close to average natural resources there is little margin for action, and drought declaration may have very important social and economic impacts. Most emergency measures imply having to alter existing water rights, face the development of new transport or storage facilities under great social pressure or impose stronger rules and penalties and stricter control. If the drought situations are declared very frequently, the global effects may be even worse than the no-action approach.

The proposed values for model parameters have to be validated by simulating system behavior for the period of historic record, implementing the proposed set of measures in every drought scenario. Final values are decided with the goal of meeting drought management objectives in each scenario and considering the possibilities of demand reduction and resource mobilization in the system. Other qualitative aspects have also to be taken into consideration. For instance, one of the issues

raised by technical staff in charge of water resources management was the situation of regulated systems for irrigation use at the end of the hydrological year. Normal operation of irrigation systems usually depletes reservoir storage at the end of the irrigation campaign. This is a normal feature of annual regulation systems. However, there is a significant probability of not being able to satisfy demands during the following year if reservoirs are almost empty in October. But declaring drought in October or November in an irrigation system is not perceived as good management policy. If the following autumn and winter are normal, the reservoirs will fill again, and there will not be a scarcity situation. If autumn and winter are dry, farmers cannot do anything to react to drought until spring. So for these systems based on annual regulation for irrigation use, declaration of drought might only make sense at the beginning of the irrigation campaign, when farmers are making decisions regarding their crops.

Drought Emergency Plans

Urban water supply systems are very sensitive to drought conditions, since water shortages can have very significant impacts on the population. For this reason, special consideration has been given to drought management for urban supply systems. In Spain, all urban supply systems serving a population of more than 20,000 inhabitants must elaborate a Drought Emergency Plan (DEP).

The objective of drought management in urban supply systems is to reduce the risks of having large impacts due to water shortage through emergency actions that imply moderate impacts and costs. These costs are accepted to reduce the probability of facing situations of greater severity, with comparatively much larger impacts (Cubillo, de Castro, 2007). Risk analysis is essential to establish the criteria for the activation of low-impact measures to prevent possible large impacts in the future.

The objectives of the DEPs for urban supply systems are to define the states of risk of drought-induced water shortages in each system, to identify the conditions to declare different levels of drought emergency situations, to establish the management objectives for drought conditions in terms of demand management or supply enhancement and to catalogue the measures that should be activated under different drought conditions, specifying the level of responsibility of each institution involved.

DEPs are specific of urban supply systems, and should be adequately coordinated with basin SDMPs, since many of the measures contemplated in DEP affect other uses in the basin, like, for instance, the temporary allocation to urban supply of water resources assigned to other uses, which should be authorized by SDMPs. Measures that restrict urban supply should be applied last, since it is, in general, the most important use. Therefore, a special classification of drought states is required for urban supply management, different from the general classification applied in SDMPs. For DEPs, the following drought states are proposed:

- Phase I: Alert: Preparation for the formal declaration of operational drought
- Phase II: Reduction: Voluntary demand reduction and supply enhancement through the activation of measures contemplated in the SDMPs.
- Phase III: Restriction: Water shortages with socioeconomic impact
- Phase IV: Emergency: Great severity scenario, with large socioeconomic impacts.

Phase I corresponds to the final level of the Alert situation in SDMPs, and phases II to IV correspond to the Emergency situation in SDMPs.

From the methodological point of view, DEPs are similar to SDMPs. They are based on the definition of drought indicators, a set of measures and a risk-based methodology to identify conditions for the activation of measures. The differences correspond to the nature of the measures and the level of detail, which should be much more precise for urban systems.

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